# Preoperative physiotherapy to prevent postoperative pulmonary complications after major abdominal surgery

**Ianthe Josephine Boden**

Bachelor of Applied Science (Physiotherapy)
Master of Health Science (Cardiopulmonary Physiotherapy)

ORCID ID: 0000-0002-9283-4779

Submitted in total fulfilment of the requirements of the
Degree of Doctor of Philosophy

**University of Melbourne student number:** 654385

June 2020

Department of Physiotherapy,
Melbourne School of Health Sciences,
The University of Melbourne.

# Abstract

Abdominal surgery is the most common major surgical procedure performed in developed countries. After surgery, postoperative pulmonary complications (PPCs) occur frequently and are a primary cause of morbidity, mortality, and prolonged hospital stay. To minimise PPCs, physiotherapy is ubiquitously provided in the postoperative phase. Physiotherapy clinical trials reporting the largest reductions in PPCs have predominately tested preoperative education and training of patients to perform their own breathing exercises after surgery. These trials were generally of low quality and therefore the results lack certainty. Currently, preoperative physiotherapy is rarely provided in Australian and New Zealand hospitals. A well-designed randomised controlled trial (RCT) investigating the benefit of preoperative physiotherapy to reduce PPC in a modern perioperative context was needed.

The aims of this thesis were to: consider the physiological basis for preoperative physiotherapy to minimise PPCs; to conduct a narrative and systematic review of research investigating PPC prevention with breathing exercises; and, to design and conduct an RCT, including quantitative, qualitative, and health economic outcomes, assessing the effectiveness of preoperative physiotherapy to minimise PPC after major abdominal surgery.

The Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) trial was a double-blinded, multicentre, RCT. In pre-admission clinics at three hospitals, 441 patients awaiting major abdominal surgery were randomised to receive an information booklet or an additional education and breathing exercise training session. Education focussed on PPC prevention via self-directed postoperative breathing exercises. A nested mixed-methods study investigated the impact and treatment fidelity of the intervention in 20 consecutive participants. Preventing pneumonia was very important to participants. Intervention participants found preoperative physiotherapy to be interesting and empowering with 94% of remembering the breathing exercises as taught.

Following surgery, PPC incidence was halved in the intervention group (adjusted hazard ratio 0.48, 95% confidence interval (CI) 0.35 to 0.75, p=0.001) with a number needed to treat of 7 (95% CI 5 to 14). Intervention participants had significantly reduced pneumonia rates, required fewer antibiotic prescriptions for respiratory infections, less purulent sputum, fewer positive sputum cultures, and were less likely to require oxygen therapy.

An integrated health economic analysis found that preoperative physiotherapy had high probability of being cost-effective with an incremental net benefit to hospitals of $4,958 (95%

CI $10 to $9,197) for each PPC prevented, given a willingness-to-pay of $45,000 for the service. Quality adjusted life year (QALY) gains were less certain. Improved cost-effectiveness and QALY gains were detected when experienced physiotherapists delivered the intervention. For each PPC prevented, preoperative physiotherapy was likely to cost hospitals less than the costs to treat a PPC.

This thesis analysed the evidence for the physiotherapy management of patients having abdominal surgery. A hypothesis for preoperative physiotherapy to minimise PPC after surgery was proposed. This hypothesis was supported with qualitative, primary, secondary, and health economic quantitative outcomes within a multicentre randomised controlled trial, and through a systematic review and meta-analysis.

These findings may not be generalisable to all settings and requires testing in different surgical populations, cultures, and hospital settings. Effective PPC prophylaxis needs to be investigated for patients unable to attend pre-admission clinics, those having emergency abdominal surgery and in other high-risk populations.

# Declaration

I declare that:

(i) this thesis comprises only my original work towards the Doctor of Philosophy

(ii) due acknowledgement has been made in the text to all other material used; and

(iii) the thesis is fewer than 100,000 words length, exclusive of tables, references and appendices.

Ianthe Boden

26 June 2020

# Preface

This is a 'thesis with publication'. It includes six publications reproduced in their entirety which are substantially unchanged from the peer-reviewed multi-author manuscripts.

Chapter 2 contains the published paper:

> Reeve J & Boden I. The physiotherapy management of patient undergoing abdominal surgery. *New Zealand Journal of Physiotherapy*. 2016**;** 44(1): 33-49. doi: 10.15619/NZJP/44.1.05

Dr Julie Reeve (JR) and the candidate, Ianthe Boden (IB), equally conceived the structure and scope of the narrative review. IB contributed more than 50% of the content to this manuscript and was primarily responsible for compiling all Tables and Figures, and the following sections; 'Introduction', 'What is abdominal surgery?', 'Postoperative pulmonary complications – what are PPCs and how are they measured?', 'What are the consequences and costs of a PPC?', 'How can we predict who is at risk of developing a PPC?', 'Complications associated with reduced or delayed mobility – postoperative paralytic ileus', 'Physiotherapy management for patients undergoing abdominal surgery', 'Preoperative physiotherapy interventions – preoperative education', and, 'Postoperative physiotherapy interventions – postoperative ambulation, postoperative breathing exercises, respiratory adjuncts'. JD was responsible for 'Complications associated with reduced or delayed mobility – venous thromboembolism, musculoskeletal and cardiovascular effects', and, 'Postoperative physiotherapy interventions – postdischarge rehabilitation'. Both co-authored 'Preoperative physiotherapy interventions – prehabilitation', and, 'Postoperative physiotherapy interventions – other adjuncts'. JD and IB co-edited all sections and approved the final version prior to submission. JD managed the manuscript submission and its providence. The manuscript presented in this thesis is unchanged from the published paper.

Chapter 5 contains the published paper:

> Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials*. 2015; 16:573. doi: 10.1186/s13063-015-1090-6.

IB initially conceived and designed the study prior to initiating the PhD. With the assistance of Professor Rebecca Lane (RL) the original study protocol and a grant application for funding was

submitted to the Physiotherapy Research Foundation in 2010. This unsuccessful application received written peer-review from two unknown reviewers.

The revised study protocol was submitted to the Clifford Craig Research Foundation in 2012. The candidate received assistance from colleagues Julie Borschmann, Nadia Zalucki (NZ) and Joanna Lane at the Launceston General Hospital Physiotherapy Department to review the study protocol and grant application. The grant application was successful following written examination and peer-review by three unknown reviewers from the Grants Review Committee.

IB enrolled in the PhD prior to trial initiation. Following PhD enrolment, the LIPPSMAck-POP study design and protocol underwent further reviews and modifications with assistance from NZ, RL, JR, Associate Professor Julio J Fiore, Dr Kimberley Haines, Associate Professor Doa El-Ansary (DE), Dr Elizabeth Skinner (EH), Dr Laura Browning (LB), and Professor Linda Denehy (LD). Iain Robertson (IR) and IB planned the statistical analysis. For the protocol paper, IB drafted the manuscript, managed co-author revisions, prepared the manuscript for submission and managed the manuscript review process. JR, DE, EH, LB, IR, LD read and contributed intellectually important content and approved the final manuscript of the study protocol for publication. The manuscript was revised following peer-review and editorial suggestions by the journal. The manuscript presented in this thesis is unchanged from the published paper.

Chapter 6 contains the published paper:

> Boden I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy*. 2018 Jun;104(2):194-202. doi:10.1016/j.physio.2017.08.008.

IB was responsible for the concept and design of the nested mixed-methods trial, recruitment of participants, providing the interventions to participants, and coordinating the trial. IB drafted the manuscript, managed co-author revisions, prepared the manuscript for submission and managed the manuscript review process. Kate Sullivan and Bronte Biggins-Tosch conducted the patient interviews. Susan Kaye transcribed the interviews. DE and NZ scored, analysed, and interpreted the interviews. IR and IB were responsible for statistical design and analysis. LD, LB, ES contributed intellectually important content to trial design. ED, NZ, IR, LB, ES, and LD contributed to interpretation of data and revision of the manuscript. The manuscript was revised following peer-review and editorial suggestions by the journal. The manuscript presented in this thesis is unchanged from the published paper.

Chapter 7 contains the published paper:

> Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, Robertson IK, Story D, Denehy L. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ.* 2018 Jan 24;360:j5916. doi:10.1136/bmj.j5916.

IB coordinated the trial, prepared the first draft of the manuscript, and was responsible for the final manuscript. IB wrote all grant applications, completed multi-site ethics submissions, amendments, and progress reports as required. IB developed an operating procedures manual for each site and trained all participating physiotherapists in the protocol. IB contributed to participant screening and recruitment, baseline data collection, delivering the intervention, data entry, database management and security, data cleaning and analyses.

At the Launceston General Hospital, Tasmania, recruitment, delivery of preoperative interventions, and baseline data collection site were performed by IB, Ms Kate Sullivan, Mr Tom Shepherd, Mr Andrew Michael, and Ms Emma Dwyer. Blinded outcome assessments were performed by Ms Bronte Biggins-Tosch, Ms Kate Sullivan, Dr Janice Tang, Dr Michael Kwok, Dr Haoyuan Lim, and Dr Leanne Fung. Ms Bronte Biggins-Tosch and Ms Kate Sullivan provided research assistance for postoperative data collection and entry. At North Shore Hospital, Auckland, the principle site investigator was Dr Julie Reeve who was responsible for oversight, conduct, and safety of the trial. Participant recruitment, delivery of preoperative interventions, and baseline data collection were performed by Ms Lesley Anderson, Mr Marcus Sullivan, Ms Victoria Lai, and Ms Jenna Ford. At North West Regional Hospital, Tasmania, the principle site investigator was Ms Cat Hill. Ms Hill with Ms Vic Stephenson assisting in the delivery of the interventions.

LD, ES, and LB provided trial conduct oversight and supported IB during the trial and PhD candidature. IB, IR, LD, and Dr Dane Blackford formed the data safety and management board to provide oversight to the safe and ethical conduct of the trial. IB and IR did the statistical analysis. IB, ES, LB, JR, IR, Professor David Story (DS), and LD contributed to data analysis, interpretation, and manuscript revision. IB drafted the manuscript, managed co-author revisions, prepared the manuscript for submission and managed the manuscript review process. The manuscript was revised following peer-review and editorial suggestions by the journal. The manuscript presented in this thesis is unchanged from the published paper.

Chapter 8 contains the manuscript submitted for publication to *Anaesthesia* on 24th June 2020

> Boden I, Reeve J, Robertson IK, Story D, Browning L, Skinner EH, Anderson L, Hill C, and Denehy L. Preoperative physiotherapy prevents pulmonary collapse and infection after major abdominal surgery: secondary analysis of the LIPPSMAck-POP randomised controlled trial.

IB and IR planned and did the statistical analysis. IB, ES, LB, JR, IR, DS, and LD analysed and interpreted the data, revised all manuscript drafts and approved the final manuscript. IB drafted the manuscript, managed co-author revisions, prepared the manuscript for submission and managed the manuscript review process. The manuscript was submitted to the United States journal *Anaesthesiology* in February 2020. Following favourable peer-review received April 2020 an editorial decision was made not to publish due to the divergence in physiotherapy clinical management between American and Australian hospitals. The manuscript presented in this thesis is the revised version submitted to the British journal *Anaesthesia*. This chapter is in the format and reference structure as submitted.

Chapter 9 contains the manuscript accepted for publication in *Journal of Physiotherapy* on June 11th, 2020.

> Boden I, Robertson IK, Neil A, Reeve J, Palmer A, Skinner EH, Browning L, Anderson L, Hill C, Story D, Denehy L. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis within a binational multicentre randomised controlled trial. *J Physiother* 2020; accepted, in press

IB devised the concept for the paper. IB and IR contributed to the research design, conducted the data analyses, and interpretation. Dr Amanda Neil and Professor Andrew Palmer reviewed the methodology, analyses, and interpretations. IB wrote the first draft of the manuscript. All authors contributed to the revised manuscript and approved the final version of the manuscript prior to submission. IB managed the manuscript submission.

Chapter 1, Chapter 3, Chapter 4, Chapter 10, and Chapter 11 are unpublished material and have not been submitted for publication.

Dr Christine Bryden and Paul Bryden provided unpaid copy editing and proof reading of the entire thesis.

# Publications

## Published manuscripts

1. Reeve J, **Boden** I. The physiotherapy management of patients undergoing abdominal surgery. *N Z J Physio* 2016; 44(1): 33-49. doi: 10.15619/NZJP/44.1.05. [Chapter 2]

2. **Boden** I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, and Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery-Major Abdominal-with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials* 2015; 16:1-15. [Chapter 5]

3. **Boden** I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, and Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised controlled study. *Physiotherapy* 2018; 104:194-202. [Chapter 6]

4. **Boden** I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, Robertson IK, Story D, and Denehy L. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ*. 2018, 360, p.j5916. [Chapter 7]

5. **Boden** I. Critically appraised paper: Preoperative physiotherapy education halved postoperative pulmonary complications in patients after upper abdominal surgery [commentary]. *J Physiother*. 2018; 64(3):195-196. [Chapter 7]

## Accepted manuscript

1. **Boden** I. Robertson IK, Neil A, Reeve J, Palmer A, Skinner EH, Browning L, Anderson L, Hill C, Story D, Denehy L. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis within a binational multicentre randomised controlled trial. *J Physiother*. 2020. [Chapter 9]

## Submitted for publication

1. **Boden** I, Reeve J, Robertson IK, Story D, Browning L, Skinner EH, Anderson L, Hill C, and Denehy L. Preoperative physiotherapy prevents pulmonary collapse and infection after major abdominal surgery: secondary analysis of the LIPPSMAck-POP randomised controlled trial. *Anaesthesia*. Submitted 20th June 2020. [Chapter 8]

# Podcasts

PTPintcast “Research review of LIPPSMAck-POP from PEDro”. Published February 19, 2020. https://www.ptpintcast.com/2020/02/19/research-review-of-lippsmack-pop-from-pedro/

Royal Australian College of Surgeons. Post Op Podcast. “Trials to prevent chest infections following upper abdominal surgery”. Published January 09, 2018. https://omny.fm/shows/racs-post-op-podcast/trials-to-prevent-chest-infections-following-upper

Australian and New Zealand Intensive Care Society Clinical Trials Group, “Post operative pulmonary complications – where are we and what can we do?”. Published March 17, 2017. https://omny.fm/shows/essential-critical-care/post-operative-pulmonary-complications-where-are-w

# Featured published blogs/online material

Frontline. NIHR: physiotherapy education before surgery reduces lung complications, with expert opinion from Charlotte Pereira. Chartered Society of Physiotherapy. https://www.csp.org.uk/frontline/article/nihr-physiotherapy-education-surgery-reduces-lung-complications. Published online December 01, 2019. Accessed February 24, 2020.

PEDro. PEDro Top 5 Trials 2014-2019. PEDro website. https://www.youtube.com/watch?v=vWFgBvH9pdI. Published online November 9, 2019. Accessed February 24, 2020.

Eady J. LIPSMAck-POP. Online slide presentation. https://prezi.com/bazpsjkgw0fa/lung-infection-post-surgery-major-abdominal-pre-operativ/. Published online May 12, 2019. Accessed February 24, 2020.

Faherty C. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: a critical appraisal. Students 4 best evidence. https://www.students4bestevidence.net/blog/2019/05/07/preoperative-physiotherapy-for-the-prevention-of-respiratory-complications-after-upper-abdominal-surgery-a-critical-appraisal/ Published online May 7, 2019. Accessed February 24, 2020.

Patman S. Preoperative physiotherapy education prevented postoperative pulmonary complications following open upper abdominal surgery. *BMJ Evid Based Med*. 2019 Apr;24(2):74-75. doi: 10.1136/bmjebm-2018-110985. https://ebm.bmj.com/content/24/2/74.long.

Black R. Breathing training prevents post-op pneumonia. Florence Health. https://www.florence-health.com/specialties/pulmonology/breathing-training-prevents-post-op-pneumonia/. Published online March 27, 2019. Accessed February 24, 2020.

Marshall J. A single preoperative physiotherapy session reduced pulmonary complications after upper abdominal surgery. ACP Journal Club. *Ann Intern Med*. 2018; 168 (10):JC51. https://annals.org/aim/article-abstract/2681288/single-preoperative-physiotherapy-session-reduced-pulmonary-complications-after-upper-abdominal

China Critcare.com. Preoperative physiotherapy for the prevention of respiratory complications. http://www.china-critcare.com/upload/2018-09-22/97303369-5785-4ce9-a3a7-041cf7907788.pdf. Published online September 22, 2018. Accessed February 24, 2020.

National Institute of Health Research Signal. Physiotherapy education before major abdominal surgery reduces lung complications. Expert commentary by Professor Anne Bruton and Associate Professor Dimitra Nikoletou. NIH. https://discover.dc.nihr.ac.uk/content/signal-00579/physiotherapy-before-abdominal-surgery-helps-prevent-pneumonia. Published online April 3, 2018. Accessed February 24, 2020.

Frellick M, Barclay L. Can preop physiotherapy prevent postop respiratory complications. Medscape. https://www.medscape.org/viewarticle/893646. Published online March 13, 2018. Accessed February 24, 2020.

White C. Physio-taught breathing exercise staves of postoperative pneumonia. Frontline. Chartered Society of Physiotherapy. https://www.csp.org.uk/frontline/article/physio-findings-physio-taught-breathing-exercise-staves-postoperative-pneumonia. Published online February 21, 2018. Accessed February 24, 2020.

O'Connor M: F1000Prime Recommendation of [Boden I et al., BMJ 2018 360:j5916]. In F1000Prime, 21 Feb 2018; 10.3410/f.732568173.793542775. Accessed February 24, 2020.

Biccard B: F1000Prime Recommendation of [Boden I et al., BMJ 2018 360:j5916]. In F1000Prime, 14 Feb 2018; 10.3410/f.732568173.793542448. Accessed February 24, 2020.

Heneghan C. Evidence watch: Carl Heneghan's view on evidence that impacts practice. Blog: BMJ EBM Spotlight. http://blogs.bmj.com/bmjebmspotlight/2018/02/22/evidence-watch-carl-heneghans-selection-evidence-impacts-practice/. Published online February 22, 2018. Accessed February 24, 2020.

Ignitephysio. 30 minutes of preoperative PT may help reduce the risk of postoperative pulmonary complications. https://ignitephysio.ca/blog/30-minutes-of-preoperative-pt-may-help-reduce-the-risk-of-postoperative-pulmonary-complications/. Published online February 19, 2018. Accessed February 24, 2020.

Wong A. LIPPSMAck-POP. The Bottom Line. https://www.thebottomline.org.uk/summaries/pom/lippsmack-pop/. Published online February 02, 2018. Accessed February 24, 2020.

PM360. Preop physiotherapy training reduces risk of postop pulmonary complications. PM360. https://www.pm360online.com/preop-physiotherapy-training-reduces-risk-of-postop-pulmonary-complications/. Published online January 31, 2018. Accessed February 24, 2020.

Kamps T. Preop physiotherapy training reduces risk of postop pulmonary complications. Pulmonary Health Hub. https://www.mdedge.com/pulmonary-health-hub/article/157515/healthcare-acquired-infections/preop-physiotherapy-training. Published online January 31, 2018. Accessed February 24, 2020.

Dunleavy B. Can breathing exercises reduce the risk of postoperative infections and antibiotic use following abdominal surgery? ContagionLive. https://www.contagionlive.com/news/can-breathing-exercises-reduce-the-risk-of-postoperative-infections-antibiotic-use-following-abdominal-surgery. Published online January 31, 2018. Accessed February 24, 2020.

Aerzteblatter.de. Atemtraining mit Physiotherapeuten vor OP kann postoperative Pneumonie verhindern. https://www.aerzteblatt.de/nachrichten/88860/Atemtraining-mit-Physiotherapeuten-vor-OP-kann-postoperative-Pneumonie-verhindern. Published online January 30, 2018. Accessed February 24, 2020.

Lehman R. Richard Lehman's journal review. The BMJ opinion. http://blogs.bmj.com/bmj/2018/01/29/richard-lehmans-journal-review-29-january-2018/ Published online January 29, 2018. Accessed February 24, 2020.

Medical Xpress. Pre-op physical therapy may cut pulmonary complications. Medical Xpress webpage. https://medicalxpress.com/news/2018-01-pre-op-physical-therapy-pulmonary-complications.html. Published online January 29, 2018. Medical Xpress.

Physician's Briefing. Pre-op physical therapy may cut pulmonary complications. Physician's briefing webpage. https://www.physiciansbriefing.com/pulmonology-17/misc-respiratory-problem-news-580/pre-op-physical-therapy-may-cut-pulmonary-complications-730458.html. Published online January 29, 2018. Accessed February 24, 2020

Benz M. Teaching deep breathing before abdominal surgery reduced post-op pneumonia. Medical research.com. https://medicalresearch.com/author-interviews/teaching-deep-breathing-before-abdominal-surgery-reduced-post-op-pneumonia/39576/. Published online January 25, 2018. Accessed February 24, 2020.

Prime L. Pre-surgery breathing physio halves risk of complications. Onmedica. http://www.onmedica.com/newsArticle.aspx?id=de4a2f16-bbf2-441a-8d1e-5da197a4c4e6. Published online January 25, 2018. Accessed February 24, 2020.

Venkataraman L. Postoperative lung complications reduced by breathing exercises training preoperatively. Medindia. https://www.medindia.net/news/healthinfocus/respiratory-training-before-surgery-significantly-reduces-risk-of-postoperative-lung-complications-176472-1.htm. Published online January 25, 2018. Accessed February 24, 2020.

# Associated publications authored by the candidate during PhD candidature

1. Thomas P, Baldwin C, Bissett B, **Boden I**, Gosselink R, Granger CL, Hodgson C, Jones AY, Kho ME, Moses R, Ntoumenopoulos G. Physiotherapy management for COVID-19 in the acute hospital setting: clinical practice recommendations. *Journal of Physiotherapy*. 2020 Mar 30.

2. Lockstone J, Parry SM, Denehy L, Robertson IK, Story D, Parkes S, **Boden I.** Physiotherapist administered, non-invasive ventilation to reduce postoperative pulmonary complications in high-risk patients following elective upper abdominal surgery; a before-and-after cohort implementation study. *Physiotherapy*. 2020 106:77-86. doi:10.1016/j.physio.2018.12.0032018. https://doi.org/10.1016/j.physio.2018.12.003.

3. Ntoumenopoulos G, Dunlop D, **Boden I**, Williams M, Johnston K, Edbrooke L. Five facts about cardiorespiratory physiotherapy. Australian Physiotherapy Association. InMotion. 1st December 2019. https://australian.physio/inmotion/5-facts-about-cardiorespiratory-physiotherapy

4. **Boden I** and Lockstone J. Response to letter to the editor re 'Physiotherapist administered, non-invasive ventilation to reduce postoperative pulmonary complications in high-risk patients following elective upper abdominal surgery; a before-and-after cohort implementation study'. *Physiotherapy*. 2019 Jul 20. pii:S0031-9406(19)30081-1. doi: 10.1016/j.physio.2019.07.005.

5. Lockstone J, **Boden I,** Zalucki N, Darvas J, Parkes S. Development of a physiotherapy-led bronchoscopy service: a regional hospital perspective. *Aust Health Rev*. 2019 Dec 12. doi: 10.1071/AH19144.

6. Hackett C, **Boden I**, Turner C. Does collapse/consolidation on medical imaging or oxyhemoglobin desaturation on room air accurately predict pulmonary complications after abdominal surgery? *Respirology*. 2019. 24:supp87.

7. Lockstone J, **Boden I**, Robertson IK, Story D, Denehy L, Parry SM. Non-Invasive Positive airway Pressure thErapy to Reduce Postoperative Lung complications following Upper abdominal Surgery (NIPPER PLUS): protocol for a single-centre, pilot, randomised controlled trial. *BMJ Open.* 2019. 9(1):e023139.

8. **Boden I**, Sullivan K, Hackett C, Winzer B, Lane R, McKinnon M, Robertson I. ICEAGE (Incidence of Complications following Emergency Abdominal surgery: Get Exercising): study protocol of a pragmatic, multicentre, randomised controlled trial testing physiotherapy for the prevention of complications and improved physical recovery after emergency abdominal surgery. *World Journal of Emergency Surgery*. 2018:*13*(1):29. https://doi.org/10.1186/s13017-018-0189-y.

9. **Boden IJ**, Reeve JC. Phase 1 evaluation of tubing PEP as an improvised positive expiratory pressure device: Pressures generated through oxygen tubing across a range of flow rates and lengths. *Pulmonol Respir Res*. 2017;5:1. doi: 10.7243/2053-6739-5-1.

10. Sullivan K, Reeve J, **Boden I**, Lane R. Physiotherapy following emergency abdominal surgery. In: Garbuzenko D, editor. Actual Problems of Emergency Abdominal Surgery [Internet]. InTechOpen; 2016 [cited 2016 Sept 21]. doi: 10.5772/63969. https://www.intechopen.com/books/actual-problems-of-emergency-abdominal-surgery/physiotherapy-following-emergency-abdominal-surgery.

# Conference Presentations

## International

1. **Boden I,** Sullivan K, Hackett C, Winzer B, McKinnon M, Robertson I, Story D, Denehy L. Incidence of Complications after Emergency Abdominal surgery Get Exercising (ICEAGE) trial: a multi-centre randomised controlled trial. *World Confederation for Physical Therapy Congress*. Geneva, Switzerland. May 2019.

2. **Boden I**, Browning L, Skinner EH, Reeve J, Anderson L, Hill C, Robertson IK, Denehy L. Oral presentation. 'Lung infection prevention post-surgery major abdominal with pre-operative physiotherapy (LIPPSMAck POP) trial: a bi-national multi-centre randomised controlled trial.' *Australian and New Zealand College of Anaesthetists Annual Scientific Meeting*. Auckland, New Zealand. May 2016.

3. **Boden I**, Browning L, Skinner EH, Denehy L. Poster. 'The Melbourne respiratory complication risk prediction tool accurately predicts patients unlikely to get a respiratory complication following major open upper abdominal surgery.' *Australian and New Zealand College of Anaesthetists Annual Scientific Meeting*. Auckland, New Zealand. May 2016.

4. **Boden I**, Skinner EH, Browning L, Denehy L. Poster. 'Hospital costs of respiratory complications following abdominal surgery: Implications for service provision and interpretation of clinical trials.' *Australian and New Zealand College of Anaesthetists Annual Scientific Meeting*. Auckland, New Zealand. May 2016.

## National

1. **Boden I**, Browning L, Skinner EH, Reeve J, Anderson L, Hill C, Robertson IK, Denehy L. 'Lung infection prevention post-surgery major abdominal with pre-operative physiotherapy (LIPPSMAck POP) trial: a bi-national multi-centre randomised controlled trial.' Oral presentation. *Royal Australian College of Surgeons Annual Scientific Congress*. Adelaide, South Australia, Australia. May 2017.

2. **Boden I**, Skinner EH, Browning L, Denehy L. 'Mortality and hospital costs of respiratory complications following abdominal surgery: The killer in our midst'. Poster. *Royal Australian College of Surgeons Annual Scientific Congress*. Adelaide, South Australia, Australia. May 2017.

3. **Boden I**, Browning L, Skinner EH, Denehy L. 'The Melbourne respiratory complication risk prediction tool accurately predicts patients unlikely to get a respiratory complication following major open upper abdominal surgery.' *Royal Australian College of Surgeons Annual Scientific Congress*. Adelaide, South Australia, Australia. May 2017.

4. **Boden I**, Browning L, Skinner EH, Reeve J, Anderson L, Hill C, Robertson IK, Denehy L. Lung Infection Prevention Post-Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) trial: 12-month mortality and sub-group effects.

*Australian Physiotherapy Association Conference*. Sydney, New South Wales, Australia. October 2017.

5. **Boden I**, El-Ansary D, Zalucki N, Browning L, Skinner EH, Robertson IK, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised controlled study. *Australian Physiotherapy Association Conference*. Sydney, New South Wales, Australia. October 2017.

6. **Boden I**, Browning L, Skinner EH, Denehy L. Allied health assistants can safely and effectively provide early ambulation following major upper abdominal surgery. Poster. *Australian Physiotherapy Association Conference*. Gold Coast, Queensland, Australia. 2015.

7. **Boden I**, Skinner EH, Browning L, Denehy L. Poster. 'Hospital costs of respiratory complications following abdominal surgery: Implications for service provision and interpretation of clinical trials.' Oral presentation. *Australian Physiotherapy Association Conference*. Gold Coast, Queensland, Australia. 2015.

8. **Boden I**, Browning L, Skinner EH, Reeve J, Anderson L, Hill C, Robertson IK, Denehy L. Oral presentation. 'Lung infection prevention post-surgery major abdominal with pre-operative physiotherapy (LIPPSMAck POP) trial: a bi-national multi-centre randomised controlled trial.' Oral presentation. *Australian Physiotherapy Association Conference*. Gold Coast, Queensland, Australia. 2015.

9. **Boden I**, Browning L, Skinner EH, Denehy L. 'The Melbourne respiratory complication risk prediction tool accurately predicts patients unlikely to get a respiratory complication following major open upper abdominal surgery.' Oral presentation. *Australian Physiotherapy Association Conference*. Gold Coast, Queensland, Australia. 2015.

# Invited Presentations

## International

1. Reeve J, **Boden I**, Valkenet K, Fiore J. 'Preoperative physiotherapy management for patients undergoing major visceral surgery.' Focused symposium FS-13. *World Confederation for Physical Therapy Congress*. Geneva, Switzerland. May 2019.

2. **Boden I.** 'What gives the best bang for buck? Preoperative intervention to prevent postoperative complications.' *Australian and New Zealand College of Anaesthetists Annual Scientific Meeting*. Kuala Lumpur, Malaysia. May 2019.

3. Story D, **Boden I,** Biccard B, Klein A. 'Seize the day! Preoptimisation instead of pre-assessment before surgery.' Masterclass. *Australian and New Zealand College of Anaesthetists Annual Scientific Meeting*. Kuala Lumpur, Malaysia. May 2019.

## National

1. **Boden I.** 'Magic without medicine: Allied Health engagement from start to finish'. *Australian and New Zealand College of Anaesthetists Perioperative Medicine Special Interest Group Conference*. Perth, Australia. April 2020.

2. **Boden I.** 'From bugger all to The BMJ', *Centre of Integrated Critical Care Medicine*. University of Melbourne, Melbourne, Australia. November 2019.

3. **Boden I.** 'The physio's role in reducing postoperative pulmonary complications.' *Australian and New Zealand College of Anaesthetists Perioperative Medicine Special Interest Group*: Updates in PoM - 360°. Brisbane, Australia. November 2019.

4. **Boden I.** 'Magic without medicine'. *Australian and New Zealand College of Anaesthetists Perioperative Medicine Special Interest Group Conference*, Art of Anaesthesia. Canberra, Australia. October 2019.

5. **Boden I**. Keynote speaker. *North East & Goulburn Valley Allied Health Conference*, Engage, Connect, Create. Beechworth, Victoria, Australia. June 2019.

6. **Boden I.** 'Prehab – could it be the difference between life and death?'. Inn$O_2$vate. Tasmanian Winter Workshop, *Australian and New Zealand College of Anaesthetists*. Barnbougle, Tasmania, Australia. August 2018.

7. **Boden I.** 'Postoperative pulmonary complications: killers, costs, and how physiotherapy can save the day'. *Monash University Cardiorespiratory Physiotherapy Seminar*. Monash University. Melbourne, Victoria, Australia. August 2017.

8. **Boden I.** Keynote speaker. *Australian Physiotherapy Association*. Tasmanian Forum, Hobart, Tasmania. May 2017.

9. **Boden I.** Keynote speaker. *Australian Physiotherapy Association Cardiorespiratory Group*. Invited Lecture. Brisbane, QLD, Australia. August 2016.

10. **Boden I**. "Preventing complications after major surgery." *Tasmanian Allied Health Symposium*. Launceston, Tasmania, Australia. May 2018.

11. **Boden I**. 'Post-Operative Pulmonary Complications following major upper abdominal surgery: Predicting, preventing, and calculating the cost.' *Australian Physiotherapy Association Western Australian Research Symposium*. Perth, Western Australia. May 2016.

12. **Boden I.** "Preventing postoperative pulmonary complications after upper abdominal surgery." *Menzies Institute*, monthly invited lecture. Hobart, Tasmania, Australia. October 2014.

13. **Boden I.** 'Preventing postoperative pulmonary complications after upper abdominal surgery. Can you handle the truth?' Evening seminar. *Australian Physiotherapy Association*. Melbourne, Victoria, Australia. November 2014.

14. **Boden I.** *Thoracic Society Australia and New Zealand* Tasmanian Branch Annual Scientific Meeting. Bicheno, Tasmania, Australia. November 2013.

# Awards

## International

2019 Physiotherapy Evidence Database (PEDro) Best Clinical Trial 2019. Incidence of Complications after Emergency Abdominal surgery: Get Exercising. *World Confederation for Physical Therapy Congress*. Geneva, Switzerland, May 2019.

2019 PEDRo award; LIPPSMAck-POP awarded as for one of the world's five most significant physiotherapy clinical trials published in the five years 2013-2018 and included within top 20 influential physiotherapy trials of all time.

*"To celebrate PEDro's 20th birthday we identified the five most important randomised controlled trials in physiotherapy published in the years 2014-2019. Again, we invited PEDro users to nominate randomised controlled trials in physiotherapy for consideration. Nominations were judged by a panel of international physiotherapy trialists. These PEDro Top 5 Trials from 2014-2019 were combined with the PEDro Top 15 Trials to form the PEDro Top 20 Trials.*

*The PEDro Top 20 Trials are ground-breaking trials that changed the way people are treated for a variety of conditions seen by physiotherapists and other healthcare professionals. Some of these trials set the stage for breakthroughs, some represent a paradigm shift, and all of them mark important milestones in the evolution of physiotherapy treatment."*
https://www.pedro.org.au/english/archive/top-20-trials/

## National

2016 Graeme Duffy award for Best Paper at the Tasmanian Royal Branch Royal Australian College of Surgeons Annual Scientific Meeting, Hobart.

*Inaugural presentation of this award to a non-surgeon.*

2016 Australian and New Zealand College of Anaesthetics Annual Scientific Meeting, Auckland, award for best oral presentation of an e-poster.

*Inaugural presentation of this award to a non-anaesthetist*

2015 Jill Nosworthy Award for Excellence in Cardiorespiratory Physiotherapy Research, Australian Physiotherapy Association Conference, Gold Coast.

2014 Tasmanian Allied Health Professional Advancement Committee Award for collaborative leadership initiatives in Allied Health – clinical trials in preventing complications and improving recovery following abdominal surgery.

2013 Sir John Ramsay Pursuit of Excellence in Health Award, Rotary Club Tasmania.

# Research grants

The LIPPSMAck-POP study was an investigator-initiated trial funded by competitive research grants from the Clifford Craig Foundation, Launceston, Australia ($65,000), the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia ($50,000), and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand ($20,000).

Support was provided from departmental sources at each participating study centre (Launceston General Hospital, North West Regional Hospital, North Shore Hospital) and by sponsorship by the Tasmanian Health Service - North to support the candidate (IB) for the period of the trial.

# Acknowledgements

Most Acknowledgement sections start with thanking all the people that have contributed to the candidate managing to complete their thesis then ending with the most important person in the candidate's life that enabled the thesis to come to fruition. This will be different. There would be no point in thanking anyone else if my partner, Nadia Zalucki, hadn't backed me completely to get this done. Without her, this body of work would never have happened, and there would be no one else to thank! During these past seven years she has held many roles; too often she has had to play solo parent to our three children whilst I had my head stuck in databases to the early hours of the mornings, wrote papers, and gallivanted from one conference to another. Maybe she knew what she was getting herself into as both parents and two siblings have PhDs, but I don't think anyone can totally prepare themselves for such an undertaking, especially as we had two children under five and a newborn when I started this PhD. Nadia has been a constant force of calm, humor, and patience whilst being both my home manager and my work manager. An unenviable task. At times she has been my fiercest critic, reining in my oft tendencies to wax lyrical about research, my heroic predictions, grandiose plans, and irreverent opinions. On the other hand she intuitively knows that I like to 'think big' and enabled me to turn words into action by giving me all the logistical support I ever needed at home to turn my dreams of running a multicentre trial into a reality. LIPPSMAck-POP is as much of a product of her hard work as it is of mine. Thank you, Nadia, for being my statistically significant other.

This now brings me to our children. For the past seven years they have missed out on countless bedtime stories, movie nights, bike rides on the weekend, hits at the cricket nets, a kick of the soccer ball, me at the dinner table, me watching them play sport or sing at a concert, pick-ups from school, rough and tumbles, and being there when they were sick. However, when my children tell me they are proud of what I have done, when I see their chests puff out when they read a newspaper article about my research, when I see Saskia my thirteen year old daughter study hard after school, telling me that she loves learning and studying, when I catch Zac, my ten year old son, reading one of my papers and tells me "Hey, this is really interesting!", and when my seven year old son Finn, hugs me and tells me he is glad that so many people in hospitals are now not getting as sick as they used to, well, it makes me hope that the sacrifices they all made in order to for me to finish this PhD are worth it with three little humans who are intimately aware of academic endeavor and what it takes to work together as a family to achieve something.

I need to thank the research assistants who worked so hard during the running of LIPPSMAck-POP, Kate Sullivan and Bronte Biggins-Tosch. Not only did we work hard, we played hard too. Thanks for the laughs as we worked through the data, for the beers and late nights afterwards!

Others involved in making this multicentre trial a reality were the principal investigators; Cat Hill at North West Regional Hospital, in Burnie, and Lesley Anderson at North Shore Hospital, Auckland. Both are incredible assets to their hospital, hard workers, with unfailing positive attitudes to their staff and patients and open enquiring minds. Thank you both for your diligence and for making this happen at your hospital. You certainly made it easier to get this project done; classic response was almost always 'No problems, Ianthe'. The physiotherapists involved in providing the LIPPSMAck-POP interventions had never participated in a clinical trial before, so thank you Marcus Sullivan, Jenna Ford, Victoria Lai, Andrew Michael, Emma Dwyer, Tom Shepherd, and Vic Stephenson, for being brave, putting your hand up, and 'preop-ing' all those patients. I must also thank Iain Robertson, biostatistician extraordinaire. Whilst we were analyzing LIPPSMAck-POP data we had some of the most interesting chats ranging from ethics, economics, politics, to statistical interpretation of trials, and the web of confounding influences. Through these conversations we dived down the rabbit hole of maths, stats, ethics, and research methodology. I loved every minute.

Without Dr Julie Reeve and Associate Prof Doa El-Ansary sharing a fateful car trip one night years ago I doubt that LIPPSMAck-POP would have ended up being multicentre. My relationship with Doa started decades ago when I was a second-year physiotherapy student and she was my student supervisor at The Canberra Hospital. Quite simply, Doa is the reason that I became enamored about cardiorespiratory physiotherapy and am where I am today. Doa's passion for physiotherapy for cardiac or respiratory conditions was infectious. It was the watershed moment in my career and I never looked back. I am forever thankful for her mentorship, boundless enthusiasm, and encouragement she has unfailingly provided me all these years. Which brings me to Julie Reeve. I am told that Doa was driving Julie around Melbourne on one of Julie's collaboration trips across 'the ditch'. Julie was telling Doa about her need to get her teeth stuck into some good clinical trial research and wished she knew someone to work with. Apparently Doa slammed on the brakes, pulled the car over, turned to Julie, and said "You *have* to work with Ianthe." And that was that. Julie is now my go-to co-author, colleague, collaborator, and conspirator. I have loved our full and frank 'discussions', ok, you can call them arguments, where we both plant our feet on the ground and go back and forth debating the research and evidence without giving an inch, then we pause, breathe, go for a walk together, then come back, grin at each other, and find that common ground that beautifully balances the uncertainty in the data. I look forward to many more barneys over a glass of Pinot.

I remember as a physiotherapy student reading a randomised controlled trial in a top surgery journal, *British Journal of Surgery*, conducted by a Swedish PhD student called Monika

Fagevik-Olsén. I was astounded. It was a stunning trial and so big at the time for physiotherapy research. A remarkable 368 participants. From that time, I keenly followed her research and became quite the acolyte. No one-hit Swedish wonder, Monika was like ABBA, coming out with hit trial after hit trial investigating physiotherapy and surgery. She was prodigious. It was her original *BJS* trial I wanted to replicate with LIPPSMAck-POP. So you can imagine how I felt when she wanted to travel to Tasmania from the other side of the planet to visit me. Me! She wanted to work with me?! I did my best to keep a lid on my bubbly groupie-like awe and not gush. Monika - I have loved not only our ongoing research collaborations, but the bike rides in Sweden, sharing a love of whisky with your husband, being Eurovision fanatics together, our many long talks and big ideas. You have been my research inspiration and guru from the beginning. I still get a buzz about proving something you did in the 90's.

For many, working at a regional hospital in Tasmania may not be the ideal place to conduct research. There is a persistent belief that the only good cardiorespiratory physiotherapy researchers work at big metro hospitals. However, in this case, it made it easier for me. A smaller hospital lacks the inertia and bureaucratic layers of larger facilities. There is also a distinct lack of ego. At the Launceston General Hospital, I was fully supported by my managers, Cindy Hollings, Shawn Lee, James Darvas, and John Cannell, my equivalent in the Neurorehabilitation physio stream, and, Anne Brierley, our department's business manager. This team assisted and facilitated my research endeavors actively, with drive, persistence, and a can-do attitude. I cannot thank the Physiotherapy Department and the LGH enough. This hospital walks the walk with great multidisciplinary collaboration, full support from anaesthetists, surgeons, administrators, and the executive. In my case, the hurdles were low, easily jumped over, and the tail wind enabling me to run faster was palpable. Thank you for your faith and trust in me to be able to turn research into deliverables for patients that improve their health.

Without grant funding, LIPPSMAck-POP would have never started. The Clifford Craig Foundation took a big punt in 2013 in awarding an ambitious physiotherapist with only a small research track record a big wad of cash to launch this clinical trial. Giving clinicians like me a leg up on the research ladder really helps. Without them taking a chance that my hypothesis was worth testing, LIPPSMAck-POP would still be a concept, not a reality. Similar thanks need to be given to the University of Tasmania and the Waitemata District Health Board and Three Harbours Health Foundation, Auckland. They looked at the preliminary runs on the board, sensed there was something in what we were doing, and supported LIPPSMAck-POP to branch out to other hospitals. This took LIPPSMAck-POP to the next level – an international,

multicentre trial. Without their support, I doubt LIPPSMAck-POP would have ever been considered for publication in one of the top four medical journals in the world.

Whilst I have been completing this opus I have had an amazing social support team in the background keeping my feet on the ground and connected to the outside world. Cat and Sam Miedecke for Christmases, swims in the dam, and the numerous kids' birthday parties; Kate and Dennis Giasli, for Catan nights, canoe rides, haloumi making, and sleep-overs at the farm; and Geoff and Leanne Purchase, for Easters, all those board-games, card games, beer nights, and for being the friends I can wear Ugg boots around. Thank you for keeping me sane, laughing, and living well during these last seven years. Two other friends have been constant supports during this time: Lara Griffiths, hand therapist extraordinaire, and Jane Lockstone, awesome ICU physiotherapist. Thank you for the Friday drinks after work, the weekends at the beach house, the doggy play dates, and most of all feigning interest whenever I would blab on about my research. The truest of friends.

I still remember the day when I was probably 10 when my mother taught me about the scientific method. How to formulate a hypothesis, how to test it, to consider strengths and weaknesses of measurement properties, and how to build on knowledge. I was always so proud of my mother. In the days when most mums stayed at home, mine was working for CSIRO and the government to establish Australia's first space agency!! She was a microbiologist by training, then a journal editor, a science policy adviser, then a top-level executive bureaucrat. My hero. Then she got really sick. I thought we would lose her. Thankfully, we didn't, but she never worked again. Long story short, but after often regretting she never did a PhD, after I had started mine, my mother said "What the hell. Nothing to lose" and she started one too! She finished hers way before mine. Of course, she did. She was always a superstar in whatever she set her mind to. So Dr Christine Bryden, PhD, MBA, BSc (Hons), Member of the Order of Australia (AM), Public Service Medal (PSM), yet most importantly to me, my mother, thank you for your patient persistence and belief that I would turn out all right in the end, despite my occasional shenanigans and wild ways. Thank you for teaching me science. Thank you for showing me women can do anything in this world by just getting in there and doing it. Thank you for teaching me about social justice. Thank you for your intelligence, generosity of spirit, and for making a mark on this world. This PhD is a memento to you Mum.

Lastly, I come to my PhD supervisory team. Professor Linda Denehy, Dr Lizzie Skinner, and Dr Laura Browning: the dream team. All had skills and attributes that were complementary and honed my research from a scratchy mess into a polished PhD. Laura Browning was a sensational editor, literally ensuring that my i's were dotted and t's crossed. Laura helped me to

learn how to write clearly and succinctly. She was also brilliant at bringing me back to look at the trees whilst I was off waving my hands around exclaiming excitedly about the forest. I loved her calm ability to ensure I didn't forget about the details of the methods. Thanks, Laura, for being that steady point of reference I often needed in the maelstrom of my big ideas and for reminding me that excellence is not always about quantity, but through quality.

I remember meeting Lizzie for the first time at a conference and I was instantly struck by her passion for research and her unflinching ability to shoot from the hip, to speak her mind boldly with confidence and knowledge. I liked this person! I was in awe of her intelligence and her grasp of so many different types of research methods. But what has impressed me most is her strong ethical and moral personal constructs and sense of social justice. Lizzie is formidable and was just the right type of supervisor for me. I'm the type of PhD student who needed a Lizzie Skinner on her team. I needed someone to say to me "You can't say that, Ianthe", or, "You're not getting it. Try again." By coming through the excoriating blow torch of Lizzie's manuscript reviews this work is inherently better, and I am a much better researcher for it. Thank you Lizzie for being the prophet and truthsayer, telling me things I didn't like hearing at the time but because of your honesty, intelligence, and moral compass, I knew needed saying. I listened, I heard, and I learnt something every time. Thank you.

My last, but nowhere near the least, thanks go to Professor Linda Denehy. I specifically chose University of Melbourne to do my PhD simply because I wanted to work with Linda. Her reputation was formidable, with successful PhD physiotherapists coming out of her stable, setting the standard of cardiorespiratory research worldwide. Linda was front and centre of abdominal surgery research in Australia, and consequently the world. Despite so many competing demands of her time; her own research, teaching, conferences, curriculum development, head of school, grant writing, Linda somehow always found time to respond to emails, review my manuscripts, and guide my research journey. And what a journey it has been! Linda has been primarily responsible for taking this ambitious, green, haphazard, upstart of a researcher from a wee little hospital in some random island off the coast of Victoria and turned me into an accomplished clinical trialist. I have valued Linda's ability to weave her networks in anaesthesiology, medicine, allied health, academia, and health administration into strategically considering how this research fits in the bigger picture. Linda has taught me not only about the details of research methodology, but about the political and social science that bubbles away in the background that is so important in getting one's findings 'noticed'. Thank you, Professor, I hope this new horse trotting out of your stable has done you proud.

# List of common abbreviations

| Abbreviation | Description |
|---|---|
| AAA | abdominal aortic aneurysm |
| AIHW | Australian Institute of Health and Welfare |
| ARR | absolute risk reduction |
| ART | Alveolar Recruitment for Acute Respiratory Distress Syndrome Trial |
| ASA | American Association of Anaesthesiologists |
| BiPAP | bilevel positive airway pressure |
| BMI | body mass index |
| CI | confidence interval |
| CONSORT | Consolidated Standards of Reporting Trials |
| CPAP | continuous positive airway pressure |
| CT | computed tomography |
| CXR | chest x-ray |
| DB&C | deep breathing and coughing |
| DVT | deep vein thrombosis |
| ERAS | Enhanced Recovery After Surgery |
| $FiO_2$ | fraction of inspired oxygen |
| FRC | functional residual capacity |
| GI | gastrointestinal |
| HR | hazard ratio |
| HRQoL | health-related quality of life |
| ICD-10 | International Classification of Diseases |
| ICU | intensive care unit |
| IMT | inspiratory muscle training |
| IPPV | intermittent positive pressure ventilation |
| IQR | inter-quartile range |
| IS | incentive spirometry |
| LAS | lower abdominal surgery |
| LIPPSMAck-POP | Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy |
| LOS | length of stay |
| MIP | maximum inspiratory pressure |

| | |
|---|---|
| MGS | Melbourne Group Score |
| MET | metabolic equivalent of task |
| NIV | non-invasive ventilation |
| NNT | numbers needed to treat |
| PE | pulmonary emboli |
| PEDro | Physiotherapy Evidence Database |
| PEP | positive expiratory pressure |
| PEEP | positive end expiratory pressure |
| POD | postoperative day |
| PPC | postoperative pulmonary complications |
| QALY | quality adjusted life year |
| RCT | randomised controlled trial |
| RPE | rating of perceived exertion |
| RR | risk ratio |
| RRR | relative risk reduction |
| Rx | treatment |
| SD | standard deviation |
| SF-36 | short-form 36 |
| SpO2 | peripheral oxygen saturation |
| Temp | temperature |
| TIDIeR | Template for Intervention Description and Replication |
| UAS | upper abdominal surgery |
| VATS | video-assisted thoracic surgery |
| VTE | venous thromboembolic event |
| VO2 max | maximum rate of oxygen consumption |
| WCC | white cell count |
| WHO | World Health Organisation |

# Table of Contents

Abstract ..... ii
Declaration ..... iv
Preface ..... v
Publications ..... ix
Podcasts ..... x
Featured published blogs/online material ..... xi
Associated publications authored by the candidate during PhD candidature ..... xiii
Conference Presentations ..... xiv
Invited Presentations ..... xvi
Awards ..... xviii
Research grants ..... xix
Acknowledgements ..... xx
List of common abbreviations ..... xxv
Table of Contents ..... xxvii
List of Tables ..... xxxii
List of Figures ..... xxxiii

**CHAPTER 1 ..... 1**
Introduction ..... 1
1.1 Background of the problem ..... 1
1.2 Evidence gaps in the literature ..... 5
1.3 Significance of the research ..... 6
1.4 Research aims ..... 8
1.5 Overview of the thesis ..... 10

**CHAPTER 2 ..... 12**
Physiotherapy management of patients having major abdominal surgery ..... 12
2.1 Introduction ..... 12
2.2 Author contributions ..... 12
2.3 Published manuscript ..... 12
Reeve J & Boden I. The physiotherapy management of patients undergoing abdominal surgery. *N Z J Physio*. 2016 ..... 12

**Chapter 3** ..... **30**
Preoperative physiotherapy to prevent postoperative pulmonary complications ..... 30
3.1 Introduction ..... 30
3.2 Pathophysiological effects of abdominal surgery to the lungs ..... 31
3.2.1 Reduction in lung volumes ..... 31
3.2.2 Atelectasis ..... 32
3.2.3 Mucociliary clearance ..... 33
3.2.4 Respiratory muscle dysfunction ..... 33
3.2.5 Anaesthesiology ..... 33
3.2.6 Relationship between respiratory pathophysiology and onset of PPC ..... 36
3.3 Timing of PPC ..... 37
3.4 Breathing exercises to prevent PPCs after abdominal surgery ..... 39
3.5 Effectiveness of breathing exercises ..... 39
3.6 Breathing exercises in the immediate postoperative phase ..... 41
3.7 Preoperative physiotherapy ..... 41
3.8 Summary ..... 44

**CHAPTER 4** ..... **45**
A systematic review and meta-analysis of chest physiotherapy to reduce PPC after abdominal surgery ..... 45
4.1 Introduction ..... 45
4.2 Objective ..... 47
4.3 Methods ..... 47
4.3.1 Identification and selection of studies ..... 47
4.3.2 Assessment of characteristics of studies ..... 49
4.3.3 Data analysis ..... 50
4.4 Results ..... 52
4.4.1 Flow of studies through the review ..... 52
4.4.2 Characteristics of included studies ..... 62
4.4.3 Synthesis of results: Meta-analysis ..... 64
4.5 Discussion ..... 67

**CHAPTER 5** ..... **72**
LIPPSMAck POP trial: study protocol ..... 72
5.1 Author contributions ..... 72

5.2 Published manuscript ..... 72
Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials*. 2015 ..... 72
5.3 Supplementary material ..... 88

**CHAPTER 6 ..... 93**
Treatment fidelity and impact of preoperative physiotherapy before major abdominal surgery 93
6.1 Author contributions ..... 93
6.2 Published manuscript ..... 93
Boden I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy*. 2018 ..... 93
6.3 Supplementary material ..... 103

**CHAPTER 7 ..... 105**
The LIPPSMAck-POP trial. ..... 105
7.1 Author contributions ..... 105
7.2 Published manuscript ..... 105
Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, Robertson IK, Story D, Denehy L. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ*. 2018 ..... 105
7.3 Supplementary material ..... 121
7.4 Response to critical appraisal of LIPPSMAck-POP trial ..... 136
7.4.1 Background ..... 136
7.4.1 Published letter ..... 136
Boden I. Critically appraised paper: Preoperative physiotherapy education halved postoperative pulmonary complications in patients after upper abdominal surgery [commentary]. *J Physiother*. 2018 ..... 136

**CHAPTER 8 ..... 140**
LIPPSMAck-POP: Secondary analyses ..... 140

8.1 Author contributions ..... 140
8.2 Submitted manuscript ..... 140
Boden I, Reeve J, Robertson IK, Story D, Browning L, Skinner EH, Anderson L, Hill C, and Denehy L. Effect of preoperative physiotherapy on clinical signs and symptoms of pulmonary collapse and infection after major abdominal surgery: secondary analysis of the LIPPSMAck-POP randomised controlled trial. 2020. ..... 140
8.3 Abstract ..... 141
8.4 Introduction ..... 142
8.5 Methods ..... 143
8.6 Results ..... 146
8.7 Discussion ..... 153
8.8 References ..... 157
8.9 Secondary analysis appendix ..... 160

**CHAPTER 9 ..... 165**
LIPPSMAck-POP: Health economic analysis ..... 165
9.1 Author contributions ..... 165
9.2 Accepted manuscript ..... 165
Boden I, Robertson IK, Neil A, Reeve J, Palmer A, Skinner EH, Browning L, Anderson L, Hill C, Story D, Denehy L. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis within a binational multicentre randomised controlled trial. *J Physiother*. 2020: ..... 165
9.3 Abstract ..... 166
9.4 Introduction ..... 167
9.5 Methods ..... 168
9.6 Results ..... 173
9.7 Discussion ..... 179
9.8 References ..... 183
9.9 Health economic analysis appendix ..... 186

**CHAPTER 10 ..... 197**
Update of thesis content to 2020 ..... 197
10.1 Introduction ..... 197
10.2 Updated volume of open elective upper abdominal surgery ..... 197
10.3 Updated systematic review and meta-analysis ..... 200

10.3.1 Background ..... 200
10.3.2 Methods ..... 200
10.3.3 Results ..... 200
10.3.4 Discussion ..... 209
10.4 Prehabilitation updated to 2020 ..... 210
10.5 Implications ..... 218

**CHAPTER 11 ..... 219**
Conclusion and future directions ..... 219
11.1 Summary of thesis findings ..... 219
11.2 Strengths and limitations of the thesis research ..... 221
11.3 Future directions ..... 221

**References ..... 227**

**Appendix ..... 253**
Appendix I PEDro scale ..... 253
Appendix II PubMed systematic review search strategy ..... 255
Appendix III Human Research Ethics Committee approval letters ..... 256
Appendix IV Patient information and consent form ..... 260
Appendix V Information booklet ..... 265
Appendix VI Data collection forms ..... 271
Appendix VII Protocol badge cards for ward physiotherapists ..... 277
Appendix VIII Interview transcript scoring template ..... 278
Appendix IX Standards of reporting qualitative research checklist ..... 280
Appendix X Invited commentary – 5 facts about cardiorespiratory physiotherapy ..... 282

# List of Tables

Table 1.1 Thesis chapter overview ..... 11
Table 4.1 Inclusion criteria for eligible trials ..... 48
Table 4.2 Details of trials excluded from analysis. ..... 53
Table 4.3 Characteristics of studies included in the review. ..... 57
Table 4.4 Methodological quality of included trials. ..... 61
Table 10.1 Major elective upper abdominal surgery procedures in Australia 2017-2018 ..... 198
Table 10.2 Excluded trials 2016 to 2020 ..... 201
Table 10.3 Characteristics of new studies (2016 – 2020) included in review ..... 203
Table 10.4 Methodological quality of new included trials in updated systematic review ..... 204
Table 10.5 Randomised controlled trials involving exercise-only prehabilitation prior to abdominal surgery. ..... 212

# List of Figures


| | | |
|---|---|---|
| Figure 3.1 | Pathogenesis of PPC development after upper abdominal surgery…….. | p. 38 |
| Figure 4.1 | Flow of studies for selection in review……. | p. 52 |
| Figure 4.2 | Meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery; sub-grouped into preoperative, postoperative, or combined pre-and postoperative treatment regimes..……..... | p. 65 |
| Figure 4.3 | Meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery, sub-grouped into high or low treatment dosage ……... | p. 66 |
| Figure 4.4 | Meta-analysis of the effect of additional postoperative chest physiotherapy compared to preoperative physiotherapy alone on PPC risk after abdominal surgery……. | p. 67 |
| Figure 10.1 | Flow of studies for selection in updated systematic review……. | p. 205 |
| Figure 10.2 | Updated meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery…….. | p. 207 |
| Figure 10.3 | Funnel plot of studies comparing chest physiotherapy to a no-treatment control……... | p. 208 |
| Figure 10.4 | Forest plot of a trial testing the addition of multimodal preoperative physiotherapy compared to postoperative chest physiotherapy alone….. | p. 209 |

# CHAPTER 1

# Introduction

## 1.1 Background of the problem

Elective upper abdominal surgery is planned surgery requiring general anaesthetic and involving an open incision of at least five centimetres long that is made above, or extends above, the umbilicus (Coventry 2014). It is performed predominately to excise cancerous lesions affecting an organ within the abdominal cavity. The high combined incidence of bowel, stomach, liver, oesophagus, pancreas, bladder, and kidney cancer ensures that cancers affecting the viscera of the abdominal cavity are the second most prevalent cancer type behind prostate cancer in men and breast cancer in women (AIHW 2018). Consequently, major abdominal surgery is currently the most common major surgery type performed in Australian public and private hospitals with annual increases in volumes of 2-5% (AIHW 2018).

Following abdominal surgery well-reported pathophysiological effects to the respiratory system occur. This is largely due to deleterious effects from the abdominal incision and anaesthesia including atelectasis (Restrepo & Braverman 2015, Hedenstierna & Edmark 2010, Duggan & Kavanagh 2007), reduced mucociliary clearance (Bilgi et al 2011, Konrad et al 1993, Gamsu et al 1976), diaphragm dysfunction (Kim et al 2010, Blaney & Sawyer 1997, Ford et al 1983), reduced lung volumes (Cheifetz et al 2010, Fagevik-Olsén, Josefson & Wiklund 2009, Stock et al 1985), and reduced respiratory muscle and cough strength (Barbalho-Moulim et al 2011, Kulkarni et al 2010, Bellinetti & Thomson 2006). It is hypothesised that these factors lead to bacterial proliferation and pulmonary collapse/consolidation which increase the risk of a chest infection and gas exchange dysfunction (Restrepo & Braverman 2015, Tusman et al 2012, Duggan & Kavanagh 2005, Smith & Ellis 2000). New respiratory abnormalities that occur after surgery and directly impact the postoperative care of a patient are termed postoperative pulmonary complications (PPC) (O'Donohue 1992). Studies have consistently found that PPCs significantly increase in-hospital morbidity, mortality (Fernandez-Bustamente et al 2017, Thompson et al 2006), hospital expenditure (Fleisher & Linde-Zwirble 2014, Thompson et al 2006, Lång et al 2001), and length of stay (LOS) (Fernandez-Bustamente et al 2017, Scholes et al 2009, Lång et al 2001, Denehy 2001a).

The reported PPC incidence, detected using symptomology-based screening assessments, in Australian hospitals specifically following abdominal surgery is between 10-53% (Lockstone et

al 2020, Parry et al 2014, Haines et al 2013, Silva, Li & Rickard 2013, Scholes et al 2009, Browning 2007a, Mackay, Ellis & Johnston 2005, Mackay & Ellis 2002, Denehy 2001a, Denehy et al 2001b). More specifically the incidence of pneumonia diagnosed with a radiological and symptom-based assessment after major abdominal surgery is 4% (Myles et al 2018). The variation in rates (4 – 53%) may be explained by different criteria used for PPC diagnosis, the surgical procedures included, and patient population risk profile. A sensitive, valid diagnosis of a PPC needs to be more than just detecting atelectasis which, on its own, is not always associated with poor clinical outcomes and often resolves spontaneously (Ferreyra, Long & Ranieri 2009, Schindler 2005). A PPC diagnostic tool that uses a combination of different outcomes related to signs and symptoms of airway infection and gas exchange abnormalities (e.g. hypoxia, pyrexia, sputum changes, auscultation changes) may more accurately reflect a clinically significant PPC.

Recent physiotherapy-led studies have used a multi-factorial threshold-based scoring tool, the Melbourne Group Score (MGS), to detect PPC incidence after upper abdominal surgery (Parry et al 2014, Haines et al 2013, Scholes et al 2009, Browning 2007a, Browning, Denehy & Scholes 2007b). These studies report a PPC rate of 13-18% across all patients undergoing major upper abdominal surgery (Scholes et al 2009, Browning 2007a, Browning, Denehy & Scholes 2007b) with 39-42% specifically in older patients having upper gastrointestinal or hepatobiliary surgery (Parry et al 2014, Haines et al 2013). Compared to the incidence of major cardiac complications after colorectal surgery, PPCs have similar in-hospital mortality effects, yet occur nine times more frequently (Fleisher & Linde-Zwirble 2014). Although there is a lack of consensus regarding the ideal method to detect a PPC (Abbott et al 2018), there is wide agreement that greater efforts are needed to reduce the incidence of PPC considering the significant costs to patients and the health care system (Shander et al 2011, Qaseem et al 2006).

In Australian and New Zealand hospitals, physiotherapists routinely provide a range of therapies and modalities aiming to prevent PPC following upper abdominal surgery (Reeve et al 2019, Patman et al 2017, Browning 2007a, Scholes et al 2005). This service provision is supported by consensus expert opinion (Griffiths et al 2018, Hanekom et al 2012), narrative reviews (Davies, Husain & Stephens 2017, Miskovic & Lumb 2017, Qaseem et al 2006) and systematic reviews (Odor et al 2020, Lawrence, Cornell & Smetana 2006, Fagevik-Olsén 2000). These papers have considered evidence investigating the efficacy of a variety of methods to improve lung expansion after surgery, including preoperative education and breathing exercise training, preoperative inspiratory muscle training (IMT), postoperative coached deep breathing and coughing exercises (DB&C), positive expiratory pressure (PEP) therapy, intermittent positive pressure ventilation (IPPV), non-invasive ventilation (NIV), continuous positive airway pressure (CPAP), incentive spirometry (IS), early ambulation, and multimodal chest physiotherapy (various combinations of

these interventions). The aim of these treatments is to improve postoperative lung volumes and clear airway secretions in order to reduce PPC after surgery. In general, reviews conclude that the evidence for prophylactic lung expansion techniques is limited due to poor methodological quality, inadequate sample sizes, invalid PPC definitions, uncontrolled and unmeasured confounding factors, single-centre trials, unblinded assessors, heterogeneous populations, and multimodal interventions. Yet despite these extensive limitations, the reviews come to a similar conclusion that despite limitations to trial methodology the balance of the evidence suggests that any type of lung expansion technique is better than no treatment. Lawrence, Cornell & Smetana further state that, "No modality seems superior, and combined modalities do not seem to provide additional risk reduction." (p.604, Lawrence, Cornell & Smetana 2006). The opinion is that at least one component of a multimodal physiotherapy treatment regime to patients having abdominal surgery is effective in preventing PPC, yet due to methodological flaws in the clinical trials to date, it is currently unknown which of the components this is. This may influence resource utilisation as providing the full package of therapy exactly as studied to gain the reported reduction on PPC rates may not be feasible, cost-effective, or indeed, wholly necessary. To aid the efficient use of resources improved knowledge of the most effective targeted physiotherapy strategy to reduce PPC is needed.

Prior to 2016, the largest trial (n=368) which investigated the benefit of physiotherapy to prevent PPC after abdominal surgery predominantly focused on preoperative preparation of the patient (Fagevik-Olsén et al 1997). This trial had fair methodological quality and demonstrated a very large 74% relative risk reduction (RRR) in PPCs (control group 27% vs intervention group 7%) giving an absolute risk reduction (ARR) of 20% and a number needed to treat (NNT) of 5 to prevent one person having abdominal surgery from getting a PPC. The intervention group received just two physiotherapy sessions: one preoperative education and training session and one session postoperatively, where the breathing exercises taught preoperatively were reviewed and reiterated. The control group received no physiotherapy at any point. A more recent multi-centre observational trial using a comparable physiotherapy protocol of a single preoperative education and training session and a single postoperative session, where breathing exercises were reviewed and an early ambulation session was provided, found a PPC rate of 13% (Scholes et al 2009). These studies involved a single preoperative physiotherapy session and minimal amounts of postoperative physiotherapy, and yet report similar PPC rates to other studies where no preoperative physiotherapy was provided; instead, therapy focused on a large amount of postoperative physiotherapy sessions (Mackay, Ellis & Johnston 2005, Haines et al 2013, Silva, Li & Rickard 2013, Parry et al 2014).

Mackay, Ellis & Johnston (2005) delivered 12 postoperative physiotherapy sessions to patients after elective high-risk upper abdominal surgery with a resultant PPC rate of 14%. Three more recent studies provided at least seven postoperative physiotherapy sessions yet had a higher PPC rate of 20-39% (Haines et al 2013, Silva, Li & Rickard 2013, Parry et al 2014). All these studies did not have preoperative physiotherapy in their protocols. Admittedly, these studies specifically involved patients with high risk profiles and these higher PPC rates may be more of a reflection of the baseline population studied. However, in a study directly comparing two Australian hospitals with equivalent patient cohorts at baseline, the provision of three times the amount of postoperative physiotherapy treatment did not correlate with lower rates of PPC following upper abdominal surgery (Mackay & Ellis 2002). The hospital that provided a preoperative physiotherapy service and less postoperative physiotherapy had a lower PPC incidence (33%) compared to the hospital that did not provide preoperative physiotherapy yet more postoperative physiotherapy (53%). Although this difference did not reach statistical significance in this underpowered exploratory study it is possible that there may not be a dose-dependent relationship for physiotherapy in the postoperative phase (Mackay & Ellis 2002). It may not be 'how much' physiotherapy, but 'when' that physiotherapy is provided that could be the key to preventing PPC (Mackay & Ellis 2002).

Preoperative physiotherapy traditionally consists of preparing patients for their operation. This involves education on the risk of a PPC and how to prevent it with early postoperative ambulation and DB&C exercises. Patients are trained on how to perform the DB&C exercises and instructed to perform them independently immediately following surgery. Currently, less than 5% of Australian and New Zealand hospitals routinely provide preoperative physiotherapy (Reeve et al 2019, Patman et al 2017, Browning 2007a). This rate has dropped from 25% in the previous 10 years (Scholes et al 2005). During this time, a significant change to perioperative admission practices occurred. Up until the mid to late 1990s, patients having elective upper abdominal surgery were admitted to hospital the day before surgery. On this day of admission to the surgical ward, patients were routinely assessed and prepared by anaesthetists, physiotherapists, and nurses on what to expect following surgery. However, from the mid-1990s to the early 2000s this progressively changed to admitting patients on the same day as the planned procedure. Consequently, preadmission assessment and preparation moved to booked appointments at outpatient clinics, sometimes many weeks before surgery (Calligaro et al 1997, Cella, Bush & Codignotto 1993, Robin 1991). This change in location and timing to access a patient preoperatively may have impacted decisions by physiotherapists to continue to provide this service. Clinical trials with preliminary findings that preoperative physiotherapy alone reduced PPCs (Fagevik-Olsén et al 1997), or that the addition of postoperative physiotherapy to a

preoperative alone service may not provide any extra prophylaxis (Denehy 2001a, Condie, Hack & Ross 1993, Castillo & Haas 1985) were all conducted within the original paradigm where preoperative physiotherapy was provided the day before the surgery on the surgical ward. It is unknown if a single education session provided days or weeks before the surgery date in an outpatient setting would have enough treatment fidelity for a patient to recall the information provided and enact the DB&C exercises as taught. Adding to uncertainty over the value of preoperative physiotherapy is a lack of qualitative studies considering the impact and importance that patients may attach to a preoperative physiotherapy service.

The evidence for preoperative physiotherapy alone to reduce PPC within modern perioperative surgical practices is uncertain. It is unknown if patients value the service, and with no cost-effectiveness data to inform hospital administrators on the relative cost to benefit value of preoperative physiotherapy, it is unsurprising that this service is not standard practice in Australia. However, considering the high costs of PPC, both fiscally to the hospital and clinically to patients, relatively high incidence rates, and preliminary trials suggesting that a large reduction in PPC incidence could be achieved with preoperative physiotherapy alone, an adequately powered, well-designed, phase-three, multicentre, randomised controlled trial with an embedded qualitative and health economic analysis is needed to determine the clinical effect, patient-reported value, and cost-effectiveness, of preoperative physiotherapy education and training to prevent PPC after major upper abdominal surgery within the context of modern perioperative surgical and anaesthetic practices.

## 1.2 Evidence gaps in the literature

A review of the literature has found the following evidence gaps which will be discussed, and in part, investigated in this thesis:

- There is a lack of consensus regarding outcomes used to measure PPC after abdominal surgery.
- There is limited high-quality evidence regarding medium- and long-term morbidity, mortality, and patient-reported outcomes for patients having upper abdominal surgery who contract a PPC in the in-hospital period.
- Evidence regarding the effect of preoperative physiotherapy specifically to reduce PPC after abdominal surgery has not been systematically reviewed or critically appraised.
- A clear hypothesis explaining a possible physiological mechanism of effect for preoperative physiotherapy to minimise PPC after surgery is needed.

- Qualitative outcomes regarding patients' views and experiences of receiving preoperative physiotherapy before upper abdominal surgery are unknown.
- It is unknown if a single session of physiotherapy education and training provided at a multidisciplinary outpatient clinic in the weeks prior to abdominal surgery would have sufficient treatment fidelity to ensure that the information provided is memorable and would enable enactment of the desired health behaviours (postoperative DB&C exercises and early ambulation).
- An adequately powered, multicentre, parallel-group, randomised controlled trial with blinding of assessors, standardisation of postoperative physiotherapy, measurement of known confounders, in a defined population using a valid PPC endpoint and conducted within a modern perioperative practice framework is needed to assess if preoperative physiotherapy education and training can effectively minimise PPC incidence following upper abdominal surgery.

## 1.3 Significance of the research

Abdominal surgery is the most common major surgery type conducted in Australia, Europe, and the United States with 400-800 operations per 100,000 people *per annum* (AIHW 2018, European Commission 2018, Steiner et al 2017. Australia has one of the highest volumes of major abdominal surgical procedures per capita with approximately 175,000 operations performed in 2018 (AIHW 2018) across most types of Australian acute care facilities; public, private, rural, regional, and metropolitan hospitals. The primary reason for abdominal surgery is cancer of an organ within the abdominal cavity. The combined total of incidence rates of cancer affecting the bowel, oesophagus, stomach, liver, pancreas, kidneys, and bladder place abdominal organ cancers as the second most common type of cancer in Australia, with incidence rates projected to rise by 2020 (AIHW 2012). Consequently, the demand for major abdominal surgery will continue to increase over time. The current annual increase in the volume of major abdominal surgery is 2-5% *per annum* (AIHW 2018).

Patients having surgery represent a quarter of hospital bed days, yet account for half of all hospital costs (McDermott, Freeman & Elixhauser 2014). Complications after abdominal surgery are the principal driver for increased costs with higher expenditure on pharmaceutical needs, diagnostic testing, intensive care unit (ICU), and surgical ward LOS (Vonlanthen et al 2011). One of the most common complications after major abdominal surgery is a PPC (Vonlanthen et al 2011, Shander et al 2011) with typologies ranging from mild atelectasis to severe hospital-acquired pneumonia and respiratory failure (Fernandez-Bustamente et al 2017, Shander et al 2011). The

incidence of PPCs in Australian hospitals can be up to 40% in high-risk patients (Parry et al 2014, Silva, Li & Rickard 2013, Haines et al 2013) with a rate of 15-20% in a general population of patients having elective upper abdominal surgery (Scholes et al 2009, Browning, Denehy & Scholes 2007b). PPCs independently increase costs following major colorectal (Fleisher & Linde-Zwirble 2014), upper gastrointestinal (Dimick et al 2003), and renal surgery (Kim et al 2013). Even mild PPCs are associated with increased hospital LOS and resource utilisation (Fernandez-Bustamente et al 2017, Shander et al 2011). PPCs are strongly associated with mortality (Fernandez-Bustamente et al 2017, Neto et al 2014, Ghaferi, Birkmeyer & Dimick 2009, Khuri et al 2005), increased risk of 30-day hospital readmission (Kassin et al 2012), and poorer health-related quality of life (HRQoL) (Brown et al 2014). Due to the high incidence of PPC and serious negative outcomes to both hospitals and patients, preventative strategies should be employed to reduce the incidence of complications (Shander et al 2011).

Chest physiotherapy is generally considered effective in reducing PPC incidence although it is unknown exactly which modality or method is most efficacious (Odor et al 2020, Griffiths et al 2018, Hanekom et al 2012, Lawrence, Cornell & Smetana 2006, Fagevik-Olsén 2000). It is possible that preoperative education and training by a physiotherapist could reduce PPC incidence by a very large amount, e.g. 75% (Fagevik-Olsén et al 1997). If this single trial estimate is a true treatment effect this could have significant worldwide impacts on patient morbidity, mortality, and hospital resource utilisation if implemented widely. However, due to methodological limitations the evidence to support preoperative physiotherapy is equivocal and this service is not routinely provided in Australian hospitals. Rather, physiotherapy services are predominantly provided in the postoperative phase (Patman et al 2017). This decision to remove preoperative physiotherapy from the perioperative management of patients having upper abdominal surgery is either correct due to lack of effectiveness and value to the patient or hospital; or hospitals have erroneously removed a highly impactful service that can significantly reduce PPCs and improve outcomes after surgery.

With approximately 175,000 patients undergoing major abdominal procedures each year in Australia (AIHW 2018) an estimated PPC prevalence rate of 15-20% (Abbott et al 2018) equates to between 30,000 to 40,000 patients annually suffering from this serious postoperative complication. If preoperative physiotherapy is effective in reducing PPC incidence by even a quarter of the current best estimated rate of 75%, this would result in 6000 to 8000 fewer patients in Australia suffering from a PPC, with likely benefits in subsequent hospital resource use and costs. Considering the high volume of abdominal surgery in Australia, the high incidence rate of PPC after this surgery type, and the significant cost of PPCs to the patient, hospital, and

community, the possible efficacy of preoperative physiotherapy needs to be tested with a robust methodological method and within the context of modern perioperative practices.

## 1.4 Research aims

This thesis comprises six main research elements:

1) a narrative review of the literature to consider the evidence regarding the physiotherapy management of patients having abdominal surgery; 2) construction of a hypothesis for a mechanism of effect for preoperative physiotherapy to reduce the risk of PPC; 3) a systematic review and meta-analysis of randomised controlled trials assessing the evidence for breathing exercises to reduce PPC incidence after abdominal surgery; 4) a nested mixed-methods (qualitative and quantitative) study on the patient-reported value and treatment fidelity of preoperative physiotherapy; 5) a phase-three, multicentre, double-blinded, randomised controlled trial powered for superiority assessing the effects of a single preoperative physiotherapy respiratory education and coaching session, compared to an information booklet alone, to prevent PPCs following major abdominal surgery; and, 6) the cost-effectiveness of preoperative physiotherapy to reduce PPCs and improve quality adjusted life years (QALYs) after major abdominal surgery.

The aims of this thesis are:

1. Narrative review aims:
    i. To report and critically appraise randomised controlled trials and observational trials that have investigated physiotherapy interventions to manage patients having abdominal surgery.

2. Hypothesis formation aims:
    i. To critically evaluate the literature on the respiratory pathophysiology related to abdominal surgery and to generate a hypothesis of effect for preoperative physiotherapy to minimise PPC.

3. Systematic review and meta-analysis aims:
    i. To synthesize the evidence of randomised controlled trials conducted from 1950 to 2020 that investigated the effect of breathing exercises on the incidence of PPC after abdominal surgery.
    ii. To consider the evidence in the context of the provision of preoperative physiotherapy.

4. Nested mixed-methods study aims:

i. To assess the impact and memorability of preoperative physiotherapy as provided within a multidisciplinary preadmission clinic within six weeks of upper abdominal surgery.

ii. To conduct an exploration of patients' opinions on preoperative information delivery.

iii. To assess the treatment fidelity of preoperative physiotherapy provided within a multidisciplinary preadmission clinic within six weeks of surgery to effectively enable patients to remember information about DB&C exercise performance after surgery.

iv. To assess the effect of preoperative physiotherapy education on early postoperative ambulation performance compared to provision of an information booklet.

5. Multicentre randomised controlled trial aims:

i. To compare the effect of preoperative physiotherapy education and training on the development of a PPC within the first 14 postoperative hospital days using the MGS diagnostic scoring tool, compared to the provision of an information booklet alone.

ii. To compare the effect of preoperative physiotherapy education and training on the following explorative secondary outcomes:

a) all-cause mortality up to 12-months
b) days of hospital LOS,
c) ICU LOS,
d) unplanned ICU admission,
e) pneumonia,
f) time to postoperative ambulation greater than one minute,
g) time to achieve ambulation greater than10 minutes,
h) time in days to discharge from physiotherapy service,
i) time in days to readiness for discharge from hospital.
j) patient reported complications at six to eight weeks post-surgery
k) unplanned hospital admissions six-weeks post-surgery

6. Health economic analysis of the randomised controlled trial aims:

i. To provide a comparative estimate in:

a) hospital resource use and costs,
b) health related quality of life (HRQoL) and health utilities at six-weeks post-surgery,
c) QALYs at 12-months post-surgery,
d) cost-effectiveness of incremental costs per PPC prevented,

e) cost-utility using incremental costs per QALY gained,

between participants given preoperative physiotherapy or an information booklet at pre-admission clinics prior to elective major abdominal surgery.

## 1.5 Overview of the thesis

The thesis structure is summarised in Table 1.1. **Chapters 1, 2, and 3** of this thesis provide a synthesis of the current literature regarding abdominal surgery, respiratory pathophysiology specific to abdominal surgery, the development of PPCs, outcome measures to assess PPC, physiotherapy methods and modalities to prevent PPC, and potential mechanisms for the effects of preoperative physiotherapy to minimise PPC following major abdominal surgery. **Chapter 4** is a systematic review and meta-analysis of randomised controlled trials investing the effect of breathing exercises on PPC after abdominal surgery.

The subsequent thesis includes the methodological design elements and trial protocol (**Chapter 5**), the nested mixed-methods assessment of patient views, memorability, treatment fidelity, and treatment enactment of preoperative physiotherapy (**Chapter 6**), and the primary results of the Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) randomised controlled trial undertaken to assess the effectiveness of preoperative physiotherapy to prevent PPC after major upper abdominal surgery (**Chapter 7**).

**Chapter 8** reports secondary results within LIPPSMAck-POP in the context of the hypothesis of effect as proposed in Chapter 3. **Chapter 9** reports the health economic analysis of LIPPSMAck-POP. **Chapter 10** provides an update to 2020 of the volume of major abdominal surgery performed in Australia, a redo of the systematic review and meta-analysis performed in Chapter 4 to include additional data from trials conducted from 2016 to 2020, and to consider the evidence for the rapidly emerging field of prehabilitation. **Chapter 11** provides a summary of the thesis findings, strengths and limitations and directions for future research to prevent PPC following major abdominal surgery.

**Table 1.1 Thesis chapter overview**

| Chapter | Overview |
|---|---|
| 1 | Introduction.<br>Thesis overview |
| 2 | Narrative review of physiotherapy management for patients having abdominal surgery |
| 3 | Narrative review of pathophysiology of PPCs<br>Hypothesis of effect for preoperative physiotherapy to reduce PPCs |
| 4 | Systematic review and meta-analysis of chest physiotherapy to prevent PPC after abdominal surgery |
| 5 | Protocol for LIPPSMAck-POP: a multicentre randomised controlled trial of preoperative physiotherapy to prevent postoperative pulmonary complications after major abdominal surgery |
| 6 | Mixed methods (qualitative and quantitative) findings of a nested study within LIPPSMAck-POP investigating the memorability of preoperative physiotherapy and recall of items taught preoperatively |
| 7 | Primary results of the LIPPSMAck-POP trial |
| 8 | Secondary results of the LIPPSMAck-POP trial |
| 9 | Health economic results of the LIPPSMAck-POP trial |
| 10 | Updated data to 2020; systematic review and meta-analysis of chest physiotherapy to prevent PPC after abdominal surgery, current surgical volumes, and evidence for prehabilitation |
| 11 | Conclusion summarising the research findings, discussing strengths and limitations of the research, and identifying areas for future research to prevent postoperative pulmonary complications after major abdominal surgery |

# CHAPTER 2

# Physiotherapy management of patients having major abdominal surgery

## 2.1 Introduction

The intended target patient population for this research is those having major abdominal surgery and the clinical problem aiming to be addressed is PPC. Included in this chapter will be an overview of major abdominal surgery, PPC recognition methods, and physiotherapy interventions for patients having abdominal surgery in the context of contemporary surgical practices. This chapter comprises a published narrative review co-authored with Dr Julie Reeve (authorship declaration, see Appendix XI).

## 2.2 Author contributions

Dr Julie Reeve (JR) and Ianthe Boden (IB) equally conceived the narrative review. IB compiled all Tables and Figures, and the sections; 'Introduction', 'What is abdominal surgery?', 'Postoperative pulmonary complications – what are PPCs and how are they measured?', 'What are the consequences and costs of a PPC?', 'How can we predict who is at risk of developing a PPC?', 'Complications associated with reduced or delayed mobility – postoperative paralytic ileus', 'Physiotherapy management for patients undergoing abdominal surgery', 'Preoperative physiotherapy interventions – preoperative education', and, 'Postoperative physiotherapy interventions – postoperative ambulation, postoperative breathing exercises, respiratory adjuncts'. JR wrote 'Complications associated with reduced or delayed mobility – venous thromboembolism, musculoskeletal and cardiovascular effects', and, 'Postoperative physiotherapy interventions – postdischarge rehabilitation'. IB and JR co-authored 'Preoperative physiotherapy interventions – prehabilitation', and, 'Postoperative physiotherapy interventions – other adjuncts'. IB and JR co-edited all sections and approved the final version prior to submission. JR managed the manuscript submission.

## 2.3 Published manuscript

Reeve J & Boden I. The physiotherapy management of patients undergoing abdominal surgery. *N Z J Physio*. 2016; 44(1): 33-49. doi: 10.15619/NZJP/44.1.05.
This is an open access journal. The content is unchanged from the published manuscript

INVITED CLINICAL COMMENTARY

# The physiotherapy management of patients undergoing abdominal surgery

**Julie C Reeve** *PhD, MSc, Grad Dip Phys*
*Senior Lecturer, School of Clinical Sciences, Faculty of Health and Environmental Studies, AUT University, Auckland, New Zealand*

**Ianthe Boden** *M. Health Sci, B. Physiotherapy*
*Cardiorespiratory Supervisor Physiotherapist, Physiotherapy Department, Launceston General Hospital, Launceston, Tasmania, Australia*

## ABSTRACT

Abdominal surgery is performed to remove cancerous tissue, to resolve visceral tissue perforations or to remove inflammatory bowel segments, benign growths or vascular aneurysms. Postoperative complications, including pulmonary complications, are common following abdominal surgery and physiotherapy aims to prevent and treat many of these complications. Much of the literature investigating physiotherapy interventions is over a decade old and advances in surgery, including minimally invasive surgery and fast track pathways, require physiotherapists to re-evaluate their practices. This narrative review aims to examine the evidence investigating the effectiveness of physiotherapy interventions and apply this to contemporary surgical practices. Recommendations for practice and research are outlined.

*Reeve J, Boden I (2016) The Physiotherapy Management of Patients undergoing Abdominal Surgery New Zealand Journal of Physiotherapy 44(1): 33-49. doi: 10.15619/NZJP/44.1.05*

Key words: Physiotherapy, General surgery, Abdomen, Evidence-Based Practice

## INTRODUCTION

Abdominal surgery is the most frequently undertaken surgery type in Australia and New Zealand. At least 130,000 operations were performed in 2012-2013 across 246 hospitals in Australia alone and this is increasing by 2-5% per year (AIHW 2013). World-wide, approximately 500 to 1,000 procedures per 100,000 head of population are performed annually in developed countries (Weiser et al 2008).

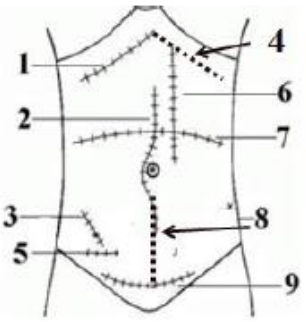
Postoperative complications are common following major abdominal surgery with one third to half of all patients having some type of complication following their operation (Aahlin et al 2015, Hamel et al 2005). Complications, such as postoperative pulmonary complications (PPC), prolonged postoperative ileus and the sequelae of prolonged immobility are potentially preventable with physiotherapy interventions. Physiotherapists have routinely provided care to patients undergoing abdominal surgery since the 1950s (Cash 1955, Innocenti 1996) and research investigating the effectiveness of physiotherapy following abdominal surgery is generally over a decade old (Pasquina et al 2006). Since this time, major advances in surgery, such as minimally invasive surgical techniques and improved perioperative management, have significantly reduced postoperative complications and length of hospital stay (LOS) (Spanjersberg et al 2015). These advances require a re-evaluation of physiotherapy for patients undergoing abdominal surgery.

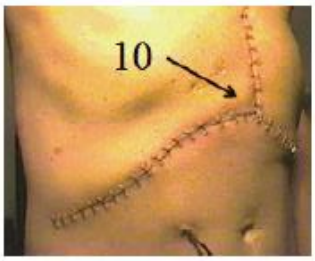
### What is abdominal surgery?

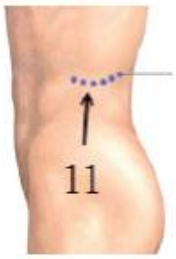
Abdominal surgery can be categorised according to the location and length of the main incision. Upper abdominal surgery (UAS) involves an incision above or extending above the umbilicus and lower abdominal surgery (LAS) involves incisions wholly below the umbilicus (see Table 1 and Figure 1). Surgery may be open (with an incision >5cm), laparoscopic or a combination of both. Historically, laparoscopic surgery was predominantly performed for cholecystectomy and gynaecological procedures only. Recently, major procedures such as bowel, liver, stomach, oesophagus and kidney resections are being performed laparascopically or as laparoscopic hand-assisted surgery (minimally invasive surgery), whereby an additional incision allows a hand to pass into the abdomen for surgical manipulation and tissue removal (see Figure 2). Although, minimally invasive surgery involves longer anaesthetic times (Owen et al 2013) compared with the equivalent open procedure, accelerated recovery, reduced complication rates and shorter LOS have been demonstrated (Spanjersberg et al 2015).

**Table 1. Type and location of abdominal surgical procedures**

| Surgical Category | Upper Abdominal | Lower abdominal |
|---|---|---|
| Colorectal | Anterior resection<br>Abdominoperineal resection<br>Hartmanns<br>Hemicolectomy<br>Low anterior resection<br>Laparoscopic (+/-hand) assisted colectomy<br>Partial colectomy<br>Proctocolectomy<br>Reversal of Hartmanns<br>Sigmoid colectomy<br>Small bowel resection<br>Subtotal colectomy<br>Total colectomy | Ultra low anterior resection<br>Recto-sigmoidectomy<br>Ileostomy<br>Appendectomy |
| Upper Gastrointestinal | Gastrectomy<br>Liver resection<br>Oesophagectomy<br>Open cholecystectomy<br>Open hiatus hernia repair<br>Pancreatic surgery<br>Whipples | |
| Urology | Adrenalectomy<br>Cystic duct excision<br>Nephrectomy<br>Laparoscopic +/- hand assisted nephrectomy<br>Pyeloplasty<br>Radical cystectomy +/- ileal conduit<br>Radical cystoprostatectomy | Radical prostatectomy<br>Ureterectomy |
| Other | Explorative laparotomy<br>Splenectomy<br>Complete pelvic exenteration | Inguinal hernia repair<br>Total abdominal hysterectomy |




| | |
|---|---|
| 1. Subcostal (Kocher) | Liver and pancreas operations |
| 2. Midline laparotomy | Upper and lower intestinal procedures, major bladder |
| 3. McBurney | Appendix removal |
| 4. Bilateral subcostal (Chevron) | Oseophageal, liver, pancreatic, and gastric procedures |
| 5. Lanz | Appendix removal |
| 6. Paramedian | Upper gastrointestinal surgery |
| 7. Transverse | Upper intestinal procedures |
| 8. Lower midline | Lower intestinal procedures and bladder |
| 9. Pfannenstiel | Major gynaecological and prostate procedures |
| 10. Mercedes (Chevron + Sternotomy) | Major trauma, combined cardiac and abdominal |
| 11. Flank/transverse lumbar | Kidney procedures |

**Figure 1: Incisions used for abdominal surgery and associated procedures (Mercedes image: Said 2008)**

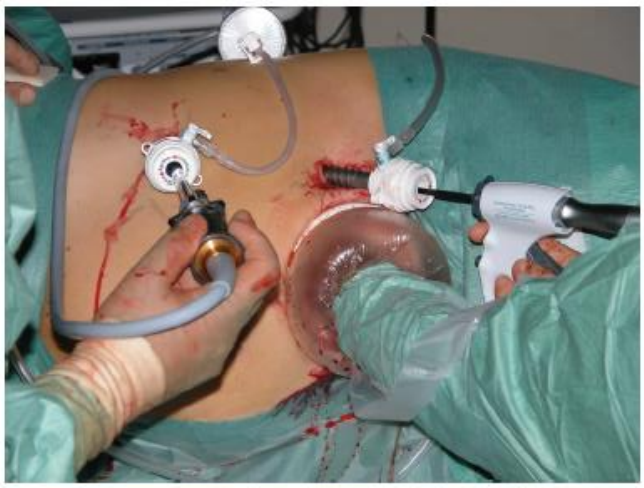


**Figure 2: Laparoscopic hand-assisted abdominal surgery (Dols et al 2009)**

Significant changes in perioperative care have also been initiated, most notably Enhanced Recovery after Surgery (ERAS) or 'fast track' pathways. Elements include minimal preoperative bowel preparation and fasting, admission on the day of surgery, aggressive early ambulation, strict analgesia protocols, early postoperative introduction of oral fluids and food, and minimal use of drips and drains. These pathways are safe, feasible and reduce complication rates and LOS across all types of abdominal surgery (Adamina et al 2011, Cerantola et al 2013, Coolsen et al 2013, Li et al 2012, Lin et al 2011, Varadhan et al 2010, Wijk et al 2014).

## Prevention of postoperative complications relevant to physiotherapy

### *Postoperative pulmonary complications (PPCs)*

#### *What are PPCs and how are they measured?*

A PPC is commonly described as "a pulmonary abnormality that produces identifiable disease or dysfunction, that is clinically significant and adversely affects the clinical course" (O'Donohue Jr 1992). This can include respiratory failure, pneumonia, severe atelectasis, pulmonary oedema, pneumothorax, and pleural effusion. A PPC is the most common complication following UAS (PROVHILO group 2014) with a reported incidence of 13-53% (Browning et al 2007, Haines et al 2013, Mackay et al 2005, Parry et al 2014, Scholes et al 2009, Silva et al 2013). This is higher than other major surgical procedures, such as open lung resection, cardiac surgery via sternotomy, and orthopaedic surgery (Arozullah 2001, Pasquina and Walder 2003, Reeve et al 2010), whereas the PPC rate following open LAS is as little as 1% (Arozullah 2001, Smith et al 2009a).

The wide range in reported PPC rates following UAS may be explained by the surgical procedures, patient populations studied, and the PPC diagnostic tool or criteria utilised. Diagnosis of a PPC differs greatly between studies. Variations include the individual signs and symptoms required for diagnosis (e.g. some tools incorporate auscultation changes where others do not), how each criterion is measured (e.g. the different grading scales used for radiographic atelectasis or consolidation) and the threshold number of positive criteria equating to a PPC (Agostini et al 2011, Wynne 2004). These inconsistencies make comparison of PPC rates and interpretation of research findings into clinical practice problematic. Although there is no consensus on the ideal tool for PPC diagnosis, recent physiotherapy-led studies have used the same multi-factorial scoring tool, the Melbourne Group Score (Table 2) in both UAS (Browning et al

**Table 2: Melbourne Group Score PPC Diagnostic Tool**

| Diagnosis confirmed when 4 or more of the following are present: |
|---|
| CLINICAL FACTORS |
| • New abnormal breath sounds on auscultation different to preoperative assessment |
| • Production of yellow or green sputum different to preoperative assessment |
| • Pulse oximetry oxygen saturation ($SpO_2$) <90% on room air on more than one consecutive postoperative day |
| • Raised maximum oral temperature >38°C on more than one consecutive postoperative day |
| DIAGNOSTIC FACTORS |
| • Chest radiograph report of collapse/consolidation. |
| • An unexplained WCC greater than 11 x $10^9$/L |
| • Presence of infection on sputum culture report |
| OTHER |
| • Physician's diagnosis of pneumonia, respiratory tract infection, undefined respiratory problem. |
| • Prescription of an antibiotic for a respiratory infection |

Notes: C, centigrade; L, litre; $SpO_2$, Peripheral oxygen saturation; WCC, white cell count.

2007, Haines et al 2013, Parry et al 2014, Scholes et al 2009) and thoracic surgery (Agostini et al 2013, Reeve et al 2010). Reliable clinometric properties for the Melbourne Group Score (MGS) are beginning to be demonstrated when compared to other PPC diagnostic tools (Agostini et al 2011). Studies using the MGS have reported PPC rates of 13-18% in all patients undergoing major UAS (Browning et al 2007, Scholes et al 2009), and specifically 39-42% in high-risk UAS patients (Haines et al 2013, Parry et al 2014).

***Key Point:***

For research, audit and clinical purposes, the use of the Melbourne Group Score tool is recommended to diagnose a PPC amenable to physiotherapy.

### *What are the consequences and costs of a PPC?*

Postoperative pulmonary complications significantly increase morbidity, mortality, hospital utilisation, cost, and length of hospital stay (Dimick et al 2004, Knechtle et al 2014, Lång et al 2001, Rotta et al 2013, Thompson et al 2006). The greatest proportion of hospital costs are associated with intensive care utilisation and hospital LOS (Knechtle et al 2014). Australian prospective observational studies measuring PPC rates using the MGS found that PPCs increased hospital LOS by 3-13 days (Denehy et al 2001, Scholes et al 2009). To date, reported costs associated with PPCs have been derived retrospectively from hospital clinical coding databases that often underreport rates of complications and costs (Koch et al 2012). The true costs of PPCs are important to establish so that the cost-effectiveness of prophylactic interventions, including physiotherapy, can be calculated. It may not be cost effective to provide physiotherapy to *all* patients undergoing abdominal surgery. Where the likelihood of developing a PPC is known to be low, e.g. one PPC in every 100 patients, providing prophylactic physiotherapy to all 100 patients may cost more than the costs saved through preventing the one PPC. However, if PPCs are shown to be high cost, the benefit of preventing one PPC in 100 patients may outweigh the cost of providing a relatively low-cost intervention such as physiotherapy to all 100 patients. Until we have contemporary high quality physiotherapy evidence and cost-benefit analyses, physiotherapists may be best to target interventions to those patients who are at high-risk of postoperative complications. It is therefore important that physiotherapists are able to determine which patients are most at risk of developing a PPC.

***Key Point:***

Cost-benefit analyses of physiotherapy interventions to reduce PPCs, improve recovery and reduce LOS are needed to inform resource allocation.

### *How can we predict who is at risk of developing a PPC?*

The ability to predict the development of a PPC has been widely investigated. An often cited large prospective cohort study (n=160,805) (Arozullah 2001) investigated *all* patients undergoing non-cardiac surgery and found that those undergoing UAS were almost three times more likely to develop pneumonia (OR 2.68, 95%CI 2.38-3.03) compared to LAS and orthopaedic surgery where the pneumonia rate was less than 1%. A recent retrospective study found that PPCs were 15 times more likely following UAS when compared to LAS (Smith et al 2009a).

The incidence of PPCs after traditional laparoscopic surgery is also negligible (<1%) (Antoniou et al 2014). However, pneumonia rates of 2-5% have recently been reported following minimally invasive bowel resections and, whilst this is half the rate of the equivalent open procedure, PPC incidence has been shown to increase by 13% with each additional 60 minutes of surgery time (Owen et al 2013). The risk of PPCs following other types of minimally invasive UAS is not well reported. Until more data and cost-benefit analyses of physiotherapy interventions are published, it is uncertain if these PPC rates are high enough to justify providing routine prophylactic physiotherapy to these lower-risk patients.

To assist in directing physiotherapy resources to the highest need patients, PPC risk prediction tools should be utilised. Most PPC risk prediction tools following UAS have been developed by medical researchers (Barnett and Moonesinghe 2011) and have limited clinical utility for physiotherapists. To address this a physiotherapist led prospective study (Scholes et al 2009) investigated predictors for PPCs (with MGS diagnosis) to enable the development of a multifactorial scoring tool to dichotomise patients having UAS into high or low risk groups. Independent predictors of PPCs were: anaesthesia longer than three hours, upper gastrointestinal surgery, current smoking history, respiratory disease and estimated $VO^{2max}$. High-risk patients were 8.5 times more likely to develop a PPC than those assessed as low-risk. Other physiotherapy studies have found additional independent risk factors for a PPC. A nasogastric tube (Parry et al 2013) for more than one day was associated with higher PPC incidence (OR 9.1, 95%CI 2.0 to 42) and delayed time to ambulate more than 10 metres (Haines et al 2013) was three times more likely to be related to the presence of a PPC (OR 3, 95%CI 1.2 to 8).These results should be interpreted with caution, as it is possible that the presence of a PPC delayed mobilisation, rather than vice versa. The use of available PPC risk prediction models to target provision of physiotherapy services to higher-risk patients may be a prudent use of finite physiotherapy resources.

***Key Points:***

1. Patients following LAS and standard laparoscopic surgery do not require routine postoperative physiotherapy to prevent PPC.
2. All patients undergoing UAS should be screened for risk of developing a PPC using a risk identification tool and those patients determined to be high-risk are targeted with PPC prophylaxis.
3. A PPC risk prediction tool is needed for advanced laparoscopic and minimally invasive UAS.

### *Complications associated with reduced or delayed mobility*

#### *Venous thromboembolism*

The absolute risk of venous thromboembolic events (VTE) after major abdominal surgery without preventative measures is approximately 15 – 40% (Cayley 2007). Given the serious

consequences of pulmonary emboli (PE), several guidelines for prevention and management have been published by the American College of Chest Physicians (Holbrook et al 2012), Scottish Intercollegiate Guidelines Network (SIGN 2010) and the National Institute for Health and Clinical Excellence (National Institute for Health and Clinical Excellence (NICE) 2010). These guidelines recommend that all major surgical patients have VTE prophylaxis, including anti-coagulation and early mobilisation. If a deep vein thrombosis (DVT) is diagnosed and anti-coagulation has been commenced, early mobilisation is not associated with increased risk of PE, new DVT or death (Aissaoui et al 2009, Anderson et al 2009), thus physiotherapists should recommence active ambulation following medical clearance.

### *Postoperative paralytic ileus*

Gut immotility immediately postoperatively is an expected consequence of abdominal surgery (Vather et al 2013). There is a widespread belief that early ambulation assists in the resolution of gut immotility and prevention of paralytic ileus, yet there is no conclusive evidence to support this hypothesis (Story and Chamberlain 2009). Indeed, there is stronger evidence for the routine use of chewing gum, which stimulates the neuro-hormonal response to eating and enhances the resolution of a normal gut peristalsis, to prevent paralytic ileus and reduce LOS (Li et al 2013), than there is for early ambulation.

### *Musculoskeletal and cardiovascular effects*

Whilst early ambulation is recommended following major abdominal surgery, surgical drains/devices and the postoperative sequelae of hypotension, nausea, pain, and fatigue mean that achieving early ambulation as recommended is frequently not achieved (Haines 2013, Boulind 2012). Although the deleterious musculoskeletal and cardiovascular effects associated with prolonged bedrest are well documented (Pavy-Le Traon et al 2007), there is little evidence to support the use of early ambulation in the prevention of PPCs. A recent randomised controlled trial (RCT) found no increase in PPC incidence following three days enforced bed rest; rather this group had prolonged LOS and required more physical rehabilitation to assist recovery (Silva 2014).

## Physiotherapy management for patients undergoing abdominal surgery

Physiotherapy aims to address well-known pathophysiological effects of abdominal surgery on the respiratory system including atelectasis (Duggan and Kavanagh 2005, Hedenstierna and Edmark 2010, Tusman et al 2012), reduced muco-ciliary clearance (Bilgi et al 2011, Gamsu et al 1976, Konrad et al 1993), diaphragm dysfunction (Blaney and Sawyer 1997, Ford et al 1983, Kim et al 2010), reduced lung volumes (Cheifetz et al 2010, Fagevik Olsén et al 2009, Stock et al 1985) and reduced respiratory muscle and cough strength (Barbalho-Moulim et al 2011, Bellinetti and Thomson 2006, Kulkarni et al 2010). It is hypothesised that combinations of these factors can lead to bacterial proliferation in the airways and/or severe atelectasis (Smith and Ellis 2000), increasing the risk of infection and PPCs.

It is a logical assumption that strategies to ameliorate the deleterious physiological effects of abdominal surgery will result in reducing the risk of PPC development. This has been the underlying premise of the delivery of 'chest physiotherapy' to patients following major surgery for several decades. Physiotherapy may consist of preoperative education and training and/or postoperative respiratory and physical rehabilitation. More recently, there has been an increasing focus on preoperative exercise training (prehabilitation). Here we present the best available evidence to guide practice decisions.

### *Preoperative physiotherapy interventions*

#### *Preoperative education*

Preoperative physiotherapy education is the delivery of targeted preparatory information to the patient regarding the expected postoperative participation in an early ambulation programme and necessity to perform deep breathing and coughing (DB&C) exercises. Patients are educated on the role these exercises have on the reduction of serious complications such as PPC and VTEs. Sessions consist of explaining the effect of anaesthesia and surgery on the lungs, teaching and training of DB&C exercises, education on the early ambulation programme and provision of any adjunctive devices as necessary.

Evidence from six clinical trials (Bourn et al 1991, Castillo and Haas 1985, Condie et al 1993, Denehy 2001, Fagevik Olsén et al 1997, Samnani et al 2014) suggests that a single preoperative physiotherapy session significantly reduces PPC rates. In the largest RCT (n=368, PEDro 5/10) the intervention group received a single preoperative physiotherapy education and training session and a single postoperative review of taught breathing exercises (Fagevik Olsén et al 1997). The control group received no pre or postoperative physiotherapy. The incidence of PPC was significantly lower in the treatment group (6% vs 27 %, $p<0.001$).Two other RCTs of 330 low-risk open abdominal surgery (Condie et al 1993) and 102 open UAS patients (Denehy 2001) concluded that the provision of additional postoperative physiotherapy of coached DB&C exercises conferred no extra benefit over and above a single session of preoperative education and DB&C training alone. A recent RCT (Samnani et al 2014) of 232 abdominal surgery patients again demonstrated a significant reduction in PPCs from 30% to 7% (ARR 22%, 95%CI 13%-32%) when preoperative education focused on the importance of postoperative early ambulation compared to no education at all. Both groups were provided with similar postoperative care. These studies demonstrate the effectiveness of preoperative education and DB&C training, independent of postoperative physiotherapy, in reducing the incidence of PPCs.

The reported reduction in PPCs with preoperative physiotherapy education is significant; however, the results need to be interpreted with caution. All trials had methodological limitations and sources of bias. This brings the reported effect on PPC rates into question. Further, most trials were conducted 10-15 years ago and there have been significant changes in surgical and perioperative care in this time. Preoperative education and training have previously been provided the day before surgery upon admission for surgery, however this no longer reflects current practice, whereby patients attend preoperative assessment clinics one to six weeks before their operation (Gupta and Gupta 2010). It is unknown whether preoperative physiotherapy education provided at these longer time intervals might reproduce the previously reported effect on PPC prophylaxis.

Surveys of physiotherapy services to UAS patients in Australia have shown a stark reduction in hospitals providing preoperative physiotherapy education over the past 15 years (Browning 2007, Scholes et al 2006). The reasons for this disinvestment of services are unknown. There are no cost-benefit analysis studies investigating physiotherapy to reduce respiratory complications, so conclusive evidence to inform the allocation of physiotherapy services to preoperative education and training is lacking. The potential to significantly reduce the incidence of a high-impact complication, such as a PPC, with a low-cost and easily provided intervention of a single preoperative physiotherapy session is appealing. It may not be *how much* physiotherapy that is important, but rather, *when* that physiotherapy is provided. The current weight of evidence appears to support the provision of a single preoperative physiotherapy education and DB&C training to all patients having abdominal surgery (Bourn et al 1991, Condie et al 1993, Denehy 2001, Fagevik Olsén et al 1997, Samnani et al 2014). Given the limitations of this research and the low incidence of PPCs following laparoscopic and LAS surgery, the authors recommend the provision of preoperative physiotherapy for all open UAS patients only. Cost benefit studies are required to analyse the fiscal benefits of providing preoperative physiotherapy to lower risk surgical patients as well.

***Key Points:***

1. A single face to face session of preoperative education and DB&C training should be administered to all patients undergoing open upper abdominal surgery.
2. It is currently unknown if other forms of this education and training, eg video or booklet, are effective.

### *Prehabilitation*

Prehabilitation refers to the use of exercise-based interventions aimed at optimising preoperative function to improve postoperative outcomes or to increase surgical options in those patients who have borderline fitness for surgery. Evidence of the effectiveness of prehabilitation is relatively new, yet systematic reviews and meta-analyses have already been undertaken (Lemanu et al 2013, Olsén and Anzén 2012, Singh et al 2013, Valkenet et al 2011), although only two focused solely on major abdominal surgery (Pouwels et al 2014, Pouwels et al 2015).

Valkenet et al (2011) and Santa Mina (2014) conducted meta-analyses on the effects of preoperative interventions including inspiratory muscle training (IMT) and/or exercise training in patients undergoing major cavity and orthopaedic surgery. Mans et al (2015) investigated IMT prior to all types of open major cavity surgery, including UAS. Meta-analyses of the data demonstrated significant reduction in the risk of PPCs (Mans et al 2015, Valkenet et al 2011) and reduced postoperative length of stay (Santa Mina et al 2014, Valkenet et al 2011). Other systematic reviews report improvements in aerobic and functional capacity (Lemanu et al 2013, Olsén and Anzén 2012, Singh et al 2013). These reviews are limited by the lack of meta-analysis due to the small number of studies included and the heterogeneity of the surgical groups, which included combinations of orthopaedic, UAS, cardiac and thoracic surgery.

To our knowledge, there are only two systematic reviews specifically relating to prehabilitation in abdominal surgery (Pouwels et al 2014, Pouwels et al 2015). These two reviews detailed six RCTs in both laparoscopic and open abdominal surgery (Pouwels et al 2014) and five studies in abdominal aortic aneurysm repair specifically (Pouwels et al 2015). Studies investigated strength and/or aerobic training, breathing exercises, education and IMT or combinations of these. The heterogeneity of the investigations precluded meta-analyses as studies utilised a variety of frequencies, intensities, durations, modes, locations and outcome measures. Both reviews (Pouwels et al 2014, Pouwels et al 2015) determined that preoperative exercise therapy is associated with improved physical fitness in patients prior to major abdominal surgery, but, due to heterogeneity and small sample sizes, whether this results in fewer complications or faster recovery remains unclear. Although the relationship between poor preoperative fitness and postoperative outcomes has been clearly demonstrated (Smith et al 2009b), the effect of improving fitness (via prehabilitation) and improved postoperative outcomes is yet to be demonstrated. Better quality, targeted research into preoperative physical fitness optimisation, particularly in high-risk patients, is warranted.

***Key Point:***

Given the small number of studies, the heterogeneity of interventions and costs involved in providing such services, the routine provision of prehabilitation in all patients undergoing abdominal surgery cannot be recommended. However, it may be worthwhile in high-risk UAS patients, given the assumed cost of complications. This remains to be confirmed with cost-benefit studies.

### *Postoperative physiotherapy interventions*

#### *Postoperative ambulation*

Early mobilisation forms a routine part of postoperative care and physiotherapists are heavily involved in the initiation of mobilisation following UAS, with up to 91% reporting they always include mobilisation in their postoperative treatment (Browning 2007). Patients perform little mobilisation outside of physiotherapy treatment in the early postoperative period (Browning et al 2007) with one study demonstrating only 48% of patients mobilised more than 10m on the first postoperative day (Haines et al 2013). To address this, aggressive early ambulation protocols have become an essential component of ERAS guidelines whereby patients sit up out of bed for six to eight hours and ambulate at least 60m up to five times on the day after surgery (Delaney et al 2001). However only 40% of patients are able to achieve this (Boulind et al 2012). Studies investigating adherence to ERAS protocols found the early mobilisation component was the least adhered to (Boulind et al 2012, Gustafsson et al 2011). Barriers to achieving early ambulation include hypotension, pain and nausea (Haines et al 2013).

Research into the efficacy of physiotherapy to improve outcomes following abdominal surgery has almost always involved ambulation as part of an intervention package (e.g. preoperative education, DB&C exercises, early ambulation, adjunctive devices). It is difficult to determine which component of the intervention is responsible for any improvements in outcomes.

Only two studies have attempted to specifically isolate the effect of DB&C from standardised early ambulation. Mackay et al (2005) compared PPC rates in 56 patients randomised to an ambulation only group or a group provided with additional supervised DB&C exercises; of note the protocol for both groups was intensive, with three ambulation sessions on the first and second postoperative day and continuing twice daily for the next two days. The overall PPC rate was 14% with no significant difference between groups. A similar study replicated this protocol with a more realistic ambulation protocol. Silva et al (2013) randomised 86 high-risk UAS patients into three groups: mobilisation alone, mobilisation plus DB&C, and delayed mobilisation (commenced on the third postoperative day) plus DB&C. Participants were ambulated once daily to a BORG intensity of 6/10. There were no significant differences in PPC rate between groups even in the group that rested in bed for three days; although this group were no more likely to get a PPC, they had increased requirements for physiotherapy to assist in their physical recovery and significantly longer LOS (MD 4.4, 95%CI 0.3 to 8.8). Both of these studies suggest that the addition of DB&C to early ambulation does not reduce the incidence of PPC. However, it is important to note that these studies were not powered to measure small to moderate differences in PPC rates (less than 20% between groups). It is possible that coached DB&C exercises could provide a small, yet clinically worthwhile effect. Much larger clinical trials would need to be performed to test this.

*Key Points:*

1. Because of the undesirable sequelae associated with prolonged bedrest, ambulation should be commenced as early as safely possible for all patients undergoing all types of abdominal surgery.
2. There is little evidence to support the use of early ambulation in the prevention of PPCs.
3. The ideal amount, duration, and frequency, of ambulation required to improve postoperative recovery is untested.

*Postoperative breathing exercises.*

Coached DB&C exercises are traditionally provided to patients following UAS aiming to prevent PPCs. Incentive spirometers (IS) (do Nascimento Junior et al 2014), PEP devices (Orman and Westerdahl 2010, Zhang et al 2015), and non-invasive ventilation (NIV) (Ferreyra et al 2008) are also utilised, but less frequently. These modalities are often delivered by physiotherapists (Haines et al 2013, Makhabah et al 2013), although in some countries these may be provided by other health professionals (Cassidy et al 2013, Zhang et al 2015). Despite widespread and ubiquitous provision of prophylactic respiratory physiotherapy following abdominal surgery, its efficacy and worth in preventing PPCs is unclear.

Two systematic reviews have investigated interventions to prevent PPCs following abdominal surgery (Lawrence et al 2006, Pasquina et al 2006). Despite being conducted in the same year, the conclusions were contradictory. Lawrence et al (2006) investigated all non-pharmaceutical interventions to prevent respiratory complications including a wide range of interventions (such as nasogastric decompression, postoperative analgesia) in open, laparoscopic, LAS and UAS. Findings suggested there is good evidence for any type of lung expansion manoeuvres compared with no treatment at all but that studies were confounded by the use of multimodal interventions, inconsistent definitions of PPC and poor methodologies. Pasquina et al (2006), in a robust and detailed systematic review, focused solely on physiotherapy interventions and meta-analysed 35 studies conducted in both LAS and UAS. Less than half of all trials found that DB&C exercises were more effective than a no-treatment control or alternative technique. They concluded that the routine use of respiratory physiotherapy after open abdominal surgery is not justified.

Since the 2006 publication of these systematic reviews (Lawrence et al 2006, Pasquina et al 2006), seven additional RCTs have been published (Baltieri et al 2014, Barbalho-Moulim et al 2011, Dronkers 2008, Kulkarni et al 2010, Samnani et al 2014, Silva et al 2013, Zhang et al 2015). The findings of these further studies are summarised in Table 3 and the results and context of the findings are discussed elsewhere in this paper where appropriate. The methodological quality of each of these trials has been assessed using the PEDro scale and absolute risk reduction (including confidence intervals) and number needed to treat have been calculated from the dichotomous PPC data supplied in the studies where possible.

One further systematic review assessed specifically the effect of breathing exercises on physiological aspects of pulmonary function following abdominal surgery such as respiratory muscle strength and diaphragm mobility (Grams et al 2012). This study and others (Grams et al 2012, Lunardi et al 2013, Lunardi et al 2015) have demonstrated that DB&C improve respiratory function following UAS, although it remains unclear whether these physiological improvements translate to clinically meaningful reductions in LOS or incidence of PPCs.

In the face of contradictory evidence for the use of DB&C exercises, an international panel of experts have attempted to provide a consensus statement on physiotherapy management for patients following UAS (Hanekom et al 2012). Using the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) approach (Guyatt et al 2008), the panel considered the potential benefits of coached DB&C exercises outweighs the potential costs and harms of the intervention. Until this is confirmed with further high-quality evidence and cost-benefit analysis this recommendation remains supported by a weak level of evidence.

Regarding laparoscopic and LAS, although respiratory physiotherapy demonstrates physiological improvements in pulmonary function (Forti et al 2009, Gastaldi et al 2008, Krishna et al 2013), the PPC rate is very low (Arozullah et al 2000, Condie et al 1993) and postoperative respiratory physiotherapy for this population has not been shown to alter clinical outcomes such as incidence of PPC and LOS . However, with the increasing use of advanced technology, more complex surgeries are now being performed laparoscopically. Due to their complexity, the average time of these type of laparoscopic operations are usually greater than three hours (Fagevik Olsen M 1999, Kuo et al 2013, Park et al 2011). In these studies, the

PPC incidence between open and laparoscopic surgery is similar, suggesting that there may be an increased PPC risk in prolonged laparoscopic surgery (Kuo et al 2013, Park et al 2011). This needs to be confirmed with prospective observational studies to enable risk prediction models to be developed, which will in turn assist physiotherapists and hospitals to determine which patients require targeted PPC prophylaxis following these newer types of procedures. To date, no study has investigated the effectiveness of any type of respiratory therapy to *treat* a PPC following diagnosis and this requires urgent investigation.

### *Key Points:*

1. DB&C exercises should not be provided routinely following LAS, standard laparoscopic surgery or for patients screened as being at low-risk of a PPC following UAS.
2. For high-risk UAS patients, on balance of the available evidence, the provision of coached DB&C exercises may be unnecessary as long as patients are provided with an early ambulation programme of assisted walking at least once a day. It is suggested this assisted walking targets a BORG score > 6/10.

### *Respiratory adjuncts*

Systematic reviews and meta-analyses (do Nascimento Junior et al 2014, Overend et al 2001) have investigated the use of incentive spirometry (IS) for patients following abdominal surgery. In the most recent meta-analysis, do Nascimento Junior et al (2014) investigated 12 studies with a total of 1834 participants undergoing UAS including laparoscopic surgery. Trials compared IS to either no respiratory treatment; DB&C; or to other types of chest physiotherapy. There were no statistically significant differences between any groups in the risk of developing a pulmonary condition. There are limitations with this literature due to mixed patient populations in some studies (UAS, LAS, laparoscopic) and due to varying risk profiles of patients. These limitations and the generally low quality of the evidence regarding the lack of effectiveness of IS in preventing PPCs following UAS highlight the need to conduct well-designed trials in this field. Recently there has been a renewed interest in investigating IS in high-risk populations. For example, a pre-post cohort study in patients undergoing high-risk UAS has shown promising results (Westwood et al 2007) and these results now need to be tested in a RCT.

Only one systematic review has investigated the use of PEP devices (including bubble PEP) in patients undergoing open abdominal or thoracic surgery (Orman and Westerdahl 2010). The review found weak evidence that PEP confers any benefit over standard respiratory physiotherapy but due to the age and limited quality of the included studies (PEDro 4 – 6), firm conclusions are unable to be drawn. A recent well-designed RCT (PEDro 8/10) compared routine medical management and early mobilisation with the use of modified oscillating PEP in 203 patients following UAS and thoracic surgery (see Table 3 for details) (Zhang et al 2015). The study found a significant reduction in days of fever and LOS in the PEP group (MD–2.6, 95% CI -4.8 to –0.4). The use of postoperative (oscillatory) PEP now requires further corroboration with studies in other countries and other surgical contexts, utilising outcome measures that include PPC incidence.

Two meta-analyses have compared prophylactic continuous positive airways pressure (CPAP), to prevent postoperative morbidity and mortality in patients following major abdominal surgery, with standard care (including physiotherapy) (Ferreyra et al 2008, Ireland et al 2014). Whilst no differences were found in the effects of CPAP on mortality and hypoxaemia, both studies showed significant reductions in atelectasis, pneumonia and re-intubation rate with CPAP. Caution is required in extrapolating these results as the included studies had substantial heterogeneity, small sample sizes and a number were old with poor methodological reporting. There is evidence to suggest that CPAP and NIV are both effective in improving outcomes in patients who have developed postoperative respiratory failure although this is based on a small number of studies (Antonelli et al 2000, Chiumello et al 2011, Kindgen-Milles et al 2005).

### *Other adjuncts*

The use of an abdominal binder, a firm removable elastic girdle placed around the abdomen, is popular in some countries following abdominal surgery in attempting to prevent wound dehiscence and improve postoperative pain and respiratory function (Bouvier et al 2014). Its use has shown improvements in postoperative walking distance following major UAS (Cheifetz et al 2010), but only weak effects on reducing pain (Rothman et al 2014) and no effect on pulmonary function or seroma formation (Fagevik Olsén et al 2009, Larson et al 2009, Rothman et al 2014) or LOS (Larson et al 2009). There is some evidence to suggest that abdominal binders improve psychological distress in the early postoperative period (Rothman et al 2014). Its use has yet to be related to PPC rates but evidence suggests that binders can be worn without compromising pulmonary function (Rothman et al 2014).

### *Key Points:*

1. Incentive spirometry should not be routinely provided following abdominal surgery.
2. The use of oscillatory PEP may assist in preventing PPCs.
3. Postoperative prophylactic CPAP/NIV is efficacious in the prevention of PPCs, although evidence is insufficient on the potential for harm and the cost implications of providing CPAP/NIV prophylactically to all patients following UAS need to be considered.

### *Post-discharge rehabilitation*

Health-related quality of life (HRQoL) has become an important end-point in the abdominal surgical literature. Delayed recovery and persistent disability following UAS has been demonstrated up to six months postoperatively (Lawrence et al 2004), with complications in the immediate postoperative period being independent predictors of poorer recovery and poor HRQoL (Davies et al 2013, Lawrence et al 2004). It is unknown if delays in functional recovery (or functional decline) following UAS are related to increased health utilisation costs, morbidity and mortality or if postoperative rehabilitation programmes would hasten recovery and reduce disability. To our knowledge, there are currently no studies investigating the impact of

postoperative rehabilitation specifically for patients having undergone UAS. There is, however, a plethora of emerging literature demonstrating positive health benefits (including disease-free survival) at all stages of treatment in cancer survivors. Given that patients with cancer frequently present for abdominal surgery, and the known delayed recovery from UAS in some patients, the value of post-discharge rehabilitation for patients following UAS warrants further exploration.

***Key Point:***
In the absence of any evidence regarding postoperative rehabilitation programmes we are unable to make any recommendations regarding post-discharge physiotherapy.

## CONCLUSION

The research regarding physiotherapy in the perioperative period for patients undergoing abdominal surgery is limited and equivocal. Physiotherapy services rely not only on the balance of evidence but on the balance of resources to provide these services. It is feasible that the potential high cost of PPCs following abdominal surgery justifies the provision of low-cost interventions such as physiotherapy. Until this has been confirmed with good quality research and cost analysis studies, physiotherapists should provide a service based on the best available evidence. This study has attempted to summarise such evidence, highlight the areas required for further research and make balanced recommendations for practice on the basis of these factors.

## DISCLOSURES

No financial support was received in the preparation of this paper.

## ADDRESS FOR CORRESPONDENCE

Julie C Reeve, School of Clinical Sciences, Faculty of Health and Environmental Studies, AUT University, Auckland, New Zealand.
Email: julie.reeve@aut.ac.nz

**Table 3: PPC incidence rates in studies investigating physiotherapy interventions in major upper abdominal surgery published since systematic reviews of Lawrence (2006) and Pasquina (2006)**

| Author/year /country | Study type | Abdominal surgery types and risk profiles | Sample size | PEDro score | Interventions | PPC diagnostic criteria | PPC rate, % (95% CI) | ARR % (95% CI) NNT | Conclusion |
|---|---|---|---|---|---|---|---|---|---|
| Randomised controlled trials | | | | | | | | | |
| (Zhang et al 2015) China | Randomised controlled trial Multi-centre | Thoracic and UAS (open and laparoscopic) Mixed risk profiles | 203 | 8/10 | C: Standard ward care. No pre or postop physiotherapy Rx: Postop flutter 5-10 reps, 3 times daily, POD1-5 | Any of the following: • Incidence of fever • Abnormal CXR • WCC • Antibiotic therapy | Fever incidence C: 39% (30-49%) Rx: 22% (15-31%) | 17% (4-29%) NNT= 6 (3 to 22) | Flutter use following major thoracic and UAS halves fever incidence and reduces LOS, but not abnormalities in CXR or WCC, nor does it reduce antibiotic usage. |
| (Baltieri et al 2014) Brazil | Randomised controlled trial Single centre | Gastric bypass via open laparotomy, BMI > 40 High-risk | 40 | 6/10 | C: Physio DB&C, incentive spirometry, early mobilisation Rx A: BiPAP 1 hr prior to surgery Rx B: BiPAP 1 hr after surgery Rx C: PEEP 10cmH20 intraoperatively | Atelectasis on CXR | C: 20% (6-51%) Rx A: 10% (2-40%) Rx B: 0% Rx C: 10% (2-40%) | Not significant | Inadequate sample size to determine a conclusion. |
| (Samnani et al 2014) Pakistan | Pseudo randomised controlled trial Single centre | Low-risk, non-smokers, ASA 1 and 2, elective and emergency, open upper and lower abdominal surgery | 224 | 5/10 | C: Basic preop education Rx: Additional preop education on early ambulation Postop all received early ambulation > 10 minutes duration and those with prolonged operation time received "chest physio" and incentive spirometers. | Modified Melbourne group scale with 3 or more of the factors | C: 30% (22-39%) Rx: 7% (4-13%) | 22% (13-32%) NNT= 4 (3 to 8) | Preop counselling on expected postoperative early ambulation leads to earlier mobilisation and significantly reduces PPCs. |
| (Silva et al 2013) Australia | Cluster randomised controlled trial Single centre | High-risk elective UAS Excluded: AAA, oesophagectomy | 86 | 7/10 | C: Assisted ambulation with Physio once daily at least RPE 6/10. RxA: As control + coached DB&C (4 x 5 reps with 3 sec inspiratory holds) RxB: Rest in bed for POD1 and 2 + coached DB&C as above. Assisted ambulation on POD3. | 3 or more in the same day: • Auscultation changes • Temp >38 • CXR changes • Sputum changes | C: 21% (10-40%) RxA: 25% (13-43%) RxB: 10% (3-26%) | No significant difference in PPC rates | Inadequate sample size to determine a difference in PPCs. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (Barbalho-Moulim et al 2011)<br>Brazil | Randomised controlled trial<br>Single centre | Elective open bariatric surgery in females of short LOS (<3days) | 32 | 7/10 | C: Preop education on DB&C and early mobilisation. Postop daily physio of DB&C, incentive spirometry, early mobilisation<br>Rx: Additional preop IMT, 15min, once daily, 6 days/wk, 2-4 wks prior to surgery. 30% MIP increasing twice weekly. | One or more of:<br>• Pneumonia<br>• CXR atelectasis with dyspnoea<br>• Acute respiratory failure | 0% | n/a | Inadequate sample size to determine a difference in PPCs in this low risk, short LOS population. |
| (Kulkarni et al 2010)<br>England | Randomised controlled trial<br>Single centre | Major elective UAS | 80 | 5/10 | C: No treatment<br>RxA: DB exercises<br>RxB: Incentive spirometry<br>RxC: IMT, 20-30% MIP<br>All exercises performed 15mins, twice daily, 7 days a week for 2 weeks prior to surgery | Chest infections requiring antibiotic treatment | C: 10% (3-30%)<br>RxA: 5% (1-24%)<br>RxB: 0%<br>RxC: 0% | ISQ | Inadequate sample size to determine a difference in PPCs. |
| (Dronkers 2008)<br>Netherlands | Randomised controlled trial<br>Single centre | High-risk AAA repairs | 20 | 7/10 | C: Preop DB&C training, incentive spirometry. Postop physio of coached DB&C, incentive spirometry and early mobilisation<br>Rx: IMT daily for 15min, 6 days a week. 2 weeks prior to surgery. 20% of MIP and increasing resistance to maintain RPE >5/10 | Atelectasis on CXR | C: 80% (49-94%)<br>Rx: 30% (11-60%) | 50% (6-74%)<br>NNT=2 (1-15) | Preop IMT reduces postoperative atelectasis following AAA repairs |
| **Pre-post cohort studies** | | | | | | | | | |
| (Lunardi et al 2011)<br>Brazil | Pre-post cohort<br>Single centre | Elective Oesophagectomy<br>High-risk | 70 | n/a | C: No physiotherapy<br>Rx: 20 minutes daily DB&C, early mobilisation | Any of the following:<br>• Atelectasis on CXR<br>• Pneumonia<br>• Pleural effusion | C: 37% (22-54%)<br>Rx: 15% (7-29%) | 21% (1-41%)<br>NNT = 5 (2 to 80) | Chest physio is likely to reduce PPCs following oesophagectomy |
| (Lunardi et al 2008)<br>Brazil | Pre-post cohort<br>Single centre | Oesophagectomy<br>High risk, elective | 40 | n/a | RxA: Chest Physio only in ICU<br>RxB: Chest Physio in ICU and through to hospital discharge | Any of the following:<br>• Atelectasis on CXR<br>• Pneumonia<br>• Pleural effusion | RxA: 30% (14-52%)<br>RxB: 10% (3-30%) | Not significant | Inadequate sample size to draw conclusions. Trend towards additional Physiotherapy beyond ICU reducing PPCs. |

**Table 3: PPC incidence rates in studies investigating physiotherapy interventions in major upper abdominal surgery published since systematic reviews of Lawrence (2006) and Pasquina (2006) *(continued)***

| Author/year /country | Study type | Abdominal surgery types and risk profiles | Sample size | PEDro score | Interventions | PPC diagnostic criteria | PPC rate, % (95% CI) | ARR % (95% CI) NNT | Conclusion |
|---|---|---|---|---|---|---|---|---|---|
| (Nakamura et al 2008) Japan | Pre-post cohort Single centre | Elective oesophagectomy High-risk | 184 | n/a | C: Open surgery, no physiotherapy 1991-1995 RxA: VATS surgery, no physiotherapy 1996-2000 RxB: VATS or open surgery, corticosteroid medication, pre-and postoperative chest physiotherapy. 2001-2005 | Any of the following: • Bronchopneumonia • Aspiration pneumonia • Acute respiratory failure • Pleural effusion | C: 27% (14-46%) RxA: 36% (25-49%) RxB: 8% (4-15%) | 28% (15-42%) NNT = 4 (2 to 7) | Patients who did not receive pre and postop physiotherapy were 4 times more likely to get a respiratory complication. |
| (Westwood et al 2007) England | Pre-post cohort Single centre | All elective and emergency UAS Mixed risk | 263 | n/a | C: Daily DB&C ex Rx: Daily DB&C ex + incentive spirometry | Presence of clinical features of collapse/ consolidation, plus one of the following: • Temp >38 • Positive CXR • Positive sputum | C: 17% (11-25%) Rx: 6% (3-12%) | 11% (3-20%) NNT=9 (5-35) | The addition of incentive spirometry to chest physiotherapy may reduce PPCs following major UAS |
| **Observational studies** | | | | | | | | | |
| (Haines et al 2013) Australia | Prospective observational Single centre | High-risk elective and emergency UAS | 72 | n/a | Daily postop physiotherapy of early mobilisation, DB&C exercises, +/- NIV for 7 days | Melbourne group scale | 39% (28-50%) | n/a | PPCs were 3 times more likely for each POD they did not mobilise away from the bed. |
| (Parry et al 2014) Australia | Prospective observational Single centre | High-risk elective and emergency UAS | 50 | n/a | Daily postop physiotherapy of early mobilisation, DB&C exercises, +/- NIV for 7 days | Melbourne group scale | 42% (29-56%) | n/a | Patients with a nasogastric tube > 1 day were 9 times more likely to have a PPC |
| (Paisani et al 2012) Brazil | Prospective observational Single centre | Elective UAS Mixed risk profiles | 137 | n/a | Daily postop physiotherapy of early mobilisation and DB&C till hospital discharge | One or more of: • Pneumonia • Tracheobronchitis • CXR atelectasis with dyspnoea • Acute respiratory failure • Bronchoconstriction | 7% (4-13%) | n/a | PPCs increase LOS and mortality. |
| (Feeney et al 2011) Ireland | Prospective observational Single centre | Elective oesophagectomy High-risk | 37 | n/a | Not specified | Melbourne group scale | 27% (15-43%) | n/a | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (Chen et al 2011) Taiwan | Prospective observational Single centre | Elective oesophagectomy High-risk | 68 | n/a | Not specified | Any of the following:<br>• Acute respiratory failure<br>• Pneumonia<br>• Pleural effusion | 35% (25-47%) | n/a | |
| (Scholes et al 2009) Australia | Prospective observational Multi-centre | All elective UAS Mixed risk | 268 | n/a | All patients standardised to receive preop education and DB&C training and a single postop physiotherapy (early mobilisation and DB&C) session on POD1 | Melbourne group scale | 13% (10-18%) | n/a | ICU admission, length of surgery, preoperative estimated VO2max, upper GI surgery, and smoking predict PPCs. |
| (Browning et al 2007) Australia | Prospective observational Single centre | All elective UAS Mixed risk | 50 | n/a | All patients standardised to receive preop education and DB&C training and a single postop physiotherapy (early mobilisation and DB&C) session on POD1 | Melbourne group scale | 18% (10-31%) | n/a | Patients are upright for only 3-13 minutes a day for the first 3 postop days. Time upright predicted LOS, but not PPC risk. |
| (Kanat 2007) Turkey | Prospective observational Single centre | All elective UAS Mixed risk | 60 | n/a | Not specified. 95% achieved early mobilization as classified as <48hr post-op. | Any of the following:<br>• Atelectasis<br>• Pulmonary emboli<br>• Bronchitis<br>• Pneumonia<br>• Pneumonitis<br>• Acute respiratory failure | 58% (46-70%) | n/a | |
| (Serejo et al 2007) Brazil | Prospective observational Single centre | All emergency UAS Mixed risk | 266 | n/a | Not detailed | Any of the following:<br>• Atelectasis on CXR<br>• Pneumonia<br>• Pleural effusion<br>• Acute respiratory failure | 28% (23-34%) | n/a | |

Notes: ARR, absolute risk reduction; ASA, American association of anaesthesiologists; AAA, abdominal aortic aneurysm; BiPAP, bi-level positive airway pressure; BMI, body mass index; C, control; CI, confidence interval; CXR, chest Xray; DB&C, deep breathing and coughing; GI, gastrointestinal; ICU, intensive care unit; IMT, inspiratory muscle training; Intraop, intraoperatively; LOS, length of stay; MIP, maximal inspiratory pressure; n/a, not applicable; NNT, number needed to treat; NIV, non-invasive ventilation; PEP, positive expiratory pressure; POD, postoperative day; Postop, postoperatively; PPC, postoperative pulmonary complication; Preop, preoperatively; RPE, rate of perceived exertion; Rx, treatment; UAS, upper abdominal surgery; VATS, video assisted thoracic surgery; WCC, white cell count.

## REFERENCES


Aahlin E, Tranø G, Johns N, Horn A, Søreide J, Fearon K, Revhaug A, Lassen K (2015) Risk factors, complications and survival after upper abdominal surgery: a prospective cohort study. BMC Surgery 15(1): 83. doi:10.1186/s12893-015-0069-2.

Adamina M, Kehlet H, Tomlinson GA, Senagore AJ, Delaney CP (2011) Enhanced recovery pathways optimize health outcomes and resource utilization: a meta-analysis of randomized controlled trials in colorectal surgery. Surgery 149(6): 830-840. doi:10.1016/j.surg.2010.11.003.

Agostini P, Naidu B, Cieslik H, Rathinam S, Bishay E, Kalkat M, Rajesh PB, Steyn R, Singh S (2011) Comparison of recognition tools for postoperative pulmonary complications following thoracotomy. Physiotherapy 97(4): 278-283. doi:10.1016/j.physio.2010.11.007.

Agostini P, Naidu B, Cieslik H, Steyn R, Rajesh PB, Bishay E, Kalkat MS, Singh S (2013) Effectiveness of incentive spirometry in patients following thoracotomy and lung resection including those at high risk for developing pulmonary complications. Thorax 68(6): 580-585. doi:10.1136/thoraxjnl-2012-202785.

AIHW (2013) Procedures Cubes 2011-2012: National Hospital Morbidity Database. http://www.aihw.gov.au/hospitals-data/procedures-data-cubes/#ardrglink [Accessed 7/9/2014].

Aissaoui N, Martins E, Mouly S, Weber S, Meune C (2009) A meta-analysis of bed rest versus early ambulation in the management of pulmonary embolism, deep vein thrombosis, or both. International Journal of Cardiology 137(1): 37-41. doi:10.1016/j.ijcard.2008.06.020.

Anderson CM, Overend TJ, Godwin J, Sealy C, Sunderji A (2009) Ambulation after deep vein thrombosis: a systematic review. Physiotherapy Canada 61(3): 133-140. doi:10.3138/physio.61.3.133.

Antonelli M, Conti G, Bufi M, Costa M, Lappa A, Rocco M, Gasparetto A, Meduri G (2000) Noninvasive ventilation for treatment of acute respiratory failure in patients undergoing solid organ transplantation: A randomized trial. JAMA: The Journal of the American Medical Association 283(2): 235-241. doi:10.1001/jama.283.2.235.

Antoniou SA, Antoniou GA, Koch OO, Pointner R, Granderath FA (2014) Meta-analysis of laparoscopic vs open cholecystectomy in elderly patients. World Journal of Gastroenterology 20(46): 17626. doi:10.3748/wjg.v20.i46.17626.

Arozullah A (2001) Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery Annals of Internal Medicine 135(10): 847-857. doi:10.7326/0003-4819-135-10-200111200-00005.

Arozullah AM, Daley J, Henderson WG, Khuri SF, for the National Veterans Administration Surgical Quality Improvement Program (2000) Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. Annals of Surgery 232(2): 242.

Baltieri L, Santos LA, Rasera-Junior I, Montebelo MIL, Pazzianotto-Forti EM (2014) Use of positive pressure in the bariatric surgery and effects on pulmonary function and prevalence of atelectasis: randomized and blinded clinical trial. Arquivos Brasileiros de Cirurgia Digestiva (São Paulo) 2726-30. doi:10.1590/S0102-67202014000S100007.

Barbalho-Moulim MC, Miguel GPS, Forti EMP, Campos FdA, Costa D (2011) Effects of preoperative inspiratory muscle training in obese women undergoing open bariatric surgery: respiratory muscle strength, lung volumes, and diaphragmatic excursion. Clinics 66(10): 1721-1727. doi:10.1590/S1807-59322011001000009.

Barnett S, Moonesinghe SR (2011) Clinical risk scores to guide perioperative management. Postgraduate Medical Journal 87(1030): 535-541. doi:10.1136/pgmj.2010.107169.

Bellinetti LM, Thomson JC (2006) Respiratory muscle evaluation in elective thoracotomies and laparotomies of the upper abdomen. Jornal Brasileiro de Pneumologia 32(2): 99-105.

Bilgi M, Goksu S, Mizrak A, Cevik C, Gul R, Koruk S, Sahin L (2011) Comparison of the effects of low-flow and high-flow inhalational anaesthesia with nitrous oxide and desflurane on mucociliary activity and pulmonary function tests. European Journal of Anaesthesiology 28(4): 279-283.

Blaney F, Sawyer T (1997) Sonographic measurement of diaphragmatic motion after upper abdominal surgery: A comparison of three breathing manoeuvres. Physiotherapy Theory and Practice 13(3): 207-215. doi:10.1016/S0004-9514(14)60363-9.

Boulind C, Yeo M, Burkill C, Witt A, James E, Ewings P, Kennedy R, Francis N (2012) Factors predicting deviation from an enhanced recovery programme and delayed discharge after laparoscopic colorectal surgery. Colorectal Disease 14(3): e103-e110. doi:10.1111/j.1463-1318.2011.02799.

Bourn J, Conway J, Holgate S (1991) The effect of post-operative physiotherapy on pulmonary complications and lung function after upper abdominal surgery. European Respiratory Journal 4325s.

Bouvier A, Rat P, Drissi-Chbihi F, Bonnetain F, Lacaine F, Mariette C, Ortega-Deballon P (2014) Abdominal binders after laparotomy: review of the literature and French survey of policies. Hernia 18(4): 501-506. doi:10.1007/s10029-014-1264-2.

Browning L (2007) Early mobilisation following upper abdominal surgery in Australian public hospitals. PhD Thesis, Melbourne: University of Melbourne.

Browning L, Denehy L, Scholes RL (2007) The quantity of early upright mobilisation performed following upper abdominal surgery is low: an observational study. Australian Journal of Physiotherapy 53(1): 47-52. doi:10.1016/S0004-9514(07)70061-2.

Cash J (1955) Physiotherapy in Some Surgical Conditions (1st edn). London: Faber and Faber.

Cassidy MR, Rosenkranz P, McCabe K, Rosen JE, McAneny D (2013) I COUGH: reducing postoperative pulmonary complications with a multidisciplinary patient care program. JAMA Surgery 148(8): 740-745. doi:10.1001/jamasurg.2013.358.

Castillo R, Haas A (1985) Chest physical therapy: comparative efficacy of preoperative and postoperative in the elderly. Archives of Physical Medicine and Rehabilitation 66(6): 376-379.

Cayley WE (2007) Preventing deep vein thrombosis in hospital inpatients. BMJ 335(7611): 147-151. doi:10.1136/bmj.39247.542477.AE.

Cerantola Y, Valerio M, Persson B, Jichlinski P, Ljungqvist O, Hubner M, Kassouf W, Muller S, Baldini G, Carli F (2013) Guidelines for perioperative care after radical cystectomy for bladder cancer: Enhanced Recovery After Surgery (ERAS) society recommendations. Clinical Nutrition 32(6): 879-887. doi:10.1016/j.clnu.2013.09.014.

Cheifetz O, Lucy SD, Overend TJ, Crowe J (2010) The effect of abdominal support on functional outcomes in patients following major abdominal surgery: a randomized controlled trial. Physiotherapy Canada 62(3): 242-253. doi:10.3138/physio.62.4.409.

Chen C-H, Huang Y-Z, Hung T-T (2011) Hand-grip strength is a simple and effective outcome predictor in esophageal cancer following esophagectomy with reconstruction: a prospective study. Journal of Cardiothoracic Surgery 6(1): 98. doi:10.1186/1749-8090-6-98.

Chiumello D, Chevallard G, Gregoretti C (2011) Non-invasive ventilation in postoperative patients: a systematic review. Intensive Care Medicine 37(6): 918-929. doi:10.1007/s00134-011-2210-8.

Condie E, Hack K, Ross A (1993) An investigation of the value of routine provision of postoperative chest physiotherapy in non-smoking patients undergoing elective abdominal surgery. Physiotherapy 79547-552.

Coolsen MM, Wong-Lun-Hing EM, Dam RM, Wilt AA, Slim K, Lassen K, Dejong CH (2013) A systematic review of outcomes in patients undergoing liver surgery in an enhanced recovery after surgery pathways. HPB:The Official Journal Of The International Hepato Pancreato Biliary Association 15(4): 245-251.

Davies SJ, Francis J, Dilley J, Wilson RJT, Howell SJ, Allgar V (2013) Measuring outcomes after major abdominal surgery during hospitalization: reliability and validity of the Postoperative Morbidity Survey. Perioperative Medicine 2(1): 1.

Delaney C, Fazio V, Senagore A, Robinson B, Halverson A, Remzi F (2001) 'Fast track' postoperative management protocol for patients with high co-morbidity undergoing complex abdominal and pelvic colorectal surgery. British Journal of Surgery 88(11): 1533-1538.

Denehy L (2001) The physiotherapy management of patients following upper abdominal surgery. PhD thesis, Melbourne: University of Melbourne.

Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S (2001) A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. Physiotherapy Research International 6(4): 236-250.

Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA (2004) Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. Journal of the American College of Surgeons 199(4): 531-537.

do Nascimento Junior P, Módolo NS, Andrade S, Guimarães MM, Braz LG, El Dib R (2014) Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. Cochrane Database of Systematic Reviews (2). doi:10.1002/14651858.CD006058.pub3.

Dols LF, Kok NF, IJzermans JN (2009) Surgical aspects of live kidney donation https://www.bioscience.org/2009/v14/af/3564/fig2.jpg [Accessed 15th March, 2016].

Dronkers J (2008) Prevention of pulmonary complications after upper abdominal surgery by preoperative intensive inspiratory muscle training: a randomized controlled pilot study. Clinical Rehabilitation 22(2): 134-142. doi:10.1177/0269215507081574.

Duggan M, Kavanagh B (2005) Pulmonary Atelectasis A pathogenic perioperative entity. Anesthesiology 102(4): 838-854.

Fagevik Olsén M, Hahn I, Nordgren S, Lonroth H, Lundholm K (1997) Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. British Journal of Surgery 84(11): 1535-1538.

Fagevik Olsen M JK, Lonroth H. (1999) Chest physiotherapy does not improve the outcome in laparoscopic fundoplication and vertical-banded gastroplasty. Surgical Endoscopy 13260-263.

Fagevik Olsén M, Josefson K, Wiklund M (2009) Evaluation of abdominal binder after major upper gastrointestinal surgery. Advances in Physiotherapy 11(2): 104-110. doi:10.1080/14038190802141073.

Feeney C, Reynolds J, Hussey J (2011) Preoperative physical activity levels and postoperative pulmonary complications post-esophagectomy. Diseases of the Esophagus 24(7): 489-494. doi:10.1111/j.1442-2050.2010.01171.x.

Ferreyra GP, Baussano I, Squadrone V, Richiardi L, Marchiaro G, Del Sorbo L, Mascia L, Merletti F, Ranieri VM (2008) Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. Annals of Surgery 247(4): 617-626. doi:10.1097/SLA.0b013e3181675829.

Ford G, Whitelaw W, Rosenal T, Cruse P, Guenter C (1983) Diaphragm function after upper abdominal surgery in humans. The American Review of Respiratory Disease 127431-436.

Forti E, Ike D, Barbalho-Moulim M, Rasera I, Costa D (2009) Effects of chest physiotherapy on the respiratory function of postoperative gastroplasty patients. Clinics (Sao Paulo) 64683 - 689. doi:10.1590/S1807-59322009000700013.

Gamsu G, Singer MM, Vincent HH, Berry S, Nadel J (1976) Postoperative impairment of mucous transport in the lung. The American Review of Respiratory Disease 114(4): 673-679.

Gastaldi A, Magalhães C, Baraúna M, Silva E, Souza H (2008) Benefits of postoperative respiratory kinesiotherapy following laparoscopic cholecystectomy. Revista Brasileira de Fisioterapia (2): 100-106.

Grams ST, Ono LM, Noronha MA, Schivinski CIS, Paulin E (2012) Breathing exercises in upper abdominal surgery: a systematic review and meta-analysis. Brazilian Journal of Physical Therapy 16345-353.

Gupta A, Gupta N (2010) Setting up and functioning of a preanaesthetic clinic. Indian Journal of Anaesthesia 54(6): 504. doi:10.4103/0019-5049.72638.

Gustafsson UO, Hausel J, Thorell A, Ljungqvist O, Soop M, Nygren J (2011) Adherence to the enhanced recovery after surgery protocol and outcomes after colorectal cancer surgery. Archives of Surgery 146(5): 571-577. doi:10.1001/archsurg.2010.309.

Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schünemann HJ (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 336(7650): 924-926. doi:10.1136/bmj.39489.470347.AD.

Haines KJ, Skinner EH, Berney S (2013) Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: an observational cohort study. Physiotherapy 99(2): 119-125. doi:10.1016/j.physio.2012.05.013.

Hamel MB, Henderson WG, Khuri SF, Daley J (2005) Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. Journal of the American Geriatrics Society 53(3): 424-429.

Hanekom S, Brooks D, Denehy L, Fagevik-Olsen M, Hardcastle T, Manie S, Louw Q (2012) Reaching consensus on the physiotherapeutic management of patients following upper abdominal surgery: a pragmatic approach to interpret equivocal evidence. BMC Medical Informatics and Decision Making 612. doi:10.1186/1472-6947-12-5.

Hedenstierna G, Edmark L (2010) Mechanisms of atelectasis in the perioperative period. Best Practice & Research Clinical Anaesthesiology 24(2): 157-169.

Holbrook A, Schulman S, Witt DM, Vandvik PO, Fish J, Kovacs MJ, Svensson PJ, Veenstra DL, Crowther M, Guyatt GH (2012) Evidence-based management of anticoagulant therapy: Antithrombotic therapy and prevention of thrombosis, 9th ed: american college of chest physicians evidence-based clinical practice guidelines. CHEST Journal 141(2_suppl): e152S-e184S. doi:10.1378/chest.11-2295.

Innocenti D (1996) An overview of the development of breathing exercises into the specialty of physiotherapy for heart and lung conditions. Physiotherapy 82(12): 681-693.

Ireland CJ, Chapman TM, Mathew SF, Herbison GP, Zacharias M (2014) Continuous positive airway pressure (CPAP) during the postoperative period for prevention of postoperative morbidity and mortality following major abdominal surgery. Cochrane Database Syst Rev 8. doi:10.1002/14651858.CD008930.pub2.

Kanat F (2007) Risk factors for postoperative pulmonary complications in upper abdominal surgery. ANZ Journal of Surgery 77(3): 135. doi:10.1111/j.1445-2197.2006.03993.x.

Kim SH, Na S, Choi J-S, Na SH, Shin S, Koh SO (2010) An evaluation of diaphragmatic movement by M-mode sonography as a predictor of pulmonary dysfunction after upper abdominal surgery. Anesthesia & Analgesia 110(5): 1349-1354. doi:10.1213/ANE.0b013e3181d5e4d8.

Kindgen-Milles D, Müller E, Buhl R, Böhner H, Ritter D, Sandmann W, Tarnow Jr (2005) Nasal-continuous positive airway pressure reduces pulmonary morbidity and length of hospital stay following thoracoabdominal aortic surgery. CHEST Journal 128(2): 821-828. doi:10.1378/chest.128.2.821.

Knechtle WS, Perez SD, Medbery RL, Gartland BD, Sullivan PS, Knechtle SJ, Kooby DA, Maithel SK, Sarmiento JM, Shaffer VO (2014) The Association Between Hospital Finances and Complications After Complex Abdominal Surgery. Annals of Surgery 262(2): 273-279. doi:10.1097/SLA.0000000000001042.

Koch CG, Li L, Hixson E, Tang A, Phillips S, Henderson JM (2012) What Are the Real Rates of Postoperative Complications: Elucidating Inconsistencies Between Administrative and Clinical Data Sources. Journal of the American College of Surgeons 214(5): 798-805. doi:10.1016/j.jamcollsurg.2011.12.037.

Konrad FX, Schreiber T, Brecht-Kraus D, Georgieff M (1993) Bronchial mucus transport in chronic smokers and nonsmokers during general anesthesia. Journal of Clinical Anesthesia 5(5): 375-380.

Krishna G, Augustine A, Anand R, Mahale A (2013) Chest physiotherapy during immediate postoperative period among patients undergoing laparoscopic surgery- A Randomized Controlled Pilot Trial. International Journal of Biomedical and Advance Research 4(2): 118-122.

Kulkarni S, Fletcher E, McConnell A, Poskitt K, Whyman M (2010) Pre-operative inspiratory muscle training preserves postoperative inspiratory muscle strength following major abdominal surgery–a randomised pilot study. Annals of the Royal College of Surgeons of England 92(8): 700-705. doi:10.1308/003588410X12771863936648.

Kuo LJ, Hung CS, Wang W, Tam KW, Lee HC, Liang HH, Chang YJ, Huang MT, Wei PL (2013) Intersphincteric resection for very low rectal cancer: clinical outcomes of open versus laparoscopic approach and multidimensional analysis of the learning curve for laparoscopic surgery. Journal of Surgical Research 183(2): 524-530. doi:http://dx.doi.org/10.1016/j.jss.2013.01.049.

Lång M, Niskanen M, Miettinen P, Alhava E, Takala J (2001) Outcome and resource utilization in gastroenterological surgery. British Journal of Surgery 88(7): 1006-1014. doi:10.1046/j.0007-1323.2001.01812.x.

Larson C, Ratzer E, Davis-Merritt D, Clark J (2009) The effect of abdominal binders on postoperative pulmonary function. The American Surgeon 75(2): 169-171.

Lawrence VA, Cornell JE, Smetana GW (2006) Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians. Annals of Internal Medicine 144(8): 596-608.

Lawrence VA, Hazuda HP, Cornell JE, Pedersen T, Bradshaw P, Mulrow CD, Page CP (2004) Functional independence after major abdominal surgery in the elderly. Journal of the American College of Surgeons 199(5): 762-772.

Lemanu D, Singh P, MacCormick A, Arroll B, Hill A (2013) Effect of Preoperative Exercise on Cardiorespiratory Function and Recovery After Surgery: a Systematic Review. World Journal Of Surgery 37711-720. doi:10.1007/s00268-012-1886-4.

Li C, Ferri LE, Mulder DS, Ncuti A, Neville A, Lee L, Kaneva P, Watson D, Vassiliou M, Carli F, Feldman LS (2012) An enhanced recovery pathway decreases duration of stay after esophagectomy. Surgery 152(4): 606-616. doi:10.1016/j.surg.2012.07.021.

Li S, Liu Y, Peng Q, Xie L, Wang J, Qin X (2013) Chewing gum reduces postoperative ileus following abdominal surgery: A meta□analysis of 17 randomized controlled trials. Journal of Gastroenterology and Hepatology 28(7): 1122-1132. doi:10.1111/jgh.12206.

Lin D-X, Li X, Ye Q-W, Lin F, Li L-L, Zhang Q-Y (2011) Implementation of a Fast-Track Clinical Pathway Decreases Postoperative Length of Stay and Hospital Charges for Liver Resection. Cell Biochemistry and Biophysics 61(2): 413-419. doi:10.1007/s12013-011-9203-7.

Lunardi A, Paisani D, da Silva CM, Cano D, Carvalho C (2013) Effect of lung expansion techniques in the incidence of pulmonary complications after upper abdominal surgery. European Respiratory Journal 42(Suppl 57): P5076.

Lunardi AC, Cecconello I, Carvalho CRF (2011) Postoperative chest physical therapy prevents respiratory complications in patients undergoing esophagectomy. Brazilian Journal of Physical Therapy / Revista Brasileira de Fisioterapia 15(2): 160-165.

Lunardi AC, Paisani DM, da Silva CCM, Cano DP, Tanaka C, Carvalho CR (2015) Comparison of lung expansion techniques on thoracoabdominal mechanics and incidence of pulmonary complications after upper abdominal surgery: a randomized and controlled trial. CHEST Journal. doi:10.1378/chest.14-2696.

Lunardi AC, Resende JM, Cerri OM, Carvalho CRFd (2008) Effect of sustained respiratory care until hospital discharge on the incidence of pulmonary complications following esophagectomy for cancer. Fisioterapia e Pesquisa 15(1): 72-77.

Mackay MR, Ellis E, Johnston C (2005) Randomised clinical trial of physiotherapy after open abdominal surgery in high risk patients. Australian Journal of Physiotherapy 51(3): 151-159.

Makhabah DN, Martino F, Ambrosino N (2013) Peri-operative physiotherapy. Multidisciplinary Respiratory Medicine 8(1): 1-6. doi:10.1186/2049-6958-8-4.

Mans CM, Reeve JC, Elkins MR (2015) Postoperative outcomes following preoperative inspiratory muscle training in patients undergoing cardiothoracic or upper abdominal surgery: a systematic review and meta analysis. Clinical Rehabilitation 29(5): 426-438. doi:10.1177/0269215514545350.

Nakamura M, Iwahashi M, Nakamori M, Ishida K, Naka T, Iida T, Katsuda M, Tsuji T, Nakatani Y, Yamaue H (2008) An analysis of the factors contributing to a reduction in the incidence of pulmonary complications following an esophagectomy for esophageal cancer. Langenbeck's Archives of Surgery 393(2): 127-133.

National Institute for Health and Clinical Excellence (NICE) (2010) Venous thromboembolism in adults admitted to hospital: reducing the risk. NICE guidelines [CG92]. http://www.nice.org.uk/guidance/cg92 [Accessed 8/9/2015].

O'Donohue Jr W (1992) Postoperative pulmonary complications. When are preventive and therapeutic measures necessary? Postgraduate Medicine 91(3): 167-170.

Olsén MF, Anzén H (2012) Effects of training interventions prior to thoracic or abdominal surgery: a systematic review. Physical Therapy Reviews 17(2): 124-131. doi:10.1179/1743288x11y.0000000054.

Orman J, Westerdahl E (2010) Chest physiotherapy with positive expiratory pressure breathing after abdominal and thoracic surgery: a systematic review. Acta Anaesthesiology Scandinavia 54(3): 261-267. doi:10.1111/j.1399-6576.2009.02143.x.

Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C (2001) The Effect of Incentive Spirometry on Postoperative Pulmonary Complications. CHEST Journal 120(3): 971.

Owen RM, Perez SD, Lytle N, Patel A, Davis S, Lin E, Sweeney JF (2013) Impact of operative duration on postoperative pulmonary complications in laparoscopic versus open colectomy. Surgical Endoscopy 27(10): 3555-3563. doi:10.1007/s00464-013-2949-9.

Paisani DM, Fiore Jr JF, Lunardi AC, Colluci DBB, Santoro IL, Carvalho CRF, Chiavegato LD, Faresin SM (2012) Preoperative 6-min walking distance does not predict pulmonary complications in upper abdominal surgery. Respirology 17(6): 1013-1017. doi:10.1111/j.1440-1843.2012.02202.x.

Park NY, Chong GO, Hong DG, Cho YL, Park IS, Lee YS (2011) Oncologic results and surgical morbidity of laparoscopic nerve-sparing radical hysterectomy in the treatment of FIGO stage IB cervical cancer: long-term follow-up. International Journal of Gynecological Cancer 21(2): 355-362. doi:10.1097/IGC.0b013e31820731bb.

Parry S, Denehy L, Berney S, Browning L (2014) Clinical application of the Melbourne risk prediction tool in a high-risk upper abdominal surgical population: an observational cohort study. Physiotherapy 100(1): 47-53. doi:10.1016/j.physio.2013.05.002.

Pasquina P, Tramèr MR, Granier J-M, Walder B (2006) Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: A systematic review. CHEST Journal 130(6): 1887-1899.

Pasquina P, Walder B (2003) Prophylactic respiratory physiotherapy after cardiac surgery: systematic review. British Medical Journal 327(7428): 1-6.

Pavy-Le Traon A, Heer M, Narici MV, Rittweger J, Vernikos J (2007) From space to Earth: advances in human physiology from 20 years of bed rest studies (1986–2006). European Journal of Applied Physiology 101(2): 143-194.

Pouwels S, Stokmans RA, Willigendael EM, Nienhuijs SW, Rosman C, van Ramshorst B, Teijink JA (2014) Preoperative exercise therapy for elective major abdominal surgery: A systematic review. International Journal of Surgery 12(2): 134-140. doi:10.1016/j.ijsu.2013.11.018.

Pouwels S, Willigendael E, van Sambeek M, Nienhuijs S, Cuypers P, Teijink J (2015) Beneficial Effects of pre-operative exercise therapy in patients with an abdominal aortic aneurysm: a systematic review. European Journal of Vascular and Endovascular Surgery 49(1): 66-76.

PROVHILO group (2014) High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. The Lancet 384(9942): 495-503. doi:http://dx.doi.org/10.1016/S0140-6736(14)60416-5.

Reeve JC, Nicol K, Stiller K, McPherson KM, Birch P, Gordon IR, Denehy L (2010) Does physiotherapy reduce the incidence of postoperative pulmonary complications following pulmonary resection via open thoracotomy? A preliminary randomised single-blind clinical trial. European Journal of Cardio-Thoracic Surgery 37(5): 1158-1166. doi:10.1016/j.ejcts.2009.12.011.

Rothman JP, Gunnarsson U, Bisgaard T (2014) Abdominal binders may reduce pain and improve physical function after major abdominal surgery - a systematic review. Danish Medical Journal 61(11): A4941.

Rotta BP, da Silva JM, Padovani C, da Silveira LTY, Mafra JM, Fu C, Tanaka C (2013) Postoperative pulmonary complications are associated to higher ICU cost. European Respiratory Journal 42(Suppl 57): P287.

Said E (2008) PACES resources, MRCP (UK) Practical Assessment of Clinical Examination Skills. http://mrcppreview.blogspot.co.nz/2008/06/scaragain.html [Accessed 15th March, 2016].

Samnani SS, Umer MF, Mehdi SH, Farid FN (2014) Impact of preoperative counselling on early postoperative mobilization and its role in smooth recovery. International Scholarly Research Notices 1-4.

Santa Mina D, Matthew AG, Hilton WJ, Au D, Awasthi R, Alibhai SM, Clarke H, Ritvo P, Trachtenberg J, Fleshner NE (2014) Prehabilitation for men undergoing radical prostatectomy: a multi-centre, pilot randomized controlled trial. BMC Surgery 14(1): 89. doi:10.1186/1471-2482-14-89.

Scholes R, Denehy L, Sztendur E, Browning L (2006) A survey of Australian physiotherapy management of patients having abdominal surgery. Australian Journal of Physiotherapy S26 (abstract).

Scholes RL, Browning L, Sztendur EM, Denehy L (2009) Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. Australian Journal of Physiotherapy 55(3): 191-198.

Serejo LGG, da Silva-Júnior FP, Bastos JPC, de Bruin GS, Mota RMS, de Bruin PFC (2007) Risk factors for pulmonary complications after emergency abdominal surgery. Respiratory Medicine 101(4): 808-813. doi:10.1016/j.rmed.2006.07.015.

Silva Y, Li S, Rickard M (2013) Does the addition of deep breathing exercises to physiotherapy-directed early mobilisation alter patient outcomes following high-risk open upper abdominal surgery? Physiotherapy 99(3): 187-193. doi:10.1016/j.physio.2012.09.006.

Singh F, Newton RU, Galvão DA, Spry N, Baker MK (2013) A systematic review of pre-surgical exercise intervention studies with cancer patients. Surgical Oncology 22(2): 92-104. doi:10.1016/j.suronc.2013.01.004.

Smith M, Ellis E (2000) Is retained mucus a risk factor for the development of postoperative atelectasis and pneumonia? Implications for the physiotherapist. Physiotherapy Theory and Practice 1669-80.

Smith PR, Baig MA, Brito V, Bader F, Bergman MI, Alfonso A (2009a) Postoperative pulmonary complications after laparotomy. Respiration 80(4): 269-274. doi:10.1159/000253881.

Smith T, Stonell C, Purkayastha S, Paraskevas P (2009b) Cardiopulmonary exercise testing as a risk assessment method in non cardio-pulmonary surgery: a systematic review. Anaesthesia 64(8): 883-893. doi:10.1111/j.1365-2044.2009.05983.x.

Spanjersberg W, van Sambeeck J, Bremers A, Rosman C, van Laarhoven C (2015) Systematic review and meta-analysis for laparoscopic versus open colon surgery with or without an ERAS programme. Surgical Endoscopy 1-11. doi:10.1007/s00464-015-4148-3.

Stock M, Downs J, Gauer P, Alster J, Imrey P (1985) Prevention of postoperative pulmonary complications with CPAP, incentive spirometry, and conservative therapy. CHEST Journal 87(2): 151-157.

Story SK, Chamberlain RS (2009) A comprehensive review of evidence-based strategies to prevent and treat postoperative ileus. Digestive Surgery 26(4): 265-275. doi:10.1159/000227765.

Thompson DA, Makary MA, Dorman T, Pronovost PJ (2006) Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. Annals of Surgery 243(4): 547-552.

Tusman G, Böhm SH, Warner DO, Sprung J (2012) Atelectasis and perioperative pulmonary complications in high-risk patients. Current Opinion in Anesthesiology 25(1): 1-10. doi:10.1097/ACO.0b013e32834dd1eb.

Valkenet K, van de Port IGL, Dronkers JJ, de Vries WR, Lindeman E, Backx FJG (2011) The effects of preoperative exercise therapy on postoperative outcome: a systematic review. Clinical Rehabilitation 25(2): 99-111. doi:10.1177/0269215510380830.

Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN (2010) The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. Clinical Nutrition 29(4): 434-440. doi:10.1016/j.clnu.2010.01.004.

Vather R, Trivedi S, Bissett I (2013) Defining postoperative ileus: results of a systematic review and global survey. Journal of Gastrointestinal Surgery 17(5): 962-972. doi:10.1007/s11605-013-2148-y.

Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, Gawande AA (2008) An estimation of the global volume of surgery: a modelling strategy based on available data. The Lancet 372(9633): 139-144. doi:10.1016/S0140-6736(08)60878-8.

Westwood K, Griffin M, Roberts K, Williams M, Yoong K, Digger T (2007) Incentive spirometry decreases respiratory complications following major abdominal surgery. The Surgeon 5(6): 339-342.

Wijk L, Franzen K, Ljungqvist O, Nilsson K (2014) Implementing a structured Enhanced Recovery After Surgery (ERAS) protocol reduces length of stay after abdominal hysterectomy. Acta Obstetricia et Gynecologica Scandinavica. doi:10.1111/aogs.12423.

Wynne R (2004) Variable definition: Implications for the prediction of pulmonary complications after adult cardiac surgery. European Journal of Cardiovascular nursing 3(1): 43-52.

Zhang X-y, Wang Q, Zhang S, Tan W, Wang Z, Li J (2015) The use of a modified, oscillating positive expiratory pressure device reduced fever and length of hospital stay in patients after thoracic and upper abdominal surgery: a random *Journal of Physiotherapy* 61(1): 16-20. doi:10.1016/j.jphys.2014.11.013.

.

# Chapter 3

## Preoperative physiotherapy to prevent postoperative pulmonary complications

> "Since vital capacity is lowered, the first principle of treatment is to train the patient to use the lungs, especially the lower areas, fully. This is not easy if the patient is still hazy from the anaesthetic and in some discomfort. It is important therefore to train good breathing before the operation. Particular stress is laid on gaining good expiration and, on the ability, to perform diaphragmatic and lower lateral costal breathing at will. An understanding of the value of the correct breathing is essential, so that the patient will be co-operative as soon as he recovers from the anaesthetic."
> (p.61. Cash JE, *Physiotherapy in some Surgical Conditions*. 1955)

> "The patient should also realise the importance of starting his exercises as soon as he recovers consciousness after surgery, and that physiotherapy is of the greatest importance during the first few postoperative days."
> (p.40. Gaskell & Webber, *The Brompton Hospital Guide to Chest Physiotherapy*. 1960)

> "The necessity for frequent and regular practice must be emphasised to all patients being taught breathing exercises. Efficient progress will not be made if the patient only does his exercises when the physiotherapist is present."
> (p.5. Gaskell & Webber. *The Brompton Hospital Guide to Chest Physiotherapy* 1960)

### 3.1 Introduction

These quotes from mid-20th century textbooks written by respected cardiorespiratory physiotherapists outline the belief of this time that initiating breathing exercises as soon as possible after surgery is important and that the best time to enable a patient to be able to do this is before surgery, not afterwards, when a patient's performance may be impacted by anaesthesia, pain, drowsiness, nausea, or anxiety (Cupples 1991). Clinical trials reviewed in Chapter 1 and 2 suggest that a perioperative physiotherapy regime that includes a single preoperative preparation session where patients are educated about their risk of PPC and taught DB&C exercises to do after surgery is an effective method to reduce PPC. However, it also appears that DB&C exercises

coached by a physiotherapist after surgery appears to be no more effective than an early ambulation program alone to prevent PPC. At first glance these summaries appear to be conflicting. How can multiple sessions of coached DB&C sessions after surgery be less effective than preoperative education and training?

This chapter presents a hypothetical framework to explain the possible effectiveness of preoperative physiotherapy to prevent PPC after abdominal surgery and why the application of coached DB&C exercises in the postoperative phase may be at a disadvantage. Firstly, the pathophysiological effects to the lungs specifically induced by abdominal surgery is outlined. This is followed by a discussion regarding the function of time in relation to interventions to prevent PPC and the possibility that for DB&C exercises to be effective they need to be started as soon as possible after surgery. The literature assessing the effectiveness of breathing exercises and preoperative physiotherapy to prevent PPC is considered within the context of the hypothesis that the timing of breathing exercises could be a factor influencing the outcome.

## 3.2 Pathophysiological effects of abdominal surgery to the lungs

The profound detrimental effects of abdominal surgery to the respiratory system have been extensively reviewed in previous publications (Miskovic & Lumb 2017, Ball, Battaglini & Pelosi 2016, Marseu & Slinger 2016, Canet & Gallart 2014, Duggan & Kavanagh 2007, Tusman et al 2012, Magnusson & Spahn 2003) and in theses (Browning 2007a, Scholes 2005, Mackay 2003, Denehy 2001a, Nteumonopolous 1994) and for this thesis, are briefly outlined below.

### 3.2.1 Reduction in lung volumes

General anaesthesia and supine positioning during major surgery reduce the lung's functional residual capacity (FRC) (Nunn 1997, Wahba 1991). FRC is the volume of air remaining in the lung at the end of a normal tidal breath and is dependent on a complex dynamic relationship between resting respiratory muscle tone, chest wall compliance, lung compliance, gravity, and the pressure balance between the abdominal and thoracic cavities. The patency of alveoli and small airways during normal tidal breathing are largely dependent on FRC. The lower the FRC, the greater the possibility of atelectasis and small airway closure in the dependent regions of the lung during normal tidal breathing. Compared to other surgery types, FRC reduction is greatest during upper abdominal surgery (Alexander et al 1973) with lung volumes remaining well below preoperative levels for up to ten days after surgery (Denehy et al 2001b, Wahba 1991, Craig 1981, Alexander et al 1973). Recent preliminary electrical impedance tomography trials have repeated findings of significant negative effects to ventilation during upper abdominal surgery (Schaefer et al 2014). This technology has also confirmed the divergent effects to postoperative respiratory

ventilation between abdominal surgery compared to peripheral surgery, with impaired dorsal ventilation and reduced forced and resting lung volumes persistent up to the third postoperative day following abdominal surgery, but not after peripheral surgery (Bauer et al 2019).

The heightened FRC reduction with upper abdominal surgery is attributed to the specific influence of a supraumbilical incision on respiratory mechanics, diaphragm dysfunction, and intraabdominal pressure (Hedenstierna & Edmark 2005, Sasaki, Meyer & Eikermann 2013, Dureuil, Cantineau & Desmonts 1987). A higher, longer, and more midline incision, such as that used for upper abdominal surgery, has greater detrimental effects to respiratory mechanics (Elman et al 1981, Lindell & Hedenstierna 1976) and is associated with postoperative hypoxemia (Xue et al 1999). Although other factors, such as impairment to surfactant production, are associated with the development of atelectasis during surgery (Duggan & Kavanagh 2007), FRC reduction is considered the most important factor for atelectasis genesis (Canet & Gallart 2014, Tusman et al 2012, Duggan & Kavanagh 2007).

### 3.2.2 Atelectasis

Atelectasis is collapsed alveoli and small airways. Atelectasis occurs immediately on induction of anaesthesia with 90% of upper abdominal surgery patients having computerised tomography (CT) diagnosed atelectasis (Lundquist et al 1995, Strandberg et al 1986). Recent studies in patients undergoing upper abdominal surgery in a modern perioperative environment show similar degrees of postoperative atelectasis, with half of all patients continuing to exhibit atelectasis 24hrs after abdominal surgery (Touw et al 2019, Pereira et al 2018) and up to 40% of patients having atelectasis by the fifth postoperative day (Ireland et al 2014). The direct consequence of significant atelectasis is rapid pulmonary shunt and impaired gas exchange with hypoxemia occurring immediately on extubation and worsening in the first 24 hours following surgery (Di Marco et al 2015, Rothen et al 1998, Lindberg et al 1992, Gunnarsson et al 1991). Clinically significant hypoxemia occurs in 20% of upper abdominal surgery patients within one hour of surgery, worsening to 30% of patients the morning of the first postoperative day (Futier et al 2016).

Supplemental oxygenation to manage hypoxemia in the perioperative period can contribute to further atelectasis formation (O'Brien 2013). Increasing the fraction of inspired oxygen ($FiO_2$) leads to a proportional reduction in the concentration of inspired nitrogen within the inhaled gas. Oxygen is rapidly absorbed along a concentration gradient at the alveolar-capillary interface. Nitrogen usually comprises 78% of inspired room air and cannot diffuse across the alveolar-capillary interface due to its molecular size. This unabsorbed nitrogen provides gas pressure within the alveoli which aids in maintaining full inflation. However, with an increase in $FiO_2$

there is a proportional decrease in the amount of nitrogen within the alveoli. Once the proportion of oxygen is elevated above 40% it is hypothesised that there is not enough nitrogen gas pressure to keep alveoli open as oxygen rapidly diffuses out of alveoli, causing alveoli to collapse (Edmark et al 2003, Rothen et al 1995).

Atelectasis is a precursor to acute lung injury and/or pneumonia, systemic inflammatory response syndrome, acute respiratory failure, acute respiratory distress syndrome (Duggan & Kavanagh 2007), with these conditions increasing the likelihood of septic shock and possible death (Jaber et al 2016, Canet & Gallart 2014). Between 10-20% of patients with severe postoperative hypoxemia develop respiratory failure requiring reintubation and mechanical ventilation within the week following abdominal surgery (Futier et al 2016, Squadrone et al 2005) with a seven-day mortality rate of 14% (Fernandez-Bustamente et al 2017).

### 3.2.3 Mucociliary clearance

Mucociliary clearance is significantly slowed after abdominal surgery, yet not after orthopaedic surgery, with airway clearance slowest in areas of atelectasis (Gamsu et al 1976). Mucociliary clearance returns to normal once atelectasis is rectified (van Kaam et al 2004, Gamsu et al 1976). This evidence suggests that atelectasis alone can be responsible for bacterial stagnation increasing the risk of pneumonia and bacteraemia (van Kaam et al 2004). Adding to the slower removal of mucous and microbes out of the lung, some anaesthetic agents cause cilial hypokinesia and dyskinesia (Bilgi et al 2011, Raphael & Butt 1997, Forbes & Gamsu 1979). Both anaesthetics and atelectasis also impair alveolar macrophage activity, limiting the immune response to microbial habitation (Kotani et al 1998, Shennib, Mulder & Chiu 1984). A combination of these factors can lead to an opportune environment for microbial infection of the airways.

### 3.2.4 Respiratory muscle dysfunction

Respiratory muscles, both inspiratory and expiratory, are compromised following upper abdominal surgery (Sasaki, Meyer & Eikermann 2013, Bellinetti & Thomson 2006). Respiratory muscle weakness is evident with a restrictive breathing pattern occurring immediately after surgery with dynamic lung volumes remaining at 50% of preoperative levels at least until the fifth postoperative day (Treschan et al 2012, Denehy et al 2001b), reducing inspiratory lung volumes and peak cough flows (Colucci et al 2015).

### 3.2.5 Anaesthesiology

Other factors associated with respiratory pathophysiology after abdominal surgery are intraoperative mechanical ventilation parameters (Neto et al 2016, Neto, Schultz & Gama de

Abreu 2015), the use of intraoperative neuromuscular blockade which can continue to inhibit respiratory muscle activation postoperatively without the use of an appropriate reversal agents (Ball et al 2019, Schepens et al 2019, McLean et al 2015), and reduced central drive to breathe from the residual effects of intraoperative anaesthetics and postoperative opioid analgesia (Marseu & Slinger 2016, Sasaki, Meyer & Eikermann 2013, Rigg et al 2002). Of these factors, two in particular (intraoperative mechanical ventilation and neuromuscular blockade) have been keenly investigated and debated over the past 10 years and are covered in more detail, as follows:

#### 3.2.5.1 Intraoperative mechanical ventilation

A logical concept to prevent PPC is to prevent the development of atelectasis at the source. Using positive end expiratory pressure (PEEP) during ventilation increases intrathoracic pressure and increases FRC. A moderate PEEP level (7-9 cm $H_2O$) has been demonstrated to prevent atelectasis during surgery compared to no PEEP (Östberg et al 2018). However, mechanical ventilation can also induce lung injury. Large swinging changes (tidal volumes) in positive pressure generated lung volume can cause lung parenchymal damage and cytokine release compared to low tidal volume ventilation (Güldner et al 2015). Even short periods (6 hrs) of ventilation with high tidal volumes are related to increased risk of acute respiratory distress syndrome, pulmonary infection, and atelectasis in both surgical and critical care patients (Serpa Neto et al 2012). Whilst the use of use of low tidal volume ventilation is now accepted (Young et al 2019), the additional use of high PEEP 'open lung' ventilation and recruitment manoeuvres to overcome atelectasis and improve postoperative outcomes, without causing over-distension and possible barotrauma, is less certain (O'Gara & Talmor 2018).

Lung parenchymal damage has also been reported to occur with static over-distension/stretch of alveoli through the use of a high PEEP (Wrigge et al 2004). Although this theory has been questioned with high PEEP (12cm$H_20$) not appearing to result in over distension (D'Antini et al 2018). It is possible that previous investigations into inflammatory damage caused by high PEEP were confounded by the variations in tidal volume and driving pressures (Wiengarten et al 2010, Wolthuis et al 2008, Wrigge et al 2004). High PEEP and recruitment manoeuvres in addition to low tidal volume delivery was associated with an increase in one of seven inflammatory biomarkers only, although this biomarker, CC-16, is a specific marker of epithelial lung injury (Serpa Neto et al 2017). The influence of high PEEP and recruitment manoeuvres during abdominal surgery to independently cause the precursor factors for ventilator induced lung injury remains unclear.

The clinical benefits of 'open lung' ventilation and recruitment manoeuvres during abdominal surgery to prevent PPC is conflicting (Yang et al 2016, Güldner et al 2015). Findings are limited

by the confounding influence of different tidal volume protocols between groups which independently influences PPC risk. Two trials (Hemmes et al 2014, Ferrando et al 2018) in abdominal surgery have standardised tidal volumes to 8ml/kg/min in patients at moderate to high risk of PPC and compared high PEEP (10-12cm $H_2O$) with recruitment manoeuvres to those ventilated with low PEEP (2-5cm $H_2O$). No difference in PPCs was found in either trial, yet more patients in the high PEEP group had hypotension and required vasoactive drugs (Hemmes et al 2014). It cannot be determined if this harmful result was due to the recruitment manoeuvres or the high PEEP, or indeed, the combination of both. Regardless, despite higher PEEP improving lung compliance and gas exchange (Hartland, Newell & Damico 2015), these changes appear not to carry over to reduce PPC following surgery.

Meta-analysis of data from all types of surgery finds an association with reduced PPC risk in patients ventilated with lower tidal volume (6-8ml/kg/min) (Yang et al 2016, Neto, Schultz & Gama de Abreu 2015) and lower driving pressure, but not with high PEEP (Neto et al 2016). Research into the influence of recruitment manoeuvres alone to prevent PPC is nascent.

Further higher quality research into the benefits of high PEEP ventilation and/or recruitment manoeuvrers during surgery may no longer be even appropriate. Unexpected, yet conclusive, evidence of increased mortality (despite improvements in lung physiology) with high PEEP ventilation and recruitment manoeuvres in addition to protective low tidal volume ventilation in mechanically ventilated patients with severe acute respiratory distress syndrome; the Alveolar Recruitment for Acute Respiratory Distress Syndrome Trial (ART) (Cavalcanti et al 2017), has anaesthetists questioning the use of high PEEP and recruitment maneuverers during surgery (Bluth et al 2019, Hemmes et al 2016). Although the mortality effect in the ART trial may not be applicable to surgical patients with healthy lungs, even the slightest possibility of increased mortality could outweigh the negligible benefit of reduced PPC. Currently the gains of increased FRC and reduced atelectasis during surgery with high PEEP and recruitment manoeuvres are not guaranteed to translate to improved postoperative clinical outcomes such as reduced PPC (Hemmes et al 2016). At best, high intraoperative PEEP and recruitment manoeuvres are ineffective in a majority of patients, at worst, they could possibly be harmful.

Although counterintuitive, prevention of atelectasis with low tidal volume ventilation appears more effective than a high PEEP. The prevention of alveolar strain and the ensuing alveolar inflammatory cytokine cascade and systemic inflammatory response may be more important to preventing PPC than preventing atelectasis through large volume changes and/or high PEEP. Another explanation for the failure of intraoperative ‘open lung’ ventilation to reduce PPC is that FRC reverts to low levels immediately following extubation, providing only a temporary method of atelectasis prevention (Weingarten et al 2010, Hedenstierna, Edmark & Perchiazzi 2015). It

may be more suitable to consider ventilation strategies to prevent PPC in the early postoperative period instead.

#### 3.2.5.2 Neuromuscular blockade

The relationship between intraoperative neuromuscular blockade, appropriate reversal, and PPCs has been extensively debated for at least 20 years (Cammu 2020, Ball et al 2019). Intraoperative neuromuscular blockade with agents, such as rocuronium, are used to limit patient dyssynchrony with mechanical ventilation during surgery. However, residual effects of these pharmacological agents can cause ongoing muscular weakness postoperatively. Weakened respiratory muscles have reduced ability to generate large dynamic lung volumes leading to atelectasis and increased risk of a PPC. The use of a reversal agent, such as neostigmine, at the end of surgery can rapidly counteract the effects of the initial neuromuscular blockade agent.

The ‘status-quo’ understanding that the risk of a PPCs is significantly increased in patients who do not receive a neuromuscular blockade reversal agent (Bronsert et al 2017, Bulka et al 2016) conflicts with findings that appear to suggest that neuromuscular blockade reversal agent use, in particular neostigmine, after surgery is ineffective (Kirmeier et al 2019) or, worse, increases the risk of hypoxemia (Grosse-Sundrup et al 2012). These conflicting results are opined as being due to clinician error in inappropriate monitoring, incorrect dosage (McLean et al 2015), and understanding of neuromuscular pharmacology, rather than a failure of the neuromuscular blockade reversing agent itself (Prielipp et al 2010).

Recent studies have moved to determine that the fault was not the clinician but the reversing agent, neostigmine. Neostigmine has been compared directly against an alternative neuromuscular blockade reversing agent, sugammadex (Togioka et al 2020, Kheterpal et al 2020, Schepens et al 2019, Martinez-Ubieto et al 2016). The consistent finding from these studies is that the use of sugammadex effectively reduced the risk of PPC are surgery and should be considered for implementation as standard care to reverse neuromuscular blockade after surgery (Leslie 2020).

### 3.2.6 Relationship between respiratory pathophysiology and onset of PPC

The combination of the factors described above; low FRC, slowed mucociliary clearance, weak respiratory muscles, poor cough, and reduced central drive to breathe in the immediate period following upper abdominal surgery produce an environment conducive to impaired gas exchange and microbial infection. It is hypothesised that if these factors are not reversed in the early

postoperative period that a PPC can occur (Ball, Battaglini & Pelosi 2016, Tusman et al 2012, Duggan & Kavanagh 2005, Smith & Ellis 2000). See Figure 3.1 outlining a proposed timeline and pathophysiological factors postulated to be related to the onset, signs, and symptoms of a PPC.

## 3.3 Timing of PPC

The timing of interventions to prevent PPC may be crucial (Ball, Bos & Pelosi 2017, Ball, Battaglini & Pelosi 2016). A majority of patients (up to 90%) have mild atelectasis in the immediate 24 hours after major abdominal surgery (Touw et al 2019, Lundquist et al 1995) with FRC becoming lowest (Denehy et al 2001b) with atelectasis becoming more extensive from the second to the third day after surgery (Lindberg et al 1992).

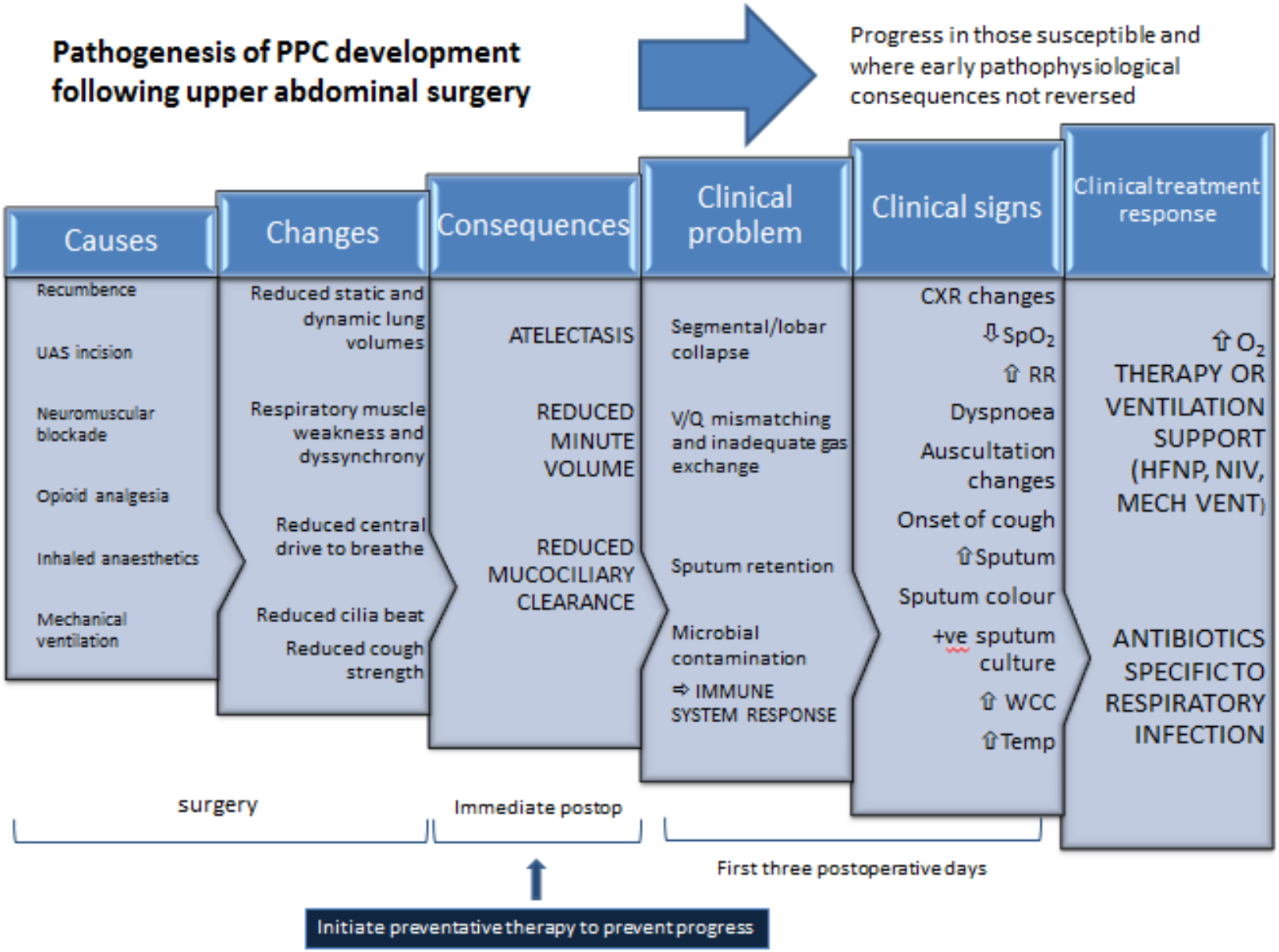
If atelectasis could be reversed within the first 24 hours after surgery, this may prevent the development of an eventual clinically important PPC. Atelectasis reduces lung compliance and increases airway resistance (Nunn 1997). As atelectasis worsens in the 24 hours after surgery, lung compliance will also become worse and greater physical work is required by respiratory muscles to generate the pleural pressures needed to reverse moderate to severe atelectasis. The immediate postoperative period when lung compliance is minimally affected may provide a narrow window of opportunity to implement prophylactic lung expansion interventions. Delaying lung expansion therapies to the first or second postoperative day when the lungs are stiffer and less compliant may reduce their effectiveness (Ball, Bos & Pelosi 2017).

Fourteen percent (14%) of diagnosed PPCs, acute lung injury or acute respiratory distress syndrome occur on the first postoperative day, increasing to 40% of diagnoses on the second day. Overall, 80-85% of all PPCs occur within the first three postoperative days (Neto et al 2014, Haines et al 2013).

It is feasible that if mild atelectasis is reversed in the very early postoperative period, this may avert the progression of atelectasis to lobar collapse and eventually a clinically significant PPC. Timing of intervention may be critical.

The next section will consider the evidence for breathing exercises to reverse respiratory pathology after abdominal surgery and whether the timing of when these breathing exercises are initiated could impact the outcome.

**Figure 3.1** Pathogenesis of PPC development after upper abdominal surgery



## 3.4 Breathing exercises to prevent PPCs after abdominal surgery

Coaching patients to perform postoperative DB&C exercises has been the foundational technique to re-expand lung tissue, improve ventilation, and aid in secretion removal after surgery since the early 1900's (MacMahon 1915). The terminology describing DB&C exercises varies including terms such as thoracic expansion techniques, bilateral basal expansion, sustained maximal inspiration, or diaphragmatic breathing, and directed coughing, forced expiratory techniques, or huffing (Pryor & Prasad 2001). Regardless of terminology, the intended endpoint is the same; to voluntarily increase inspiratory dynamic lung volumes and clear airway secretions with an aim to reverse or prevent atelectasis and prevent bacterial stagnation in the airways after surgery. These exercises were initially delivered by nurses and doctors until the mid-century when physiotherapists started assuming this as one of their primary roles within hospitals (Cash 1955).

In modern times, physiotherapy is routinely provided across hospitals following surgery to patients having upper abdominal surgery in Australia (Patman et al 2017), New Zealand (Reeve et al 2019), and the Netherlands (van Beijsterveld et al 2019) with primary aims to prevent PPC and improve physical recovery after surgery (Reeve et al 2019, Patman et al 2017, Browning 2007a). Although there is an absence of published surveys of practice from other countries the author is aware anecdotally that the Australian, New Zealand, and Dutch surveys are closely representative of the ubiquitous involvement of physiotherapists in the perioperative management of patients undergoing major abdominal surgery in hospitals across most, if not all, developed countries. Unfortunately, there is a paucity of data on the physiotherapy clinical practice for this population in developing countries.

## 3.5 Effectiveness of breathing exercises

Assumptions from the beginning of the 20th century that DB&C improves respiratory outcomes after surgery were eventually supported by physiological evidence. Deep breathing exercises are associated with improvements in peripheral oxyhaemoglobin saturations ($SpO_2$), dynamic lung function volumes, diaphragmatic excursion, respiratory muscle strength, cough strength, pulmonary shunt, and chest X-ray (CXR) signs (Grams et al 2012, Fiore et al 2008, Blaney & Sawyer 1997, Ntoumenopoulos & Greenwood 1996). Breathing exercises have also been reported to benefit longer term clinically relevant endpoints, such as atelectasis, pneumonia, and PPCs in randomised trials from the 1980's to the late 1990's (Chumillas et al 1998, Fagevik-Olsén et al 1997, Roukema, Carol & Prins 1988, Celli, Rodriguez & Snider 1984, Morran et al 1983).

The combination of physiological and clinical evidence supporting DB&C exercises to prevent PPCs following open abdominal surgery ensured that these exercises were routinely

recommended in textbooks, guidelines, and reviews (Qaseem et al 2006, Lawrence, Cornell & Smetana 2006, Pryor & Prasad 2001) and postoperative coached DB&C exercises have been implemented as common practice (Reeve et al 2019, van Beijsterveld et al 2019, Patman et al 2017). However, following some negative randomised controlled clinical trials in cardiothoracic surgery (Reeve et al 2010, Brasher et al 2003, Jenkins et al 1990, Jenkins et al 1989) and abdominal surgery (Silva, Li & Rickard 2013, Mackay, Ellis & Johnston 2005), and persuasive opinion papers by respected cardiorespiratory physiotherapists (Stiller & Munday 1992, Dean & Ross 1992, Wallis & Prasad 1999), the foundational concept that DB&C exercises prevent PPC following major surgery was challenged. Declarations that DB&C exercises provided no additional benefit in reducing PPC over early ambulation alone were strongly made (Mackay, Ellis & Johnston 2005, Jenkins et al 1990).

Systematic reviews that have evaluated the evidence for lung expansion techniques to prevent PPC after open abdominal surgery have conflicting conclusions (Pasquina et al 2006, Lawrence, Cornell & Smetana 2006, Overend et al 2001, Fagevik-Olsén 2000, Thomas & McIntosh 1994) providing little help in rationalising the conflict between negative clinical trials and positive physiological evidence and clinical trials conducted in the mid-to-late 20$^{th}$ century.

In the face of equivocal reviews and conflicting evidence, an international group of experts in the field of cardiorespiratory physiotherapy and abdominal surgery convened in 2011 to consider the available evidence and construct a consensus statement to guide clinical practice for physiotherapists working in this area (Hanekom et al 2012). These authors concluded that the evidence is difficult to interpret due to the poor methodological quality of trials, variety of interventions investigated, use of uncertain outcomes, and heterogeneity in populations. However, they were also careful to highlight that considering the uncertainty in the research, there is a risk of making a type II error: that the absence of strong evidence does not mean that DB&C exercises can be discarded. Although it cannot be concluded with confidence that DB&C exercises are effective, conversely, it cannot be concluded that DB&C are ineffective. Considering this, the authors recommend that on balance of risks versus benefit, coached DB&C exercises should be provided as routine care after major abdominal surgery until proven otherwise. This advice appears to be followed with current surveys of practice in Australia and New Zealand reporting 80% to 90% of physiotherapists provide some type of DB&C intervention in the postoperative period (Patman et al 2017, Reeve et al 2019). The rate is higher in the Netherlands where almost all (98%) physiotherapists provide coached DB&C exercises as part of postoperative care (van Beijsterveld et al 2019).

One factor that has not yet been considered in published clinical trials and reviews is whether the timing of when DB&C exercises are started could impact their effectiveness in preventing PPC. As discussed in section 3.3 above the pathophysiological effects of abdominal surgery are likely to be best reversed in the first 24 hours after surgery.

## 3.6 Breathing exercises in the immediate postoperative phase

Breathing exercises coached by physiotherapists in the immediate postoperative phase after major visceral surgery in the recovery unit or in the ICU have been shown to immediately improve atelectasis (Westerdahl et al 2005), pulmonary shunt (Ntoumenopoulos & Greenwood 1996), lung function (Zoremba et al 2009), and oxygenation (Manzano et al 2008). However, the effectiveness for breathing exercises performed in the early postoperative period to continue to be clinically effective in the following days after surgery remains to be tested and it is unknown if they would affect significant clinical endpoints such as pneumonia or other important types of PPCs.

The practical delivery of coached breathing exercises in the immediate postoperative period may also be a limitation of this therapy. In many countries, patients having elective abdominal surgery are rarely treated by physiotherapists in the recovery unit (Reeve et al 2019, van Beijstervel et al 2019, Patman et al 2017). Patient related factors, such as somnolence, pain, delirium, anxiety, nausea and vomiting experienced in the immediate postoperative period may also limit the ability of patients to remember to continue to perform the exercises as coached in the ongoing period after the physiotherapist has finished the initial coached session.

In the absence of a regularly staffed physiotherapy service to abdominal surgery patients immediately after the operation, a logical alternative would be to meet a patient prior to surgery and provide education and training on how to perform self-directed breathing exercises as soon as they wake from anaesthesia. This could enable and encourage a patient to perform efficacious breathing exercises in the first 24 hours when these exercises may be most effective in reversing atelectasis.

## 3.7 Preoperative physiotherapy

Prior to the early 2000's patients used to be routinely admitted to surgical wards the day *before* surgery (Cash 1955, Gaskell & Webber 1960, Mackay 2003). On this day, ward-based physiotherapists routinely met patients and educated them on the benefit of DB&C exercises to prevent pneumonia, taught them how to do the exercises, and instructed them to start these DB&C exercises on waking from surgery. The expectation was that patients would be performing self-directed DB&C exercises in the immediate postoperative period and patients would continue

these hourly until the follow-up physiotherapy session which would normally occur on the first postoperative day.

[See p.37 of Reeve & Boden 2016 in Chapter 2 of this thesis for a detailed summary of the evidence related to preoperative physiotherapy education and training.]

The balance of evidence appears to support the hypothesis that preoperative education is independently efficacious in reducing PPC incidence after major abdominal surgery compared to the delivery of coached DB&C exercises after surgery. It is reasonable to consider that this is because earlier initiation of breathing exercises immediately after surgery can reverse atelectasis and prevent bacterial stagnation. Delaying the first DB&C session to more than 24 hours after surgery may be too late, with 14% of patients already suffering from a clinically relevant PPC at this point (Neto et al 2014, Haines et al 2013).

However, the current clinical application of preoperative physiotherapy does not reflect the summary of the evidence. Less than 5% of patients in Australia and New Zealand are taught breathing exercises before surgery by a physiotherapist (Reeve et al 2019, Patman et al 2017). This is starkly different to practice in the Netherlands where 44% of hospitals surveyed had patients routinely seen by physiotherapists preoperatively. Regardless, if preoperative physiotherapy education is indeed an effective intervention to reduce PPC, this is still clearly inadequate, with less than half of patients receiving this therapy.

How did a clinical practice ubiquitous in the mid to late 20$^{th}$ century become so uncommon by 2015 onwards? The answer may in part be due to hospital administrative changes. In the past two decades hospital admission practices have changed significantly, with patients being admitted on the day of surgery rather than on the day prior. Preoperative assessment and preparatory information provided by health professionals, including anaesthetists, nurses, and surgeons, is now provided in outpatient preadmission clinics usually within six weeks of the surgery date. This logistical change in the timing and location of a patient's pre-surgical preparation may have proven difficult for ward-based physiotherapists to be able to service at the same time as managing a full caseload on a surgical ward. Preoperative physiotherapy services in Australia and New Zealand became uncommon, with physiotherapy now almost exclusively provided in the postoperative phase (Patman et al 2017, Reeve et al 2019).

Another factor adding to service disinvestment could have been the lack of conclusive evidence for the benefit of preoperative physiotherapy. Either physiotherapists have correctly interpreted the available evidence, ceasing an ineffective treatment and have redirected these resources more appropriately, or patients are missing out on a highly effective, low-risk, treatment that could

significantly reduce a serious postoperative complication. Another option is that the available evidence has not been analysed, interpreted, and reported in a way that specifically considers the effect of DB&C exercises to independently minimise the risk of PPC. Systematic review results are confounded by multimodal interventions and active therapy comparison groups, and do not consider the possibility of preoperative physiotherapy as a stand-alone intervention. This then may not be a failure of clinicians to evaluate the evidence as reported, but a failure of academics and researchers to interrogate and report the evidence appropriately, considering the possible confounding influences of preoperative physiotherapy and DB&C alone to minimise PPCs.

Almost all trials conducted prior to the mid 2000's included preoperative physiotherapy within the multimodal package of lung expansion techniques being tested. As such, it is not possible to separate the individual effectiveness of each component of the treatment package. For example, where the intervention was preoperative physiotherapy followed by a postoperative treatment protocol of coached DB&C exercises and then compared against a no physiotherapy treatment control, if a reduction in PPC is found, it is unknown if this was caused through the preoperative physiotherapy or the coached DB&C exercises or indeed the outcome is dependent on receiving the full combination of both.

The apparent lack of perspective in considering preoperative physiotherapy as a possible independent active intervention is highlighted by how five clinical trials have been interpreted. These trials tested the addition of postoperative chest physiotherapy to preoperative physiotherapy alone (Laszlo et al 1973, Hallböök et al 1984, Bourn, Conway & Holgate 1991, Condie, Hack & Ross 1993, Denehy 2001a). Some have interpreted the findings of these trials to mean that DB&C exercises are ineffective in reducing PPC (Pasquina et al 2006, Wallis & Prasad 1999). Considering that all patients in the control group received preoperative physiotherapy and were likely to be performing self-directed DB&C exercises as taught, a more correct interpretation should have been that the addition of postoperative coached DB&C exercises to preoperative physiotherapy may not be any more effective in reducing PPC than preoperative physiotherapy alone.

Previous studies and systematic reviews have generally not considered the possible influence of *when* DB&C exercises are started after surgery. With sound physiological benefits to respiratory mechanics and the possibility of increasing the dosage of therapy there is a reasonable hypothesis that preoperative physiotherapy directed education and training facilitates earlier performance of postoperative DB&C exercises and this could enhance their effectiveness in reducing PPCs. The literature needs to be systematically reviewed and synthesised to test this theory.

## 3.8 Summary

Deep breathing exercises are known to successfully reverse the pathophysiological respiratory effects of abdominal surgery. Initiation of these exercises immediately after surgery, rather than on the day after surgery, could increase the effectiveness of these simple exercises to prevent the onset of a serious PPC. Preoperative education and training by a physiotherapist on how to perform breathing exercises after surgery could enable a patient to start breathing exercises much sooner after surgery than if the first physiotherapy session occurs on the first day after surgery. The next chapter tests this theory by conducting a systematic review and meta-analysis of RCTs investigating DB&C exercises to prevent PPC after abdominal surgery. The evidence from these trials are synthesised through the perspective that preoperative chest physiotherapy could be an independent treatment strategy to reduce PPC.

# CHAPTER 4

# A systematic review and meta-analysis of chest physiotherapy to reduce PPC after abdominal surgery

## 4.1 Introduction

With approximately 175,000 operations annually, upper abdominal surgery is by far the most common major surgery type performed in Australia. Following upper abdominal surgery, significant deleterious pathophysiological effects to the respiratory system are evident and caused through the combined effects of anaesthesia, intraoperative mechanical ventilation, recumbent positioning, neuromuscular blockade, and abdominal incisions. Atelectasis occurs in most patients immediately following surgery and if unresolved is associated with hypoxemia, pulmonary shunt, and infection. Consequently, PPCs are unfortunately common in patients after major upper abdominal surgery. In attempts to reduce PPCs, physiotherapy interventions are ubiquitously provided to patients having abdominal surgery. These prophylactic interventions range from preoperative education and teaching of DB&C, IMT, and postoperative interventions such as early ambulation, coached DB&C, IS, PEP, and NIV.

Several systematic reviews of clinical trials investigating lung expansion techniques have been conducted. Three early reviews (Overend et al 2001, Fagevik-Olsén 2000, Thomas & McIntosh 1994) were flawed by narrow search strategies for trial selection and including multimodal interventions and heterogeneous patient populations. Two later systematic reviews attempted to overcome these identified flaws (Pasquina et al 2006, Lawrence, Cornell & Smetana 2006).

Pasquina and colleagues (2006) evaluated data from 35 clinical trials conducted up to 2005 that contained data on 4,145 adult patients having open abdominal surgery and treated with a range of lung expansion techniques including DB&C, PEP, NIV, IPPV, and IS. The authors separated trials into two main analyses: intervention versus a no-treatment control group (true control), and intervention versus another intervention (active control). However, on close inspection, two trials were erroneously considered in the no-treatment control comparisons although all patients in the control groups were provided with preoperative education and training on DB&C exercises with a physiotherapist (Hallböök et al 1984, Laszlo et al 1973) thus these trials should have been classified as an active comparison. Another included trial was not a randomised trial rather it was

a pre/post cohort design (Wiklander & Norlin 1957). It also appears that four clinical trials that complied with the specified inclusion criteria were not included and it is unclear why this was the case. These four trials all tested DB&C exercises alone and had a true no-treatment control group (Fagevik-Olsén, Josefson & Lönroth 1999, Fagevik-Olsén et al 1997, Roukema, Carol & Prins 1988, Stein & Cassara 1970). Based on the presented analysis and these apparent errors in trial classification, inclusions and exclusions, their conclusion that the "routine use of prophylactic respiratory physiotherapy in patients after abdominal surgery does not seem to be justified" (p. 1897, Pasquina et al 2006) may not be based on accurate data.

Lawrence, Cornell & Smetana (2006), conducted a broad systematic and narrative review of all types of interventions to reduce PPCs, including anaesthetic and surgical interventions. Due to the extensive nature of this review, the section analysing the evidence for lung expansion methods was briefer than Pasquina and colleagues' systematic review (2006). The authors reconsidered the combined meta-analyses results from previous reviews (Overend et al 2001, Thomas & McIntosh 1994), adding five additional trials: two investigated DB&C exercises alone versus a no-treatment control (Chumillas et al 1998, Fagevik-Olsén et al 1997), two investigated IS compared to DB&C exercises (Hall et al 1996, Hall et al 1991), and one investigating the benefit of NIV (Böhner et al 2002). Despite analysing similar trials to those reviewed in Pasquina et al 2006, Lawrence, Cornell & Smetana offer an alternative conclusion that, "For patients having abdominal surgery, the evidence suggests that any type of lung expansion intervention is better than no prophylaxis." (p. 604, Lawrence, Cornell & Smetana 2006). However, due to the limited search strategy utilised, this may again not accurately represent the data.

Previous chapters of this thesis have outlined that whilst there is expert consensus that physiotherapy directed lung expansion techniques are likely to be beneficial in reducing PPC rates after major abdominal surgery (Griffiths et al 2018, Hanekom et al 2012), the comparative efficacy of the different modalities remain to be determined. A narrative review of these prophylactic strategies presented in Chapters 1, 2 and 3 suggest that DB&C exercises are an effective independent strategy to minimise PPCs following abdominal surgery, especially if taught preoperatively with the aim for the patient to start them immediately after surgery. All systematic and narrative reviews (Overend et al 2001, Fagevik-Olsén 2000, Thomas & McIntosh 1994, Lawrence, Cornell & Smetana 2006, Pasquina et al 2006) have neglected to analyse the published trials by comparing DB&C exercises alone against a true no-treatment control, or to consider the effect of timing of the physiotherapy intervention. Other significant limitations to these systematic reviews include uncertainty surrounding trial selection, misclassification of comparators, inadequate management of the potential confounding influence of preoperative physiotherapy, and heterogeneity of included lung expansion techniques.

An updated systematic review and meta-analysis of clinical trials investigating DB&C exercises alone to impact PPC after abdominal surgery is needed[1]. This review should involve an extensive search strategy, clear definitions of what comprises a no-treatment control and needs to consider preoperative physiotherapy as an active comparator.

## 4.2 Objective

The primary objective for this systematic review and meta-analysis is to synthesise the evidence of the effectiveness of DB&C exercises on PPC incidence in adults undergoing abdominal surgery when compared to a no-treatment control group.

A secondary objective is to estimate the effect of preoperative education and DB&C training alone, postoperative coached DB&C exercises alone, or the combination of both, on the incidence of PPC following abdominal surgery as compared to a no-treatment control group. The effect on PPC incidence of adding postoperative coached DB&C exercises to preoperative education and training alone service will also be estimated.

## 4.3 Methods

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Liberati et al 2009).

### 4.3.1 Identification and selection of studies

All trials included within previous systematic reviews (Fagevik-Olsén 2000, Pasquina et al 2006, Lawrence, Cornell & Smetana 2006) were reassessed for inclusion. Additional trials were identified by searching the following electronic databases: PubMed, EMBASE, CINAHL, Cochrane CENTRAL (Wiley InterScience), Google Scholar, and the Physiotherapy Evidence Database (PEDro). Databases were searched in January 2016[1] for papers restricted to those published in English from December 1950 to December 2015. The search strategy combined population specific terms (e.g. abdominal, visceral, noncardiac surgery), intervention terms (e.g. physiotherapy, physical therapy, chest physiotherapy, breathing exercises), and outcomes (e.g. pulmonary complications, pneumonia, atelectasis) in both subject headings, keywords, titles, abstracts, and MeSH headings. See Appendix II for the PubMed search strategy as an exemplar.

[1] See Chapter 10 for a full updated analysis including trials to June 2020

Further eligible trials were identified through manually investigating the reference lists of identified trials, a previous expert consensus article (Hanekom et al 2012), and within PhD theses written by physiotherapists in this field published since 2000 (Denehy 2001a, Mackay 2003, Scholes 2005, Browning 2007a). Titles and abstracts of identified articles were screened with full-text articles retrieved from those possibly meeting inclusion eligibility or if the title or abstract did not provide enough information to exclude. All full-text papers were evaluated according to the inclusion criteria (Table 4.1).

**Table 4.1** Inclusion criteria for eligible trials

| | |
|---|---|
| **Design** | • Randomised or pseudorandomised controlled trial |
| **Language** | • English |
| **Participants** | • Adults (aged 18 years and above)<br>• Patients having elective or emergency abdominal surgery involving any type of incision to the abdomen, including open upper, lower or laparoscopic procedures. Where a trial also involved thoracic or cardiac procedures the trial was included if the abdominal surgery data was able to be isolated and analysed separately<br>• Patients have no defined signs or symptoms of postoperative respiratory deterioration on entry into trial |
| **Interventions** | • Preoperative education and training on the performance of postoperative DB&C without preoperative respiratory adjuncts e.g IMT, IS<br>• Postoperative coached sessions of DB&C exercises without augmentation from adjunctive devices e.g. PEP, IS, IPPV, NIV<br>• Combination of both pre- and postoperative interventions as above<br>• Where a trial involved respiratory adjuncts, the trial was included if data specific to those who received DB&C exercises alone was able to be isolated and analysed separately |
| **Comparator** | • No treatment control |
| **Outcome measures** | • Atelectasis<br>• Pneumonia<br>• Acute respiratory failure<br>• Hypoxemia<br>• Composite measure of PPC |
| **Comparisons** | • All interventions compared with the comparator and to each other |

### 4.3.2 Assessment of characteristics of studies

*Quality*

The methodological quality for each eligible trial was appraised using existing PEDro scores extracted from the PEDro database (Sherrington et al 2000). The PEDro score was utilised as it is the most used score for methodological quality in physiotherapy clinical trials (Moseley et al 2019a), is valid (de Morton 2009), and reliable (Maher et al 2003) in assessing trial methodological quality. In the absence of an existing score, one was purposively calculated using standardised scoring criteria (Moseley et al 2019b). See Appendix I. Each criterion and the overall score for included trials was individually tabulated.

*Participants*

The country of recruitment, study sample size, and type of surgeries involved were extracted for each included trial.

*Intervention*

For the purposes of this analysis "chest physiotherapy" was defined as: 1. preoperative education and training of DB&C exercises and instruction to perform these exercises in the postoperative period, and, 2. postoperative coached DB&C exercises without augmentation with respiratory devices (e.g. IS, IMT, PEP, IPPV, NIV). To characterise the experimental interventions the timing of the intervention (preoperative, postoperative), frequency (times per day), and duration (days provided), and total number of face-to-face sessions provided were extracted and tabulated. In circumstances where the total number of sessions not reported this was classified as "not stated".

Trials that also investigated DB&C exercises augmented with IS, PEP, IPPV, or NIV were included if one group was provided with DB&C exercises alone and the data for this group could be isolated and analysed separately.

The comparator, a no-treatment control group, was defined as participants receiving no pre- or postoperative directed education or coaching in DB&C exercises, nor treatment with respiratory adjuncts aimed at prophylaxis, e.g. IS, IMT, PEP, IBBV, or NIV.

*Outcome measures*

A PPC was defined as any of the following: atelectasis (as diagnosed from CXR, CT, or lung ultrasound), pneumonia (any diagnostic construct), acute respiratory failure (any diagnostic

construct), acute bronchitis, acute hypoxemia (arterial blood gases, pulse oximetry), or composite PPC diagnostic tools (any diagnostic construct).

If a number of variants of PPC were reported in the same trial (e.g. atelectasis, pneumonia, and acute bronchitis) the outcomes for comparison purposes were selected according to the following hierarchy: total number of PPCs reported when it was clear that the diagnoses were not double reported within participants, for example, a participant could only have one diagnosis of either atelectasis, or pneumonia, or composite PPC. When it was not clear if outcomes were reported as single events per participant report then the most severe PPC variant was extracted according to the following structure: pneumonia, composite PPC, acute bronchitis, clinical atelectasis (atelectasis on imaging with clinical symptoms), atelectasis detected on imaging, and, lastly, hypoxemia.

### 4.3.3 Data analysis

Primary analyses were considered for:

1. Chest physiotherapy versus no chest physiotherapy (true no-treatment control).

   This analysis was sub-grouped into:

   a) chest physiotherapy provided in preoperative phase only,

   b) chest physiotherapy provided in the postoperative phase only,

   c) combination of both pre- and postoperative chest physiotherapy.

2. The addition of postoperative chest physiotherapy to preoperative chest physiotherapy alone (active control).

The difference between interventions and comparators was calculated by comparing the incidence rate of PPC (number of participants with a PPC/number of participants in the group) between-groups using dichotomised risk ratios (RR) with 95% confidence intervals (95% CI). Pooled-effects were estimated using Mantel-Haenszel random-effects methods where the heterogeneity of studies was $I^2 > 50\%$ or fixed-effects methods where the heterogeneity of studies was $I^2 < 50\%$. Pooled-effects were represented graphically using forest plots. An outer boundary of 95% CI less than or greater than 1.0 was regarded as statistically significant. Significant results were additionally represented using pooled-effects absolute risk reductions and converted to equivalent NNT with 95% CI.

Statistical heterogeneity of results amongst the studies was assessed using the $I^2$ inconsistency test, where values <40% represent homogenous results, 40-60% moderate heterogeneity, 60-75% high heterogeneity, >75% considerable heterogeneity (Huedo-Medina et al 2006).

Four sensitivity analyses were conducted to assess the possible influence of study methodological quality, treatment dosage, and the use of additional manual therapies on overall RR in analyses pools. Firstly, studies with PEDro methodological scores less than five were deleted from the model. Poorer methodological quality studies are at higher risk of biasing and overestimating results (Moseley et al 2011). Secondly, studies comparing chest physiotherapy to no-treatment control group were grouped into those providing three or less chest physiotherapy treatment sessions (low treatment dosage) and those providing more than three treatments sessions (high treatment dosage). The pooled analysis for each cohort was calculated. This was conducted to assess if a dose-dependent relationship existed with coached DB&C exercises. Thirdly, all studies that provided adjunct manual therapies (postural drainage, chest percussions and/or vibrations) were removed from analysis to consider the possibility of a confounding influence on effect. Lastly, all trials that did not include preoperative chest physiotherapy in the intervention protocol was removed from the pooled estimate to replicate the current clinical practice within Australia and New Zealand.

Data were entered, analysed, and reported using Review Manager (RevMan). Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014.

## 4.4 Results

### 4.4.1 Flow of studies through the review

The search strategy yielded 692 articles, from which 61 were considered possibly eligible for inclusion. Full-text manuscripts were retrieved for consideration. Of these, 41 were excluded according to the specified eligibility criteria (see Table 3.2 for all excluded trials and reasons for exclusion). Figure 4.1 shows the flow of trial selection.

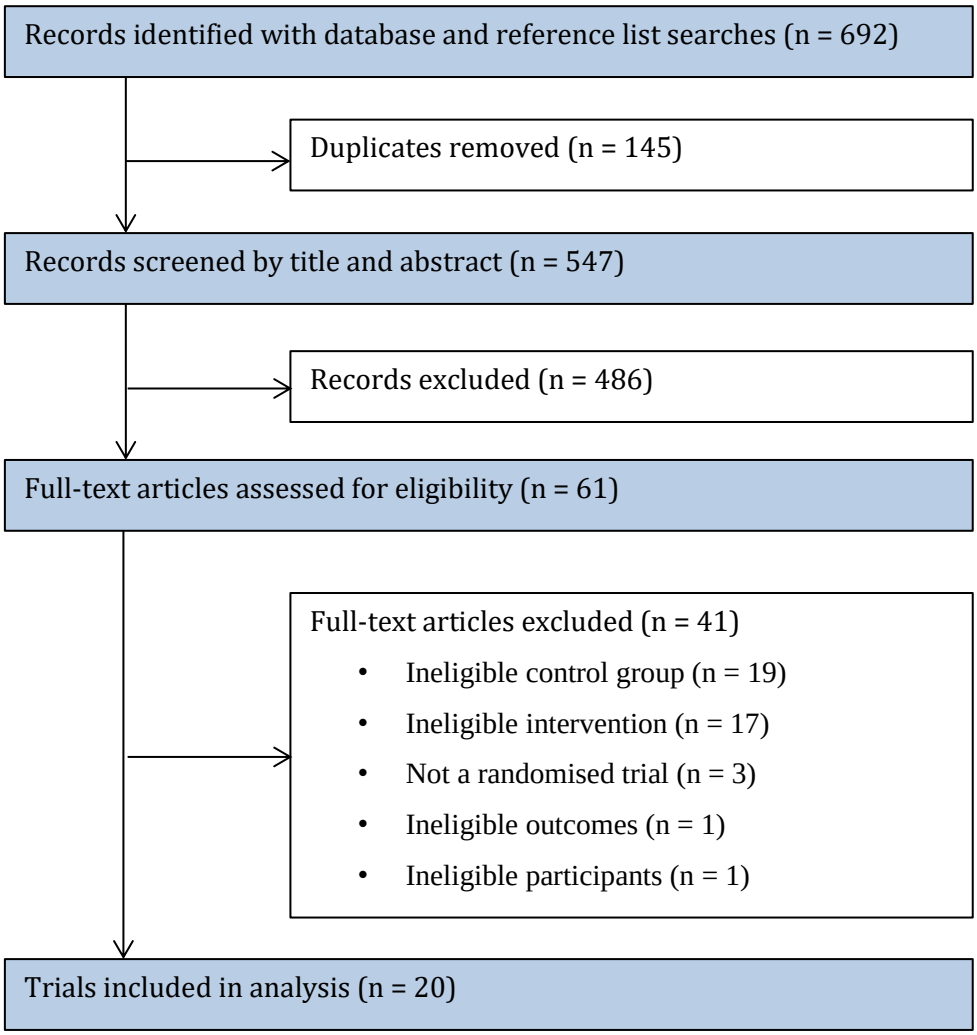



**Figure 4.1** Flow of studies for selection in review.

**Table 4.2** Details of trials excluded from analysis.

| Reason for exclusion | Study | Details |
|---|---|---|
| **Not randomised or pseudorandomised allocation** | Martinez BP, Silva JR, Silva VS, Neto MG, Forgiarini Júnior LA. Influence of different body positions in vital capacity in patients on postoperative upper abdominal. *Rev Bras Anestesiol.* 2015 May-Jun;65(3):217-21. | Cross over trial |
| | Wiklander O, Norlin U. Effect of physiotherapy on post-operative pulmonary complications; a clinical and roentgenographic study of 200 cases. *Acta Chir Scand*. 1957 Mar 28;112(3-4):246-54. | No random allocation. Pre/post cohort. |
| | Neligan PJ, Malhotra G, Fraser M, Williams N, Greenblatt EP, Cereda M, Ochroch EA. Noninvasive ventilation immediately after extubation improves lung function in morbidly obese patients with obstructive sleep apnea undergoing laparoscopic bariatric surgery. *Anesth Analg.* 2010 May 1;110(5):1360-5. | Retracted manuscript |
| **Ineligible participants** | Squadrone V, Coha M, Cerutti E, Schellino MM, Biolino P, Occella P, Belloni G, Vilianis G, Fiore G, Cavallo F, Ranieri VM; Piedmont Intensive Care Units Network(PICUN). Continuous positive airway pressure for treatment of postoperative hypoxemia: a randomized controlled trial. *JAMA.* 2005 Feb 2;293(5):589-95. | Participants entered into the trial with existing hypoxemia |
| **Ineligible control group** | Ali J, Serrette C, Wood LD, Anthonisen NR. Effect of postoperative intermittent positive pressure breathing on lung function. *Chest.* 1984 Feb;85(2):192-6. | Postop coached DB&C v additional IPPV |
| | Campbell T, Ferguson N, McKinlay RGC. The use of a simple self-administered method of positive expiratory pressure (PEP) in chest physiotherapy after abdominal surgery. *Physiotherapy*. 1986 Oct;72(10):498-500. | Preop edu/postop DB&C v additional postop PEP |
| | Christensen EF, Schultz P, Jensen OV, Egebo K, Engberg M, Grøn I, Juhl B. Postoperative pulmonary complications and lung function in high-risk patients: a comparison of three physiotherapy regimens after upper abdominal surgery in general anaesthesia. *Acta Anaesthesiol Scand*. 1991 Feb;35(2):97-104. | Preop edu + postop DB&C v additional postop PEP v additional postop PEP + IMT |
| | Craven JL, Evans GA, Davenport PJ, Williams RH. The evaluation of the incentive spirometer in the management of postoperative pulmonary complications. *Br J Surg*. 1974 Oct;61(10):793-7. | Preop edu + postop DB&C v incentive spirometry |
| | Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S. A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. *Physiotherapy Research International.* 2001;6(4):236-250. | Preop edu + postop DB&C v additional CPAP |
| | Forgiarini LA Jr, Carvalho AT, Ferreira Tde S, Monteiro MB, Dal Bosco A, Gonçalves MP, Dias AS. Physical therapy in the immediate postoperative period after abdominal surgery. *J Bras Pneumol.* 2009 May;35(5):455-9. | Postop chest PT immediately postop v Postop chest PT start on ward<br>Outcomes: Lung function, respiratory muscle strength |

| | | |
|---|---|---|
| | Hall JC, Tarala R, Harris J, Tapper J, Christiansen K. Incentive spirometry versus routine chest physiotherapy for prevention of pulmonary complications after abdominal surgery. *Lancet.* 1991 Apr 20;337(8747):953-6. | Postop DB&C v incentive spirometry |
| | Hall JC, Tarala RA, Tapper J, Hall JL. Prevention of respiratory complications after abdominal surgery: a randomised clinical trial. *BMJ*. 1996 Jan 20;312(7024):148-52. | Preop edu v incentive spirometry |
| | Heisterberg L, Johansen TS, Larsen HW, Holm M, Andersen B. Postoperative pulmonary complications in upper abdominal surgery. A randomized clinical comparison between physiotherapy and blow-bottles. *Acta Chir Scand*.1979;145(8):505-7. | Preop edu + postop coached DB&C v preop edu + self-directed Bubble PEP |
| | Lindner KH, Lotz P, Ahnefeld FW. Continuous positive airway pressure effect on functional residual capacity, vital capacity and its subdivisions. *Chest.* 1987 Jul;92(1):66-70. | Preop edu/postop coached DB&C v additional CPAP |
| | Lyager S, Wernberg M, Rajani N, Bøggild-Madsen B, Nielsen L, Nielsen HC,Andersen M, Møller J, Silberschmid M. Can postoperative pulmonary conditions be improved by treatment with the Bartlett-Edwards incentive spirometer after upper abdominal surgery? *Acta Anaesthesiol Scand*. 1979 Aug;23(4):312-9. | Preop edu/postop coached DB&C v additional incentive spirometry |
| | Minschaert M, Vincent JL, Ros AM, Kahn RJ. Influence of incentive spirometry on pulmonary volumes after laparotomy. *Acta Anaesthesiol Belg*. 1982;33(3):203-9. | Preop edu/postop coached DB&C v additional IS |
| | O'Connor M, Tattersall MP, Carter JA. An evaluation of the incentive spirometer to improve lung function after cholecystectomy. *Anaesthesia.* 1988 Sep;43(9):785-7. | Postop chest PT v preop edu and postop self-directed incentive spirometry |
| | Ricksten SE, Bengtsson A, Soderberg C, Thorden M, Kvist H. Effects of periodic positive airway pressure by mask on postoperative pulmonary function. *Chest*. 1986 Jun;89(6):774-81. | Postop chest PT v preop edu and postop self-directed CPAP or incentive spirometry |
| | Schuppisser JP, Brändli O, Meili U. Postoperative intermittent positive pressure breathing versus physiotherapy. *Am J Surg.* 1980 Nov;140(5):682-6. | Postop chest PT v IPPV |
| | Schwieger I, Gamulin Z, Forster A, Meyer P, Gemperle M, Suter PM. Absence of benefit of incentive spirometry in low-risk patients undergoing elective cholecystectomy. A controlled randomized study. *Chest.* 1986 May;89(5):652-6. | No pre/post chest PT v preop edu + postop incentive spirometry |
| | Soares SM, Nucci LB, da Silva MM, Campacci TC. Pulmonary function and physical performance outcomes with preoperative physical therapy in upper abdominal surgery: a randomized controlled trial. *Clin Rehabil*. 2013 Jul;27(7):616-27. | Postop DB&C v additional preop edu, IMT, prehab |
| | Stock MC, Downs JB, Gauer PK, Alster JM, Imrey PB. Prevention of postoperative pulmonary complications with CPAP, incentive spirometry, and conservative therapy. *Chest.* 1985 Feb;87(2):151-7. | Preop edu/postop coached DB&C v CPAP v incentive spirometry. |

| | | |
|---|---|---|
| | Tyson AF, Kendig CE, Mabedi C, Cairns BA, Charles AG. The effect of incentive spirometry on postoperative pulmonary function following laparotomy: a randomized clinical trial. *JAMA Surg.* 2015 Mar 1;150(3):229-36. | Postop DB&C v additional incentive spirometers<br>Outcomes: Lung function |
| **Ineligible intervention group** | Baltieri L, Santos LA, Rasera I Jr, Montebelo MI, Pazzianotto-Forti EM. Use of positive pressure in the bariatric surgery and effects on pulmonary function and prevalence of atelectasis: randomized and blinded clinical trial. *Arq Bras Cir Dig.* 2014;27 Suppl 1:26-30. | Postop coached DB&C + incentive spirometer v additional NIV |
| | Baxter WD, Levine RS. An evaluation of intermittent positive pressure breathing in the prevention of postoperative pulmonary complications. *Arch Surg.* 1969 Jun;98(6):795-8. | IPPV v no treatment control<br>Physiotherapy management not described |
| | Böhner H, Kindgen-Milles D, Grust A, et al. Prophylactic nasal continuous positive airway pressure after major vascular surgery: results of a prospective randomized trial. *Langenbecks Arch Surg.* 2002 Apr;387(1):21-6. | CPAP v standard oxygen therapy<br>Physiotherapy management not described |
| | Carlsson C, Sondén B, Thylén U. Can postoperative continuous positive airway pressure (CPAP) prevent pulmonary complications after abdominal surgery? *Intensive Care Med*. 1981;7(5):225-9. | Usual care v postop CPAP<br>No descriptions of physiotherapy |
| | Dohi S, Gold MI. Comparison of two methods of postoperative respiratory care. *Chest*. 1978 May;73(5):592-5. | Postop incentive spirometry v postop IPPV |
| | Dronkers J, Veldman A, Hoberg E, van der Waal C, van Meeteren N. Prevention of pulmonary complications after upper abdominal surgery by preoperative intensive inspiratory muscle training: a randomized controlled pilot study. *Clin Rehabil.*2008 Feb;22(2):134-42. | Preop edu, incentive spirometry, + postop coached DB&C v additional preop IMT |
| | Ebeo CT, Benotti PN, Byrd RP Jr, Elmaghraby Z, Lui J. The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. *Respir Med*. 2002 Sep;96(9):672-6. | Incentive spirometry v NIV<br>Outcome: Lung function, $SpO_2$ |
| | Fagevik Olsén M, Wennberg E, Johnsson E, Josefson K, Lönroth H, Lundell L. Randomized clinical study of the prevention of pulmonary complications after thoracoabdominal resection by two different breathing techniques. *Br J Surg*. 2002 Oct;89(10):1228-34. | DB&C exercises + IMT/PEP v CPAP |
| | Joris JL, Sottiaux TM, Chiche JD, Desaive CJ, Lamy ML. Effect of bi-level positive airway pressure (BiPAP) nasal ventilation on the postoperative pulmonary restrictive syndrome in obese patients undergoing gastroplasty. *Chest.* 1997 Mar;111(3):665-70. | NIV v usual care<br>Outcomes: Lung function, $SpO_2$ |
| | Jung R, Wight J, Nusser R, Rosoff L. Comparison of three methods of respiratory care following upper abdominal surgery. *Chest.* 1980 Jul;78(1):31-5. | Preop edu + incentive spirometry v IPPV v blow glove |
| | Lederer DH, Van de Water JM, Indech RB. Which deep breathing device should the postoperative patient use? *Chest.* 1980 May;77(5):610-3. | Incentive spirometer A v Incentive spirometer B v Incentive spirometer C |

| | | |
|---|---|---|
| | Lloréns J, Rovira L, Ballester M, Moreno J, Hernández-Laforet J, Santonja FJ, Cassinello N, Ortega J. Preoperative inspiratory muscular training to prevent postoperative hypoxemia in morbidly obese patients undergoing laparoscopic bariatric surgery. A randomized clinical trial. *Obes Surg*. 2015 Jun;25(6):1003-9. | Usual care v preop IMT<br>Outcome: Arterial blood gases and respiratory muscle strength |
| | Neligan PJ, Malhotra G, Fraser M, Williams N, Greenblatt EP, Cereda M, Ochroch EA. Continuous positive airway pressure via the Boussignac system immediately after extubation improves lung function in morbidly obese patients with obstructive sleep apnea undergoing laparoscopic bariatric surgery. *Anesthesiology.* 2009 Apr;110(4):878-84. | CPAP immediately after extubation v CPAP in recovery unit |
| | Samnani SS, Umer MF, Mehdi SH, Farid FN. Impact of preoperative counselling on early postoperative mobilization and its role in smooth recovery. *Int Sch Res Notices.* 2014 Oct 28;2014:250536. | No preop edu on postoperative early ambulation v additional preop edu on early amb |
| | Sleszynski SL, Kelso AF. Comparison of thoracic manipulation with incentive spirometry in preventing postoperative atelectasis. *J Am Osteopath Assoc*. 1993 Aug;93(8):834-8, 843-5. | Incentive spirometry v thoracic manipulation |
| | Torrington KG, Sorenson DE, Sherwood LM. Postoperative chest percussion with postural drainage in obese patients following gastric stapling. *Chest.* 1984 Dec;86(6):891-5. | IPPV + incentive spirometry + coached DB&C exercises v additional manual chest PT |
| | Zhang XY, Wang Q, Zhang S, Tan W, Wang Z, Li J. The use of a modified, oscillating positive expiratory pressure device reduced fever and length of hospital stay in patients after thoracic and upper abdominal surgery: a randomised trial. *J Physiother.* 2015 Jan;61(1):16-20. | No chest PT v postop self-directed PEP |
| **Ineligible outcome measure** | Crawford BL, Blunnie WP, Elliott AG. The value of self-administered peri-operative physiotherapy. *Ir J Med Sci.* 1990 Feb;159(2):51-2. | Preop edu physio only v additional postop physio DB&C<br>Outcome: Lung function |

**Legend:** CPAP: continuous positive airway pressure, DB&C: deep breathing and coughing, edu: education, IMT: inspiratory muscle training, IPPV: intermittent positive pressure ventilation, NIV: non-invasive ventilation, PEP: positive expiratory pressure, postop: postoperative, prehab: prehabilitation, preop: preoperative PT: physiotherapy, SpO2: pulse oximetry, v: versus.

**Table 4.3** Characteristics of studies included in the review.

| **Author; year** | Country; centres, n | n | PEDro score | Pop | Control | Intervention | Outcome | Result: Control v Intervention/s | Relative risk | Comparison | Interpretation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Palmer 1952** | England Single | 82 | 4 | LAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br>Postop chest PT bd for 3d<br><br>PT sessions: 6 | CXR | 5/42 (12%) v 8/40 (20%) | 1.7 (0.60 to 4.7) | No PT v pre/postop chest PT | Postop coached DB&C may, or may not, reduce CXR abnormalities. Underpowered for observed effect. |
| **Stein 1970** | USA Single | 8 | 3 | OAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br>Postop chest PT + PD, 1-3 x/d<br><br>PT sessions: NS | PPC | 1/3 (30%) v 1/5 (20%) | 0.60 (0.06 to 6.4) | No PT v pre/postop chest PT | Underpowered. No conclusion can be drawn. |
| **Laszlo 1973** | England Single | 86 | 3 | OAS | Preop chest PT<br><br>PT sessions: 1 | Preop chest PT<br>Postop chest PT + percs bd 5d<br><br>PT sessions: 11 | Bronchitis<br>Atelectasis<br>Pneumonia<br>Total PPC | 8/42 (19%) v 10/44 (23%)<br>7/42 (17%) v 1/44 (2%)<br>4/42 (10%) v 8/44 (18%)<br>19/42 (45%) v 19/44 (43%) | 1.2 (0.52 to 2.7)<br>**0.14 (0.02 to 1.0)**<br>1.9 (0.62 to 5.9)<br>0.95 (0.59 to 1.5) | Preop chest PT v additional postop chest PT | Additional postop chest PT may reduce atelectasis but not PPC compared to preop chest PT alone |
| **Morran 1983** | Scotland Single | 102 | 5 | UAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Postop chest PT + chest vibes daily 2d<br><br>PT sessions: NS | Atelectasis<br>Pneumonia<br>Total PPC | 11/51 (22%) v 18/51 (35%)<br>19/51 (37%) v 7/51 (14%)<br>30/51 (59%) v 25/51 (49%) | 1.6 (0.86 to 3.1)<br>**0.37 (0.17 to 0.80)**<br>0.83 (0.58 to 1.2) | No PT v postop chest PT | Postop coached DB&C prevents pneumonia, but not atelectasis, compared to no chest PT. |
| **Celli 1984** | Venezuela Single | 172 | 6 | OAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br>Postop chest PT qid 4d<br><br>PT sessions: 17 | CXR<br>ARF<br>PPC | 9/44 (21%) v 15/41 (37%)<br>4/44 (9%) v 2/41 (5%)<br>21/44 (48%) v 9/41 (22%) | 1.8 (0.88 to 3.6)<br>0.54 (0.10 to 2.8)<br>**0.46 (0.24 to 0.89)** | No PT v pre/postop chest PT | Preop chest PT and postop supervised DB&C reduce PPC |
| **Hallböök 1984** | Sweden Single | 137 | 5 | UAS | Preop chest PT<br>Postop early amb<br><br>PT sessions: 1 | As per control<br>Postop chest PT+ PD bd 3d<br><br>PT sessions: 7 | Atelectasis<br>Pneumonia | 11/45 (24%) v 19/92 (21%)<br>1/45 (2%) v 8/92 (9%) | 0.84 (0.44 to 1.6)<br>3.9 (0.5 to 30.3) | Preop chest PT v additional postop chest PT | Additional postop DB&C + PD is no more effective than preop chest PT and early ambulation in reducing atelectasis or pneumonia. |

**Table 4.3** Characteristics of studies included in the review (cont)

| **Author; year** | Country; centres, n | n | PEDro score | Pop | Control | Intervention | Outcome | Result: Control v Intervention/s | Relative risk | Comparison | Interpretation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Giroux 1987** | Canada Single | 54 | 4 | LAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Postop chest PT once/d for 3 d<br><br>PT sessions: 3 | Atelectasis | 5/27 (19%) v 8/27 (30%) | 1.6 (0.60 to 4.3) | No PT v postop chest PT | Postop supervised DB&C exercises may not be necessary after open hysterectomy. |
| **Roukema 1988** | Holland Single | 153 | 1 | UAS | No preop chest PT<br>No postop chest PT<br>Early ambulation<br><br>PT sessions: 0 | Preop chest PT x 2<br>Postop chest PT once day 0<br>bd POD1-2, once daily POD3-5<br><br>PT sessions: 10 | Mild PPC<br>Mod PPC<br>Pneumonia<br>Total PPC | 21/84 (25%) v 10/69 (15%)<br>14/84 (17%) v 3/69 (4%)<br>15/84 (18%) v 0/69 (0%)<br>50/84 (60%) v 13/69 (19%) | 0.58 (0.29 to 1.1)<br>**0.26 (0.08 to 0.87)**<br>**n/a**<br>**0.32 (0.19 to 0.53)** | | Preop chest PT and intensive postop coached DB&C reduce PPC and pneumonia compared to early ambulation alone. |
| **Bourn 1991** | England Single | 48 | 4 | UAS | Preop chest PT<br><br>PT sessions: 1 | Preop chest PT<br>Postop chest PT<br><br>PT sessions: NS | PPC | 2/24 (8%) v 2/24 (8%) | 1.0 (0.15 to 6.5) | Preop chest PT v additional postop chest PT | The addition of postop supervised DB&C exercises to preop preparation may not be necessary following low risk cholecystectomy |
| **Condie 1993** | Scotland Multi; n=6 | 310 | 6 | OAS | Preop chest PT<br><br>PT sessions: 1 | Preop chest PT<br>Postop chest PT once daily 3d<br><br>PT sessions: 4 | PPC | 12/152 (8%) v 5/158 (3%) | 0.40 (0.14 to 1.1) | Preop chest PT v additional postop chest PT | Postop supervised DB&C may, or may not, prevent PPC over and above preop education and training alone. Underpowered for observed effect. |
| **Fagevik-Olsén 1997** | Sweden Single | 368 | 5 | OAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br>Postop early amb<br><br>PT sessions: 2 | Desat RA | 32/153 (21%) v 4/132 (3%) | **0.14 (0.05 to 0.40)** | No chest PT v preop chest PT | Preop education DB&C training and early ambulation prevents hypoxemia. |

**Table 4.3** Characteristics of studies included in the review (cont)

| **Author; year** | Country; centres, n | n | PEDro score | Pop | Control | Intervention | Outcome | Result: Control v Intervention/s | Relative risk | Comparison | Interpretation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chumillas 1998** | Spain Single | 81 | 5 | UAS | No preop chest PT<br>No postop chest PT<br><br><br><br><br><br>PT sessions: 0 | Preop chest PT<br>Postop chest<br><br><br><br><br><br>PT sessions: 9 | Bronchitis<br>Atelectasis<br>Pneumonia<br>CXR<br>Total PPC | 1/41 (2%) v 2/40 (5%)<br>6/41 (15%) v 1/40 (3%)<br>1/41 (2%) v 0/40 (0%)<br>16/41 (39%) v 6/40 (15%)<br>8/41 (20%) v 3/40 (8%) | 2.1 (0.19 to 22)<br>0.17 (0.02 to 1.4)<br>n/a<br>**0.38 (0.17 to 0.88)**<br>0.38 (0.11 to 1.3) | No chest PT v pre/post chest PT | Pre/postop chest PT minimises CXR changes postop and may prevent PPC compared to early ambulation alone. Underpowered for observed effect. |
| **Fagevik-Olsén 1999** | Sweden Single | 40 | 5 | LAS | No preop chest PT<br>No postop chest PT<br><br><br><br>PT sessions: 0 | Preop chest PT<br>Postop chest PT bd<br><br><br><br>PT sessions: 3 | Desat RA<br>Pneumonia | 3/20 (15%) v 1/20 (5%)<br>1/20 (5%) v 0/20 (0%) | 0.33 (0.04 to 2.9)<br>n/a | No PT v pre/post chest PT | Chest PT may or may not be effective in reducing PPC after laparoscopic surgery. Underpowered for observed effect. |
| **Denehy 2001a** | Australia Single | 102 | 5 | UAS | Preop chest PT<br>No postop chest PT<br><br><br><br>PT sessions: 1 | Preop chest PT<br>Postop chest PT<br><br><br><br>PT sessions: 5 | PPC | 1/52 (2%) v 3/50 (6%) | 3.1 (0.34 to 29.0) | Preop chest PT v additional postop chest PT | The addition of postop chest PT to preop education and DB&C training may not be necessary to reduce PPC |
| **Mackay 2005** | Australia Single | 52 | 8 | UAS | No preop chest PT<br>No postop chest PT<br><br><br><br>PT sessions: 0 | Postop chest PT<br><br><br><br><br>PT sessions: 13 | PPC | 3/21 (14%) v 6/29 (17%) | 1.4 (0.41 to 5.1) | Postop early ambulation v additional postop chest PT | Coached DB&C exercises may not minimise PPC further if patients are provided with intense early mobilisation. |
| **Manzano 2008** | Brazil single | 31 | 5 | UAS | No preop chest PT<br>No postop chest PT<br><br>PT session: 0 | Postop chest PT once<br><br>PT session:1 | patient reported PPCs | 1/16 (6%) v 0/15 (0%) | n/a | No PT v single postop chest PT | A single session of coached DB&C in the recovery unit may not reduce PPC. |
| **Kulkarni 2010** | England Single | 66 | 5 | OAS | No preop chest PT<br>No postop chest PT<br><br>PT sessions: 0 | Preop chest PT once<br><br>PT sessions: 1 | PPC | 2/17 (12%) v 1/17 (6%) | 0.50 (0.05 to 5.0) | No chest PT v additional preop chest PT | Preop chest PT may or may not reduce PPCs. Underpowered for observed effect. |

**Table 4.3** Characteristics of studies included in the review (cont)

| **Author; year** | Country; centres, n | n | PEDro score | Pop | Control | Intervention | Outcome | Result: Control v Intervention/s | Relative risk | Comparison | Interpretation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Carneiro 2013** | Brazil Single | 75 | 3 | UAS | No preop chest PT<br>No postop chest PT<br><br><br><br>PT session: 0 | Preop chest PT<br>Postop chest PT once daily 2d<br><br><br><br>PT sessions: 3 | CXR<br>Atelectasis<br>Pneumonia<br>Total PPC | 6/39 (15%) v 2/36 (6%)<br>2/39 (5%) v 1/36 (3%)<br>4/39 (10%) v 1/36 (3%)<br>12/39 (31%) v 4/36 (11%) | 0.36 (0.08 to 1.7)<br>0.54 (0.05 to 5.7)<br>0.27 (0.03 to 2.3)<br>**0.36 (0.13 to 1.0)** | | Preop education and training and coached postop DB&C may prevent PPC |
| **Silva 2013** | Australia Single | 86 | 7 | UAS | No preop chest PT<br>Post op early amb<br><br><br><br><br>PT sessions: 0 | No preop chest PT<br>Postop early amb + chest PT<br>OR<br>Rest in bed + chest PT<br><br><br><br>PT sessions: NS | PPC | 6/28 (21%) v 7/28 (25%) v 3/30 (10%) | 0.80 (0.33 to 1.99) | Early ambulation v additional postop chest PT v rest in bed + postop chest PT | Coached DB&C may not minimise PPC further if patients are provided with early ambulation. For patients resting in bed coached DB&C may reduce PPCs. Underpowered for observed effect. |
| **Lunardi 2015** | Brazil Single | 70 | 5 | UAS | No preop chest PT<br>No postop chest PT<br><br><br><br>PT sessions: 0 | No preop chest PT<br>Postop chest PT tds day 5d<br><br><br><br>PT sessions: 15 | PPC | 0/35 (0%) v 8/35 (23%) | **n/a** | No PT v postop chest PT | Postop coached DB&C exercises may not minimise PPC risk |

Legend: amb = ambulation, ARF = acute respiratory failure, bd = twice daily, CXR = chest xray, d = days, DB&C = deep breathing and coughing, desat = desaturation, LAS = lower abdominal surgery, mod = moderate, multi = multicentre trial, n = number, NS = not stated, OAS = open abdominal surgery, PD = postural drainage, PEDro = physiotherapy evidence database, percs = chest percussions, POD = postoperative day, pop = population, PPC = postoperative pulmonary complication, postop = postoperative, preop = preoperative, PT = physiotherapy, qid = four times daily, RA = room air, single = single centre trial, tds = three times daily, UAS = upper abdominal surgery, v = versus, vibes = chest vibrations
Statistically significant results are in **bold font**

**Table 4.4** Methodological quality of included trials.

| Study | Random allocation | Concealed allocation | Baseline comparability | Participant blinding | Therapist blinding | Assessor blinding | <15% dropouts | Intention-to-treat analysis | Between-group difference | Point estimate | Total score (0 to 10) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Palmer 1952 | Y | N | Y | N | N | N | Y | N | Y | N | 4 |
| Stein 1970 | Y | N | N | N | N | N | Y | N | Y | N | 3 |
| Laszlo 1973 | Y | N | N | N | N | Y | N | N | Y | N | 3 |
| Morran 1983 | Y | N | Y | N | N | N | Y | N | Y | Y | 5 |
| Celli 1984 | Y | N | Y | N | N | Y | Y | N | Y | Y | 6 |
| Hallböök 1984 | Y | Y | Y | N | N | N | N | N | Y | Y | 5 |
| Giroux 1987 | Y | N | N | N | N | Y | Y | N | N | Y | 4 |
| Roukema 1988 | N* | N | N | N | N | N | N | N | Y | N | 1 |
| Bourn 1991 | Y | N | Y | N | N | N | N | N | Y | N | 3 |
| Condie 1993 | Y | N | Y | N | N | Y | Y | N | Y | Y | 6 |
| Chumillas 1998 | Y | N | Y | N | N | N | Y | N | Y | Y | 5 |
| Fagevik-Olsén 1997 | Y | N | Y | N | N | N | Y | N | Y | Y | 5 |
| Fagevik-Olsén 1999 | Y | N | Y | N | N | N | Y | N | Y | Y | 5 |
| Denehy 2001a | Y | Y | Y | N | N | Y | Y | Y | Y | Y | 8 |
| Mackay 2005 | Y | Y | Y | N | N | Y | Y | Y | Y | Y | 8 |
| Manzano 2008 | Y | N | Y | N | N | N | N | Y | Y | Y | 5 |
| Kulkarni 2010 | Y | Y | Y | N | N | N | N | Y | N | Y | 5 |
| Silva 2013 | N* | Y | N | Y | N | N | Y | Y | Y | Y | 6 |
| Carneiro 2013 | Y | N | Y | N | N | N | N | N | Y | Y | 3 |
| Lunardi 2015 | Y | N | Y | N | N | N | N | Y | Y | Y | 5 |

* Roukema 1988 and Silva 2013 were pseudorandomised controlled trials

### 4.4.2 Characteristics of included studies

The 20 included studies involved a total of 1919 participants having major abdominal surgery. Table 4.3 summaries the characteristics of included studies. Fifteen studies investigated the effect of chest physiotherapy against a true no-treatment control. Of these, two studies assessed the effectiveness of preoperative chest physiotherapy alone (Fagevik-Olsén et al 1997, Kulkarni et al 2010), six trials assessed the benefit of chest physiotherapy solely provided in the postoperative phase (Morran et al 1983, Giroux et al 1987, Mackay, Ellis & Johnston 2005, Manzano et al 2008, Silva, Li & Rickard 2013, Lunardi et al 2015), and seven assessed combined pre- and postoperative chest physiotherapy services (Palmer & Sellick 1952, Stein & Cassara 1970, Celli, Rodriguez & Snider 1984, Roukema, Carol & Prins 1988, Chumillas et al 1998, Fagevik-Olsén, Josefson & Lönroth 1999, Carneiro et al 2013). Across these 15 trials, 615 participants were allocated to an intervention (149 preoperative chest physiotherapy alone, 215 postoperative chest physiotherapy alone, and 251 with combined pre- and postoperative chest physiotherapy) and 621 participants allocated to a no-treatment control group.

For the analysis comparing the addition of postoperative chest physiotherapy to preoperative chest physiotherapy alone, five trials assessed the benefit of adding postoperative chest PT to preoperative chest PT (Laszlo et al 1973, Hallböök et al 1984, Bourn, Conway & Holgate 1991, Condie, Hack & Ross 1993, Denehy 2001a). These trials involved 368 participants allocated to receiving additional chest physiotherapy in the postoperative phase and 315 participants who received preoperative physiotherapy alone.

*Quality*

Most included studies had fair to moderate methodological quality with an average PEDro score of 4.8 (standard deviation (SD) 1.7). A high risk of bias exists regarding group allocation and assessment of the outcome, with only 25% of trials using concealed allocation techniques (Hallböök et al 1984, Denehy 2001a, Mackay, Ellis & Johnston 2005, Kulkarni et al 2010, Silva, Li & Rickard 2013) and 30% utilising blinded assessors (Laszlo et al 1973, Celli, Rodriguez & Snider 1984, Giroux et al 1987, Condie, Hack & Ross 1993, Denehy 2001a, Mackay, Ellis & Johnston 2005). See Table 4.4 for total and criterion scores for included trials using the PEDro scale.

*Participants*

Trials involved adult participants having either open lower abdominal surgery (Palmer & Sellick 1952, Giroux et al 1987), laparoscopic bariatric surgery (Fagevik-Olsén, Josefson, Lönroth 1999), open upper abdominal surgery (Morran et al 1983, Hallböök et al 1984, Roukema, Carol & Prins

1988, Bourn, Conway & Holgate 1991, Chumillas et al 1998, Denehy 2001a, Mackay, Ellis & Johnston 2005, Manzano et al 2008, Carneiro et al 2013, Silva, Li & Rickard 2013, Lunardi et al 2015), or a combined population of open upper and lower abdominal surgery (Stein & Cassara 1970, Laszlo et al 1973, Celli, Rodriguez & Snider 1984, Condie, Hack & Ross 1993, Fagevik-Olsén et al 1997, Kulkarni et al 2010). Trials originated predominately from developed countries (Britain, n=6; Scandinavia/Europe, n=5; Australia, n=3; USA/Canada, n=2) with two trials from developing countries (Brazil, n=3, and Venezuela, n=1). The median sample size was 82 participants (interquartile range (IQR) 54 – 111).

*Interventions*

In trials of preoperative chest physiotherapy alone this intervention comprised of a single session only, provided most often the day before surgery, and comprising of education on the need to perform DB&C exercises after surgery and training in the performance of these exercises (Laszlo et al 1973, Hallböök et al 1984, Bourn, Conway & Holgate 1991, Condie, Hack & Ross 1993, Fagevik-Olsén et al 1997, Denehy 2001a, Kulkarni et al 2010).

Postoperative chest physiotherapy treatments all involved coached sessions of DB&C exercises, without augmentation with devices (IS, PEP, IMT, IPPV, or NIV). A small number of older trials employed additional manual therapy techniques such as postural drainage (Stein & Cassara 1970, Hallböök et al 1984), chest percussion (Laszlo et al 1973), or chest vibrations (Morran et al 1983). The most common treatment frequency of coached DB&C exercises was once (Morran et al 1983, Giroux et al 1987, Condie, Hack & Ross 1993, Chumillas et al 1998, Fagevik-Olsén et al 1997, Manzano et al 2008, Carneiro et al 2013, Silva, Li & Rickard 2013) or twice daily (Palmer & Sellick 1952, Laszlo et al 1973, Hallböök et al 1984, Roukema, Carol & Prins 1988, Fagevik-Olsén, Josefson, Lönroth 1999). The other trials provided chest physiotherapy three times daily (Mackay, Ellis & Johnston 2005, Lunardi et al 2015), four times a day (Celli, Rodriguez & Snider 1984), or at the discretion of the physiotherapist (Stein & Cassara 1970, Denehy 2001a). The first postoperative chest physiotherapy session was predominately provided the day after surgery, with only two trials initiating coached DB&C exercises immediately following surgery (Roukema, Carol & Prins 1988, Manzano et al 2008).

The number of postoperative days that chest physiotherapy treatments were provided was also quite varied, with trials providing chest physiotherapy for one day only (Fagevik-Olsén et al 1997, Fagevik-Olsén, Josefson, Lönroth 1999), two days (Morran et al 1983, Carneiro et al 2013), three days (Palmer & Sellick 1952, Hallböök et al 1984, Condie, Hack & Ross 1993), four days (Celli, Rodriguez & Snider 1984), or five or more (Laszlo et al 1973, Roukema, Carol & Prins 1988, Chumillas et al 1998, Mackay, Ellis & Johnston 2005, Lunardi et al 2015). Due to this variance

in frequency and duration in postoperative physiotherapy treatments, total dosage differed amongst included trials: ranging from 1 to 17 treatment sessions, with a median total number of treatment sessions across all trials of 6 (IQR 3 – 10).

*Outcome measures*

A majority of trials (70%) reported on PPCs using composite symptom-based diagnostic tools (Laszlo et al 1973, Morran et al 1983, Celli, Rodriguez & Snider 1984, Roukema, Carol & Prins 1988, Condie, Hack & Ross 1993, Denehy 2001a, Mackay, Ellis & Johnston 2005, Silva, Li & Rickard 2013) or according to the composite incidence of different respiratory diagnoses (Stein & Cassara 1970, Bourn, Conway & Holgate 1991, Chumillas et al 1998, Kulkarni et al 2010, Carneiro et al 2013, Lunardi et al 2015). Others reported on specific diagnoses such as pneumonia (Hallböök et al 1984, Fagevik-Olsén, Josefson, Lönroth 1999) or clinical outcomes such as desaturation on room air (Fagevik-Olsén et al 1997), CXR abnormalities (Palmer & Sellick 1952), atelectasis (Giroux et al 1987), or patient-reported PPCs (Manzano et al 2008).

### 4.4.3 Synthesis of results: Meta-analysis

***Effect of chest physiotherapy versus no chest physiotherapy***

The pooled-effect across 15 studies on the incidence of PPC after abdominal surgery comparing chest physiotherapy, either preoperatively, postoperatively, or a combination of both, to no chest physiotherapy is shown in Figure 4.2. Individual trial results varied significantly between the 15 studies ($I^2 = 75\%$).

The pooled RR estimate of 15 trials finds that chest physiotherapy significantly reduced PPC compared to no chest physiotherapy (RR 0.86, 95% CI 0.81 to 0.91), equivalent to a NNT of 7 (95% CI 5 to 11). The pooled estimated PPC incidence was 29% (95% CI 25% to 32%) in the 621 control group participants who did not receive chest physiotherapy, 3.3% (95% CI 1.4% to 7.6%) in the 149 participants provided with preoperative physiotherapy alone, 27% (95% CI 21% to 33%) in 215 participants who received only postoperative physiotherapy, and 15% (95% CI 11% to 20%) in the 251 participants who were treated with a combination of both pre- and postoperative chest physiotherapy.

No substantial changes to the pooled RR estimate occurred with removal of trials with low methodological quality (PEDro < 5) or those involving manual therapy. The pooled estimate of effect in trials with low treatment dosage (three or less sessions) was 0.87 (95% CI 0.81 to 0.93) and similar to the estimate of effect of 0.84 (95% CI 0.76 to 0.93) in high treatment dosage trials (six to 17 sessions). This sub-group analysis is presented in Figure 4.3.

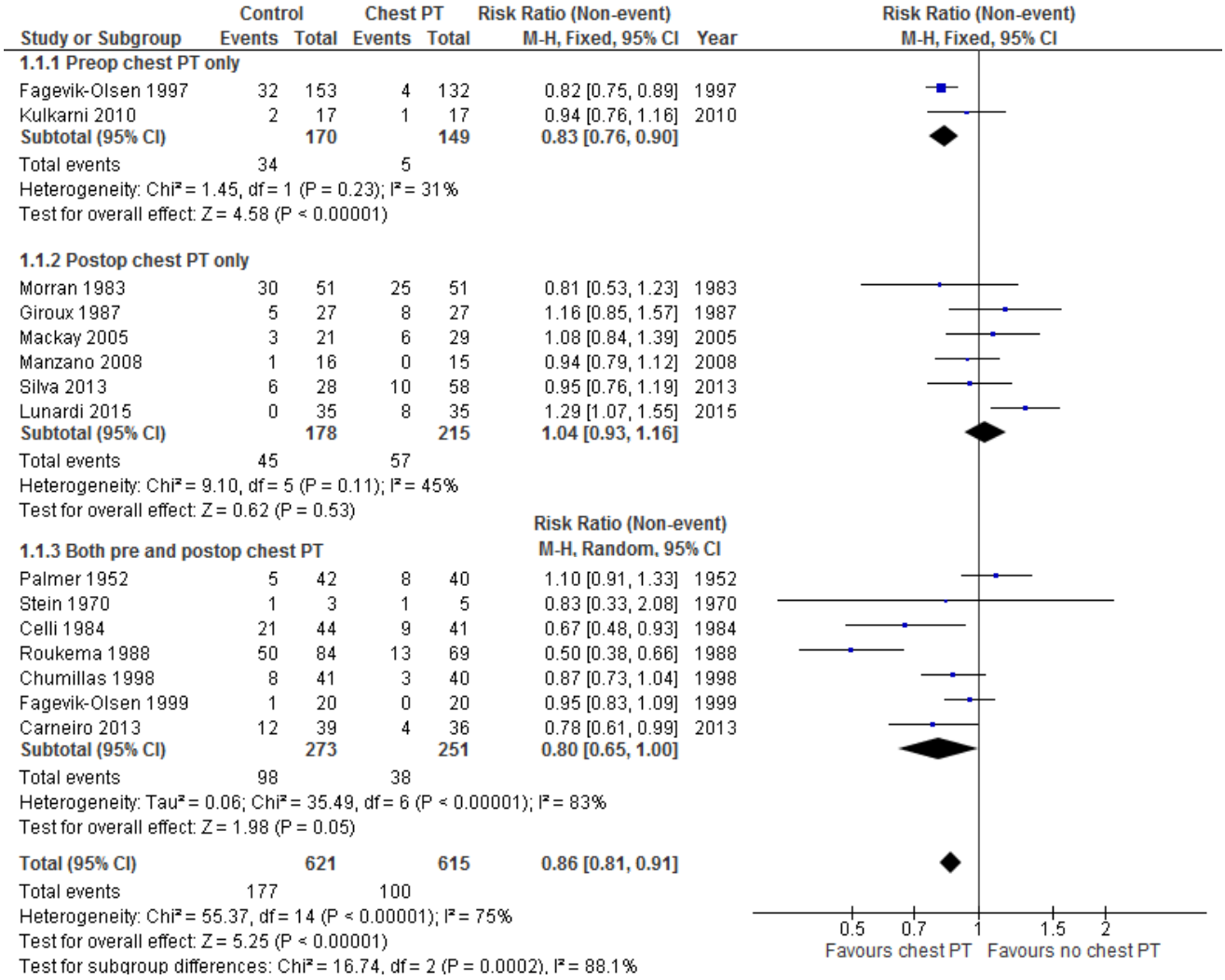
Trials (n=9) where preoperative physiotherapy was provided as part of the perioperative regime (preoperative chest physio alone or combined preoperative and postoperative service) had a significant estimated risk reduction in PPC incidence with a pooled RR of 0.79 (0.74 to 0.85), equivalent to a NNT of 5 (95% CI 4 to 7).

***Effect of preoperative chest physiotherapy alone versus no chest physiotherapy***

As shown in Figure 4.2, 1.1.1, there was significantly less risk of a PPC in those provided with preoperative chest physiotherapy alone compared to patients who received no chest physiotherapy with the true result being between 10% to 24% less risk in the treatment group (RR 0.83, 95% CI 0.76 to 0.90) providing a NNT of 6 (95% CI 4 to 10). There was good homogeneity within results ($I^2$ = 31%). A sensitivity analysis was not indicated as the two included studies had similar methodological scores, and treatment dosages, and did not employ manual techniques.

***Effect of postoperative chest physiotherapy alone versus no chest physiotherapy on PPCs***

The incidence of PPC was not significantly different when patients were provided with postoperative chest physiotherapy only (RR 1.04, 95% CI 0.93 to 1.16) as shown in Figure 4.2,



1.1.2. There was moderate heterogeneity between trial results ($I^2$ = 45%). Outcomes were not altered in sensitivity analyses according to methodological quality, treatment dosage, or additional usage of manual therapies.

**Figure 4.2** Meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery, sub-grouped into preoperative, postoperative, or combined pre- and postoperative treatment regimes.

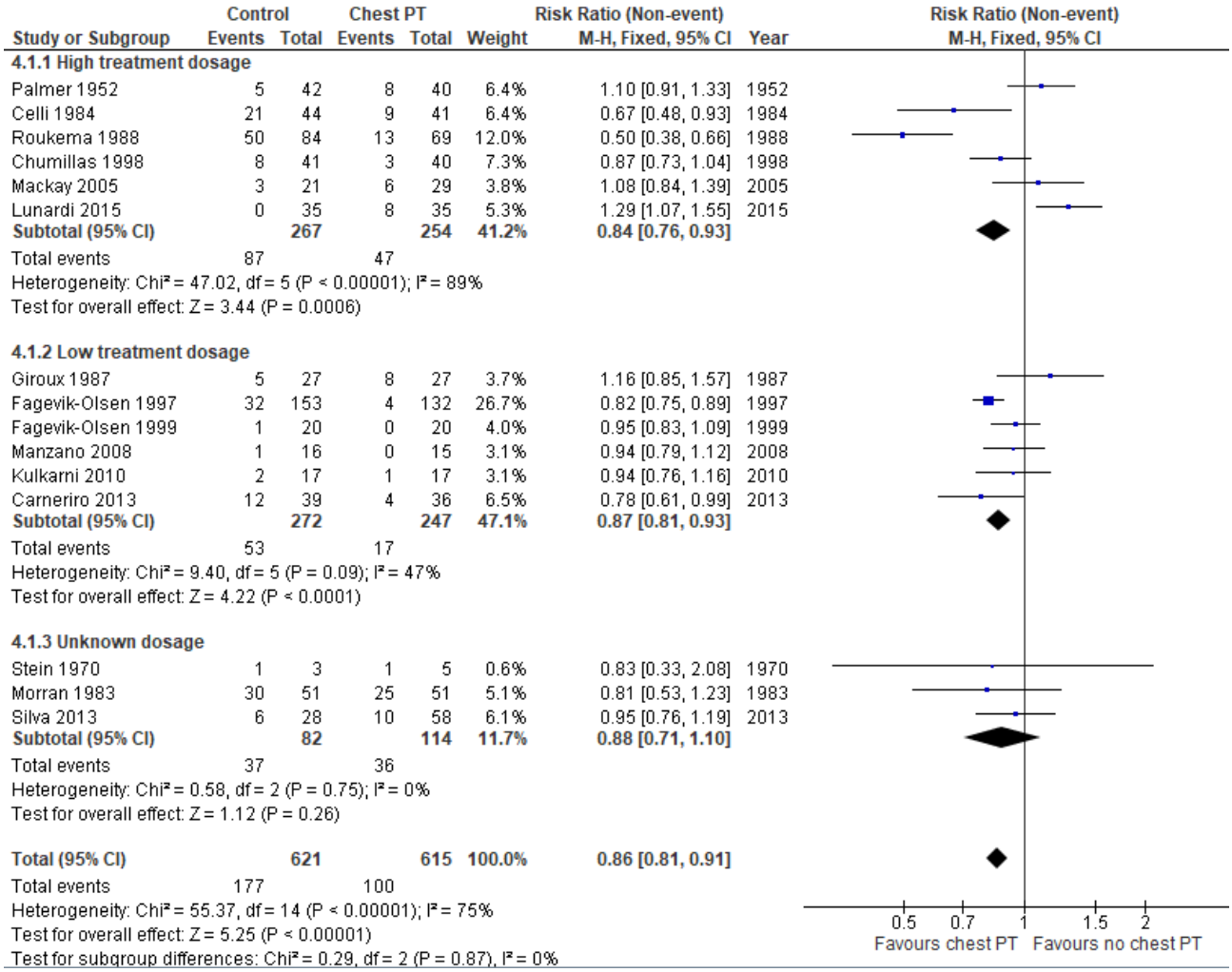



**Figure 4.3** Meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery, sub-grouped into high or low treatment dosage.

***Effect of combined pre- and postoperative chest physiotherapy versus no chest physiotherapy***

The RR estimate of 0.80 favoured participants provided with a combination of both pre- and postoperative chest physiotherapy (i.e. the risk of PPC was 20% lower). However, the 95% CI of 0.65 to 1.00 is wide. With the upper limit including 1.00, the possibility that combined pre- and postoperative chest physiotherapy is no better than no-treatment cannot be excluded (Figure 4.2,

1.1.3). There was a high degree of heterogeneity in individual trial RR estimates ($I^2$ = 83%). Sensitivity analyses did not alter the results.

***Effect of adding postoperative chest physiotherapy to preoperative chest physiotherapy alone***

Adding postoperative chest physiotherapy to preoperative education and breathing exercise training did not significantly influence the estimate of PPC risk compared with participants who received preoperative chest physiotherapy alone (RR 1.07, 95% CI 0.71 to 1.60, Figure 4.4). The individual trial results were homogenous ($I^2$ = 29%). Sensitivity analyses found no substantial change to the pooled estimates.

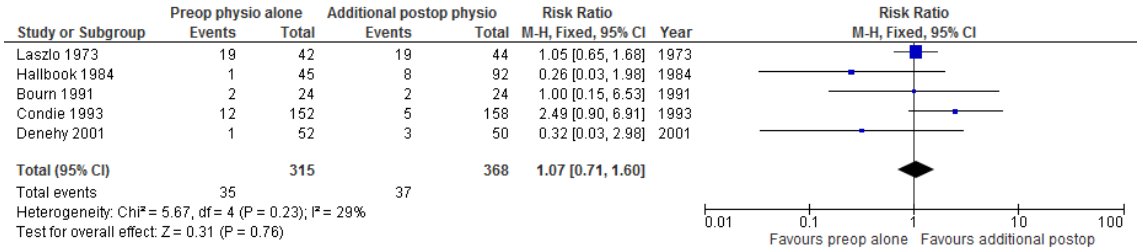



**Figure 4.4** Meta-analysis of the effect of additional postoperative chest physiotherapy compared with preoperative physiotherapy alone on PPC risk after abdominal surgery.

## 4.5 Discussion

This meta-analysis of 1236 participants having abdominal surgery from 15 trials, conducted 1950 to 2016, finds that compared to no treatment, chest physiotherapy of coached DB&C exercises significantly reduced PPC risk by approximately 14% with a true value between 9% and 19%. This is equivalent to a NNT of 7 (95% CI 5 to 11). However, confidence in this estimate may be dependent on *when* the patient is first seen by a physiotherapist. Sub-group analysis of these trials finds a statistically significant impact to PPC evident only in trials employing preoperative chest physiotherapy as part of the perioperative regimen, with a reduction in PPC risk 95% certain to be between 15% and 26%, giving a NNT of 5 (95% CI 4 to 7).

The effect of chest physiotherapy provided only in the postoperative phase is less certain. The sub-group meta-analysis of six RCTs finds that providing postoperative physiotherapy alone may not minimise PPC risk after abdominal surgery. With wide confidence intervals, however, there is not enough evidence to rule postoperative chest physiotherapy in, or out, as an effective method of PPC prophylaxis. This may be due to the delay in initiating DB&C exercises to the day after surgery. Forgiarini et al (2009) randomised 36 patients via concealed allocation into receiving physiotherapy in the immediate postoperative period and compared this to first receiving chest

physiotherapy the next day on the surgical ward. No preoperative physiotherapy had been provided to participants. Postoperative lung function was significantly less affected in those treated immediately after surgery, compared with those where the first physiotherapy session was the day after surgery. Although lung function may have benefited, it remains to be tested if chest physiotherapy in the recovery room immediately after surgery reduces PPC incidence in the absence of a preoperative physiotherapy service.

In trials testing a combined service of both pre- and postoperative chest physiotherapy, a significant reduction in PPC was detected, although the risk reduction was of a similar magnitude to a preoperative alone service. This raises the question whether adding a postoperative chest physiotherapy service of coached DB&C exercises confers any additional benefit over and above preoperative physiotherapy alone.

A meta-analysis of five trials conducted from 1973 to 2001 involving 683 participants finds that the addition of postoperative coached DB&C exercises to a preoperative physiotherapy service may not confer an additional benefit in reducing PPCs after abdominal surgery, compared with preoperative physiotherapy alone. However, with very wide confidence intervals this estimate lacks some precision. The possibility that PPC risk could be reduced with additional postoperative coached DB&C exercises cannot be excluded, nor that additional DB&C exercises could confer some harm by increasing the risk of PPC.

Grouping trials into high total dosage (6 to 17 treatment sessions) and low total dosage (3 or less sessions) of physiotherapy sessions finds pooled RR estimates are similar in both groups. This suggests that ‘more’ may not be necessarily better in minimising the risk of PPC. However, these data may be confounded by other factors of dosage, such as daily repetitions, frequency of delivery, and patient compliance, that have not been adequately explored with this analysis. Additionally, this sub-group analysis arbitrarily sets a total dosage cut-off of three sessions. A single-centre RCT has reported that patients instructed preoperatively to perform 30 reps of breathing exercises hourly for 2 days with a PEP device immediately after open cardiac surgery had improved oxygenation levels, compared with patients instructed to perform 10 reps per hour. (Urell et al 2011). Further RCTs are needed to test the influence of DB&C exercise dosage in preventing clinically relevant PPCs.

This systematic review of randomised controlled trials appears to support a physiological construct and preliminary clinical trials that timing of initiation of DB&C, rather than treatment dosage, may confer an advantage in minimising PPC after abdominal surgery. Atelectasis is present in almost all patients immediately following abdominal surgery (Lundquist et al 1995,

Strandberg et al 1986), with protracted postoperative atelectasis leading to hypoxemia and airway infection (van Kaam et al 2004, Duggan & Kavanagh 2005, Tusman et al 2012). Coached breathing exercises performed immediately after surgery have been shown to successfully reduce atelectasis (Westerdahl et al 2005), pulmonary shunt (Ntoumenopolous & Greenwood 1996), improve oxygenation (Manzano et al 2008), and limit deterioration in dynamic lung function (Zoremba et al 2009). Preparing and training a patient prior to surgery on the importance of performing breathing exercises immediately on waking from surgery could enable DB&C exercises to be initiated at a time when atelectasis is thought to be most malleable to prophylactic lung expansion efforts (Ball, Battaglini & Pelosi 2016, Baltieri et al 2014). It is feasible that if a patient initiates breathing exercises early and is motivated to continue to perform them self-directed and hourly over the following days that this could lead to reduced risk of PPC, without need for additional postoperative chest physiotherapy input.

A single preoperative education and DB&C training session has been found to ameliorate lung function deterioration by the second postoperative day (King & Tarsitano 1982) and is more effective in improving lung function than postoperative chest physiotherapy after abdominal surgery (Crawford, Blunnie & Elliott 1990). One of the earliest trials in physiotherapy was a non-randomised trial by Thoren (1954) who found that patients who received no chest physiotherapy after open cholecystectomy had a PPC rate of 42%. The addition of postoperative coached DB&C exercises reduced the PPC rate by a third to 27%. Adding preoperative physiotherapy reduced PPC incidence further again down to 12%. However, this non-randomised, non-blinded trial is likely to overestimate the benefit. Warren & Grimwood (1980) reported a prospective blinded observational trial of 194 patients having open cholecystectomy. Patients who did not receive preoperative physiotherapy were one to 3.5 times more likely to contract a PPC in the postoperative phase (RR 2.0, 95% CI 1.2 to 3.5). In 1985, Castillo & Haas completed a non-randomised trial of 280 participants having lung, cardiac, and abdominal surgery, where adding preoperative physiotherapy to a postoperative physiotherapy alone service significantly reduced atelectasis.

Given the results of this systematic review, it might be a concern that current physiotherapy practice for abdominal surgery patients is predominantly a postoperative alone service (Patman et al 2017, Reeve et al 2019, van Beijsterveld et al 2019). If these meta-analysis findings are generalizable to current populations and modern perioperative practices, this would suggest that current models of physiotherapy for abdominal surgery are ineffective in reducing PPC incidence after abdominal surgery. However, there are significant limitations to this systematic review and the included studies that would indicate that no firm conclusions can yet be made and predicate a cautionary approach to practice change.

The quality of included studies was generally limited by methodological weaknesses, multiple confounders, and poorly defined or uncertain endpoints. Only a fifth of included studies had a PEDro score of six or greater, and only one was a multicentre study. Most concerning was the risk of assessor bias with only six trials employing a blinded assessor to measure PPC incidence postoperatively. This could increase the likelihood of an overestimate of effect. Trials were also limited to those published in English. The primary PPC outcome was determined by a wide range of variants and definitions, which may or may not be valid in accurately detecting a clinically important complication (Abbott et al 2018). Other factors limiting the generalisability of findings to current practice are that most trials were conducted prior to 2010. Since this time there have been significant changes to perioperative surgical and anaesthetic practices. It is unknown if preoperative chest physiotherapy would be effective within Enhanced Recovery after Surgery (ERAS) frameworks (Gustafsson et al 2018), minimally invasive surgery techniques, and same day surgical admissions. All preoperative interventions studied in these included trials provided preoperative physiotherapy on the day before surgery. Preoperative physiotherapy may not be effective if it is moved to an outpatient pre-admission clinic conducted in the two to six weeks before surgery. It is possible that the impact of preoperative physiotherapy may be lost by not being delivered immediately before surgery, or if provided within the context of enhanced recovery pathways. Additionally, only two studies investigated a preoperative physiotherapy alone service compared to a no treatment control group, and most of the patients included in that sub-group meta-analysis came from a study that is now 33 years old. Moreover, the systematic review for this thesis was conducted by a single reviewer only. This could lead to biased trial selection, reporting, and interpretation (Page et al 2014). To improve the quality of this systematic review to a publishable standard would require an independent second reviewer to replicate the methods and reporting, with a third reviewer adjudicating any differences.

There are several strengths of this systematic review compared to others (Odor et al 2020, Pasquina et al 2006, Lawrence, Cornell & Smetana 2006). Firstly, included data were strictly limited to interventions only involving DB&C exercises without augmentation from incentive spirometers, PEP devices, or NIV. This ensures that the results are not confounded by the potential additive effect of these devices, with findings largely limited to the effect of DB&C exercises alone. Secondly, the search strategy included a broad range of databases, including modern indexing such as Google Scholar, and extensive hand-searching of reference lists and ‘grey’ literature sources, such as peer-reviewed PhD theses. This systematic review also carefully restricted trials to those with a true no-treatment control group. This provides a ‘clean slate’ in order to answer important clinical questions with confidence: in the absence of a current chest physiotherapy service “If I provide chest physiotherapy to patients having abdominal surgery

what effect will it have on PPC incidence?", or, conversely, if already provided as standard care, "What's the risk if I don't provide chest physiotherapy to patients having abdominal surgery?".

The divergence between current clinical practice and these meta-analysis findings strongly warrants an adequately powered, multicentre, randomised controlled trial with blinded assessors of a valid PPC endpoint, along with standardised early ambulation, an integrated health economic analysis conducted within modern perioperative practices of outpatient preadmission clinics, ERAS frameworks, and minimally invasive surgery techniques. This will confirm or discount the value of preoperative physiotherapy to reduce PPC after major abdominal surgery and provide clinicians and administrators with the information required to either reinstate preoperative physiotherapy or confidently know that this service is ineffective within the modern context.

The following three chapters present the protocol, primary results, and qualitative analyses from such a trial, all of which have been peer reviewed and published.

# CHAPTER 5

# LIPPSMAck POP trial: study protocol

## 5.1 Author contributions

IB conceived and designed the study, drafted and revised the protocol. LB, ES, JR, DE, and LD revised the study design and protocol. IR planned the statistical analysis. IB prepared the manuscript and was the corresponding author. All authors read and contributed intellectually important content and approved the final manuscript.

This study was supported by competitive research grants from the Clifford Craig Foundation, Launceston, Australia; the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia; and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand.

## 5.2 Published manuscript

Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials*. 2015 Dec 15;16:573. doi: 10.1186/s13063-015-1090-6.

This is an open-access journal. This chapter contains content which is unchanged from the accepted paper.

Further details are provided as thesis appendices (Human Research Ethics Committee letters of approval (Appendix III), participant information and consent forms (Appendix IV), information booklet (Appendix V), data collection forms (Appendix VI), and protocol badge cards for ward physiotherapists (Appendix VII)).

Boden et al. Trials (2015) 16:573
DOI 10.1186/s13063-015-1090-6

Trials

STUDY PROTOCOL Open Access

# The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial

Ianthe Boden[1,2*], Laura Browning[2,3], Elizabeth H. Skinner[2,4], Julie Reeve[5,6], Doa El-Ansary[2], Iain K. Robertson[7,8] and Linda Denehy[2]

## Abstract

**Background:** Post-operative pulmonary complications are a significant problem following open upper abdominal surgery. Preliminary evidence suggests that a single pre-operative physiotherapy education and preparatory lung expansion training session alone may prevent respiratory complications more effectively than supervised post-operative breathing and coughing exercises. However, the evidence is inconclusive due to methodological limitations. No well-designed, adequately powered, randomised controlled trial has investigated the effect of pre-operative education and training on post-operative respiratory complications, hospital length of stay, and health-related quality of life following upper abdominal surgery.

**Methods/design:** The Lung Infection Prevention Post Surgery - Major Abdominal- with Pre-Operative Physiotherapy (LIPPSMAck POP) trial is a pragmatic, investigator-initiated, bi-national, multi-centre, patient- and assessor-blinded, parallel group, randomised controlled trial, powered for superiority. Four hundred and forty-one patients scheduled for elective open upper abdominal surgery at two Australian and one New Zealand hospital will be randomised using concealed allocation to receive either i) an information booklet or ii) an information booklet, plus one additional pre-operative physiotherapy education and training session. The primary outcome is respiratory complication incidence using standardised diagnostic criteria. Secondary outcomes include hospital length of stay and costs, pneumonia diagnosis, intensive care unit readmission and length of stay, days/h to mobilise >1 min and >10 min, and, at 6 weeks post-surgery, patient reported complications, health-related quality of life, and physical capacity.

**Discussion:** The LIPPSMAck POP trial is a multi-centre randomised controlled trial powered and designed to investigate whether a single pre-operative physiotherapy session prevents post-operative respiratory complications. This trial standardises post-operative assisted ambulation and physiotherapy, measures many known confounders, and includes a post-discharge follow-up of complication rates, functional capacity, and health-related quality of life. This trial is currently recruiting.

(Continued on next page)

* Correspondence: ianthe.boden@ths.tas.gov.au
[1]Physiotherapy Department, Launceston General Hospital, Charles St, Launceston, Tasmania 7250, Australia
[2]Department of Physiotherapy, Melbourne School of Health Sciences, University of Melbourne, Parkville, Victoria 3010, Australia
Full list of author information is available at the end of the article

BioMed Central

© 2015 Boden et al. **Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

(Continued from previous page)

**Trial registration:** Australian New Zealand Clinical Trials Registry number: ACTRN12613000664741, 19 June 2013.

**Keywords:** Physiotherapy, Abdominal surgery, Breathing exercises, Post-operative pulmonary complication, Pre-operative education, Prevention, Randomised controlled trial

## Background

Elective upper abdominal surgery (UAS) is planned surgery involving an open incision above or extending above the umbilicus [1] and is predominately performed to remove cancerous tissue. Approximately 500 to 1000 procedures per 100,000 head of population are performed annually in developed countries [2, 3]. The most common complication following UAS is a post-operative pulmonary complication (PPC) [4] with a reported incidence of 13–53 % [5–10]. This is higher than the incidence for other major surgical procedures such as open lung resection, cardiac surgery via sternotomy, open lower abdominal surgery, and orthopaedic surgery [11–13]. A PPC is either a specific respiratory complication such as pneumonia or an undefined respiratory dysfunction that is clinically significant, compromises a patient's predicted recovery, and requires additional medical management [14]. The variability in PPC rates following UAS may be explained by the differing studied patient risk profiles and PPC definitions utilised.

Respiratory pathophysiological changes after UAS are well reported, including atelectasis, impaired mucociliary clearance, diaphragm dysfunction, reduced lung volumes, and respiratory muscle and cough strength deficiencies [15–28]. These can contribute to bacterial proliferation and/or severe atelectasis [17, 29], thus increasing respiratory infection risk [14, 15]. PPCs are associated with increased morbidity, mortality, hospital expenditure, and length of stay (LOS) [5, 30–32]. Strategies to prevent PPCs should remain a high priority [33] due to their relatively high prevalence, relationship to poor patient outcomes, and increased health care costs.

Preventative non-pharmaceutical therapies such as coached deep breathing and coughing (DB&C) exercises and early ambulation are traditionally provided to patients following UAS [34]. Additionally, incentive spirometers [35], positive expiratory pressure (PEP) devices [36], and non-invasive ventilation (NIV) [37] can be utilised. These are often delivered by physiotherapists [8, 38], though in countries where physiotherapists are not involved with this patient group, this type of respiratory therapy is provided by nurses, doctors, or other health professionals [36, 39]. However, the efficacy of post-operative respiratory therapy to prevent PPCs following UAS is controversial. Systematic reviews and meta-analyses have concluded that lung expansion exercises including DB&C [40], incentive spirometry [35], and PEP [41] are of little benefit in reducing PPCs, with only NIV considered efficacious [37, 42]. Specifically, when post-operative ambulation is standardised, the addition of DB&C exercises does not reduce the incidence of PPCs in addition to assisted early ambulation alone [7, 10]. However, almost all clinical trials have included pre-operative physiotherapy (Pre-Op) education and training as usual care delivery to all participants. It is possible that this intervention alone may have independently reduced the risk of a PPC.

Evidence from six clinical trials [43–48] suggests that a single Pre-Op education session may reduce PPC rates by up to 78 % [47, 48] after UAS. However, these trials have methodological limitations, including small sample sizes, inconsistent end points, generalisability restrictions (single-centre trials, predominantly low-risk patient groups), sources of bias (non-random sampling, unblinded assessors and Hawthorne effects), and non-standardisation or reporting of potential confounders. These methodological limitations bring the reported effect on PPC rates with pre-operative physiotherapy education into question.

Even if the reported benefit on PPC rates is a true effect, it is not known if Pre-Op education and training would be effective in the context of recent advances in perioperative management such as Enhanced Recovery After Surgery (ERAS) guidelines. This multimodal package of 10–18 care elements provides significant improvements in complication rates and LOS [49]. Pre-operative education and lung expansion training are strongly recommended within ERAS guidelines, although it is acknowledged that evidence to support this specific element is weak [50]. Additionally, Pre-Op physiotherapy interventions previously studied were predominantly provided the day before surgery. This may not reflect current practice where, in many centres, patients attend a multi-disciplinary assessment clinic one to 6 weeks before their operation [51–53]. It is unknown whether Pre-Op physiotherapy education provided at these longer time intervals might also produce the previously reported effect on PPC prophylaxis.

Surveys of physiotherapy services to UAS patients in Australia have shown a stark reduction in hospitals (20 % down to 5 %) providing Pre-Op physiotherapy over the past 15 years [34, 54]. The reasons for this disinvestment of services are unknown. There are no cost-benefit analysis studies investigating physiotherapy to reduce respiratory complications, so conclusive evidence to

inform the allocation of physiotherapy services to pre-operative education and training is lacking. Additionally, only short-term outcomes have been assessed. Reducing PPCs during the acute hospital stay may also improve important patient-focused longer term outcomes such as health-related quality of life (HRQoL) and physical capacity following discharge.

Considering the relative high incidence of PPCs following major UAS and the benefit to both the patient and the health care system if these were reduced, a well-designed, adequately powered trial is needed to determine both the clinical effect and cost benefit that Pre-Op physiotherapy education and training may, or may not, have on reducing PPC incidence following major UAS. Results will guide future cost-effective allocation of services to patients who require UAS.

### Trial objectives

The primary objective of the Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy (LIPPSMAck POP) trial is to estimate the effect that Pre-Op physiotherapy education and training has on the incidence of PPCs following major UAS, when compared to an information booklet alone. Secondary objectives are to evaluate the effect of Pre-Op physiotherapy on hospital and ICU LOS, hospital costs, incidence of pneumonia, unplanned ICU admissions, time to early ambulation, readiness to discharge from hospital, and, at six weeks following surgery, patient-reported complications, HRQoL, and functional capacity.

## Methods/design

### Trial design

The LIPPSMAck POP trial is a pragmatic, investigator-initiated, bi-national, multi-centre, randomised controlled, parallel group, clinical trial. It is patient- and assessor-blinded, and powered for superiority. Eligible patients will be randomly assigned via concealed allocation to receive 1) a pre-operative assessment by a physiotherapist and provision of an information booklet (control) or 2) a pre-operative assessment, information booklet, plus an additional education and DB&C training session by a physiotherapist (intervention). Post-operative respiratory physiotherapy and assisted early mobilisation will be standardised for both groups. See Fig. 1 for a CONSORT diagram of the LIPPSMAck POP trial and Table 1 for an overview of the trial methods and design.

### Trial setting

The three participating centres: the Launceston General Hospital (Launceston, Tasmania, Australia), North Shore Hospital (Auckland, New Zealand), and North West Regional Hospital (Burnie, Tasmania, Australia), represent a range of public hospital types. The North West Regional Hospital is a 240-bed rural secondary referral hospital; the Launceston General Hospital is a 330-bed inner-regional, primary referral hospital; and the North Shore Hospital is a 600-bed metropolitan, primary referral hospital. North Shore Hospital has also implemented Enhanced Recovery After Surgery (ERAS) guidelines to all surgical units. All hospitals are government funded, university affiliated, teaching hospitals.

Patients undergoing elective UAS at the participating centres attend an outpatient Pre-Admission Clinic (PAC) session one to six weeks prior to their operation where they are assessed by a multi-disciplinary team consisting of, as a minimum, a registered nurse, anaesthetist, and doctor from the admitting surgical team. Information about the surgical process, pain management, post-operative drips and drains, and expected recovery process are provided as standard care. Whereas, Pre-Op physiotherapy education and training at PAC is not normally provided, post-operative respiratory therapy and assisted ambulation by a physiotherapist are provided as standard care at the participating centres.

Each participating hospital's institutional review board has approved the trial (the Human Research Ethics Committee (Tasmania) Network, Tasmania, Australia (protocol reference: H0011911), the Health and Disability Ethics Committee, New Zealand (protocol reference: 14/NTA/233)). The trial is conducted in accordance with the Declaration of Helsinki and was prospectively registered on 19 June 2013 at the Australian New Zealand Clinical Trials Registry (http://www.anzctr.org.au): ACTRN12613000664741.

### Eligibility and exclusion criteria

Eligible participants are patients over the age of 18 years attending PAC at the participating centres who are scheduled for UAS expecting to require an abdominal incision longer than 5 cm that will be above, or extending above, the umbilicus (Table 2) and requiring a minimum overnight hospital stay.

Patients are excluded for any of the following criteria: (i) unable to understand verbal instructions in English; (ii) unable to participate in a single pre-admission session with a physiotherapist; (iii) requiring emergency surgery; (iv) a current hospital patient for a separate episode of care; (v) requiring organ transplant; (vi) open abdominal hernia repairs (hernia repairs are generally low-risk procedures which frequently do not involve extensive visceral manipulation and have fewer complications [55]); (vii) being unable to stand upright and ambulate for a maximum of 1 min.

### Randomisation and allocation

An administration assistant independent to the trial will prepare 441 sequentially numbered (1 to 441) opaque envelopes each containing an allocation card wrapped in

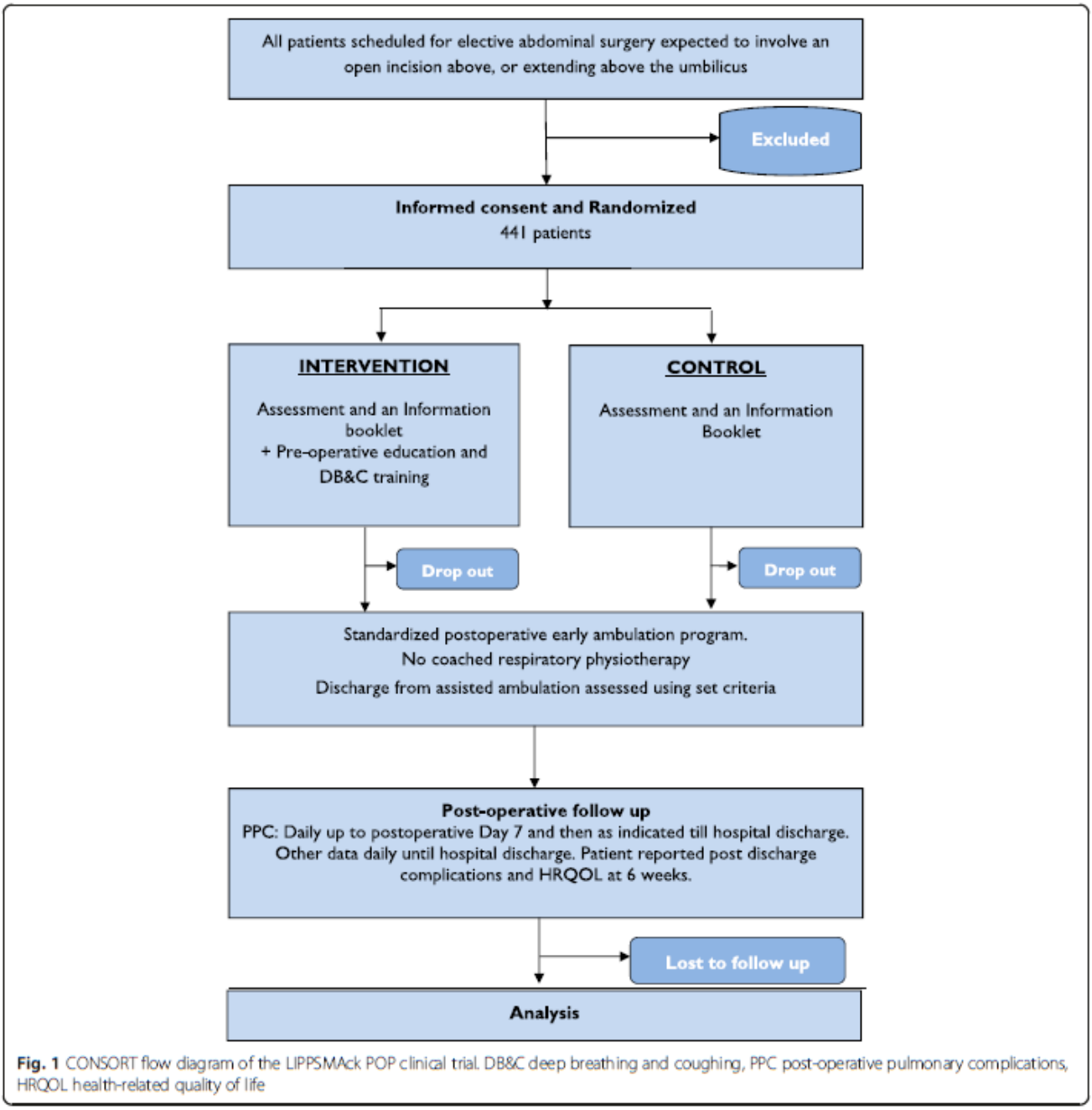



**Fig. 1** CONSORT flow diagram of the LIPPSMAck POP clinical trial. DB&C deep breathing and coughing, PPC post-operative pulmonary complications, HRQOL health-related quality of life

extra paper or aluminium foil [56]. Allocation sequence is determined by a web-based computer generated (http://www.randomizer.org/) blocked random number table (7 blocks of 63; 1 = intervention, 2 = control). The randomisation tables are then sealed in an opaque envelope, locked within the research institute, and made unavailable to trial personnel. The number of consecutively numbered envelopes provided to each site will be dependent on funding agreements (that is, funded to recruit one block of 63 participants or, on a per patient recruit basis, until the end of the trial).

Local investigators will screen elective surgery and PAC lists daily for eligible patients who will be met face to face by local investigators at their PAC appointment. Informed consent will be obtained from potential participants; each eligible participant will be provided with a trial information sheet which is explained verbally to them and will be invited to participate. Those agreeing will sign a consent form as required by local ethics committees and in accordance with the Declaration of Helsinki. Where the local investigator or eligible patient is unable to attend PAC, the latter will be contacted by

**Table 1** World Health Organisation (WHO) Trial Registration Data Set for LIPPSMAck POP trial

| Data category | Information |
|---|---|
| Primary registry and trial identifying number | Australian New Zealand Clinical Trials Registry number: ACTRN12613000664741 |
| Date of registration in primary registry | 19/6/2013 |
| Secondary identifying numbers | n/a |
| Trial protocol version | This is Version 4 of the protocol and was enacted on June 2013 |
| Source(s) of monetary or material support | Clifford Craig Medical Research Trust ($60,000 AUD) |
| | University of Tasmania, virtual Tasmanian Academic Health Precinct ($50,000 AUD) |
| | Waitemata District Health Board and Three Harbours Health Foundation ($20,000 NZD) |
| | Tasmanian Health Service - Northern Region ($120,000 AUD) |
| Primary sponsor | Tasmanian Health Service - Northern Region |
| Secondary sponsor | Waitemata District Health Board |
| Contact for public queries | IB, ianthe.boden@ths.tas.gov.au |
| Contact for scientific queries | IB, ianthe.boden@ths.tas.gov.au |
| Public title | Pre-operative physiotherapy education for the prevention of chest infections following major abdominal surgery |
| Scientific title | LIPPSMAck POP trial – Pre-operative physiotherapy education for the prevention of post-operative pulmonary complications following major upper abdominal surgery: a bi-national, multi-centre, randomised, double-blinded placebo controlled trial. |
| Countries of recruitment | Australia, New Zealand |
| Health condition(s) or problem(s) studied | Pulmonary complications following major upper abdominal surgery |
| Intervention(s) | Active comparator: Pre-operative physiotherapy education and training |
| | Placebo comparator: Education booklet |
| Key inclusion and exclusion criteria | Ages eligible for study: ≥ 18 years |
| | Sexes eligible for study: both |
| | Accepts health volunteers: No |
| | Inclusion criteria: All adults awaiting elective upper abdominal surgery involving an open incision above the umbilicus. |
| | Exclusion criteria: 1. Any pre-existing condition that would limit ability to participate in the standardised post-operative mobilisation protocol. Defined as any person unable to stand upright and walk for a maximum of 1 min without a seated rest. 2. Unable to understand verbal instructions in English. 3. Unable to attend a pre-admission assessment and education session with a physiotherapist. 4. Open abdominal hernia repairs. |
| Study type | Type: Investigator initiated, interventional, non-pharmacological, pragmatic, study |
| | Allocation: Concealed randomisation |
| | Intervention model: parallel assignment |
| | Masking: patient and assessor blinded |
| | Primary purpose: Prevention |
| | Phase: Phase III |
| Date of first enrolment | 24/6/2013 |
| Target sample size | 441 |
| Recruitment status | Recruiting |
| Primary outcome(s) | Post-operative pulmonary complications during the first 14 days of the hospital stay |
| Key secondary outcomes | Pneumonia, length of hospital stay, hospital costs, day of ambulation >10mins, length of ICU stay, ICU readmission, post-operative adverse events, day to discharge from post-operative physiotherapy services, patient-reported complications, health-related quality of life, and physical capacity at 6 weeks following discharge from hospital. |

**Table 2** List of eligible upper abdominal surgical procedures

| Surgical category | Procedure |
|---|---|
| Colorectal | Anterior resection |
| | AP resection |
| | Hartmanns |
| | Hemicolectomy |
| | Low anterior resection |
| | Laparoscopic (+/−hand) assisted colectomy |
| | Partial colectomy |
| | Proctocolectomy |
| | Reversal of Hartmanns |
| | Sigmoid colectomy |
| | Small bowel resection |
| | Subtotal colectomy |
| | Total colectomy |
| Upper gastrointestinal | Gastrectomy |
| | Liver resection |
| | Oesophagectomy |
| | Open cholecystectomy |
| | Open hiatus hernia repair |
| | Pancreatic surgery |
| | Whipples |
| Urology | Adrenalectomy |
| | Cystic duct excision |
| | Nephrectomy |
| | Laparoscopic +/− hand assisted nephrectomy |
| | Pyeloplasty |
| | Radical cystectomy +/− ileal conduit |
| | Radical cystoprostatectomy |
| Other | Explorative laparotomy |
| | Splenectomy |

telephone and invited to enter the trial. The information and consent form will be mailed by post for signing, and the participant will be requested to bring them to hospital on the day of their operation.

Once informed consent has been obtained and the consent form signed, the pre-operative physiotherapist receives the group allocation for participants by opening the next sequentially numbered sealed opaque envelope containing the randomised group allocation. Patient details will be written on the envelope once opened to ensure that patients are randomised in the same order as recruited and the envelopes filed securely along with the consent form. Potential selection bias will be studied by extracting basic demographic data and planned surgical procedure from all excluded patients' medical records.

### Trial interventions

Consenting participants will be randomly assigned to receive either i) a pre-operative assessment from a physiotherapist and provision of an information booklet (control) or ii) an additional education and DB&C training session (intervention).

### Control group

Participants will have a standardised assessment conducted by a physiotherapist consisting of: questioning on current health co-morbidities, mobility and functional status, smoking history, lung auscultation, subjective assessment of cough quality and strength, sputum production and colour, hand grip strength, Rapid Assessment of Physical Activity (RAPA) [57] and Specific Activity Questionnaire (SAQ) [58] to determine current activity and fitness levels, and Short Form 36 (SF-36 V2) [59] to measure HRQoL (see Data Collection section for further details). Participants will then be provided with an education booklet. This colour booklet contains written and pictorial information about abdominal surgery, expected types of pain management, medical lines and drains, post-operative recovery process, and how to prevent post-operative respiratory complications with early ambulation and self-directed DB&C exercises. The booklet includes detailed written instructions to perform DB&C exercises for two sets of 10 deep breaths followed by three coughs every hour during waking hours. Participants will be instructed to bring the booklet to hospital for reference following the operation. The contents of the booklet will not be discussed with participants in the control group and there will be no additional physiotherapy provided pre-operatively.

### Intervention group

Intervention group participants will be assessed and provided with an information booklet as per the control group and will then receive an additional single education and training session of approximately 30 min with a physiotherapist. Participants will be given an estimate of their likelihood of a PPC based on a risk prediction tool [5] and educated about the effect of anaesthesia, UAS, and bed rest on mucociliary clearance and lung volumes [19, 20]. To ameliorate these factors and prevent bacteria stagnation [15, 16] the importance of participating in an early post-operative ambulation program and performing self-directed DB&C exercises will be emphasised. Participants will be informed that a physiotherapist will assist them to walk as soon as possible on the first post-operative day, aiming for a duration longer than 10 min and at a pace causing mild breathlessness. Outside these assisted sessions, participants will be advised to walk or exercise by their bedside as frequently as they are able.

As it is frequently not possible to ambulate as early and as often as recommended to assist in preventing respiratory complications [8, 60], participants will be educated on the necessity of performing self-directed breathing exercises to protect their lungs following their operation. They will be instructed to perform DB&C exercises immediately from waking from the anaesthetic and then every hour during daytime waking hours until their first ambulation session, and then at any time when they are not ambulant. The physiotherapist will coach each participant in at least three repetitions, and as many as required to master technique as judged by the physiotherapist. This trial's DB&C exercises consist of two sets of 10 slow-flow breaths to maximum inspiratory capacity with two to three inspiratory sniff breath stacking manoeuvres [61]. Each breath is held for 3 to 5 s. Each set of 10 breaths is followed by three coughs, or a forced expiratory technique with an open glottis called a 'huff', with a small firm pillow pressed over on the abdominal incision to support the wound and to encourage greater expiratory force. Participants will be encouraged to practice these exercises prior to their operation to develop familiarity.

### Standardisation of pre-operative interventions

The information booklet content will remain consistent between participating centres, although the formatting may change for site-specific requirements. All participating pre-operative physiotherapists will be required to view a scripted audio-visual recording of the pre-operative intervention prior to recruiting their first patient. They are instructed to adhere to the overall themes and premises of information delivery as included within the protocol script and video. Years of experience, seniority grade, and numbers of participants seen by each physiotherapist will be reported.

Ideally, interventions will be provided in person at PAC within six weeks of the scheduled surgery. However, in keeping with a pragmatic approach, if an eligible patient or physiotherapist is unable to attend PAC, patients can be enrolled, randomised, and provided with the interventions on another convenient day, or via telephone, prior to surgery. The mode of delivery will be recorded and the total proportion of telephone sessions will be reported. If a participant's operation is delayed and the time from Pre-Op physiotherapy to day of surgery becomes greater than 42 days, a physiotherapist will contact the participant by phone for a review assessment and to remind them to read the booklet as provided at PAC. Participants allocated to the intervention group will, in addition, have a review of the education session and the DB&C exercises repeated over the phone.

### Standardisation of post-operative procedures

At the first available opportunity following surgery, all participants will be seen by a physiotherapist for a standardised assisted ambulation session (see Table 3). Ambulation is defined as marching on the spot beside the bed or walking away from the bedside for more than 1 min. Once a patient is ambulant for more than one minute, an Allied Health Assistant (AHA) will conduct all further ambulation sessions. If an AHA is unavailable, then a physiotherapist will continue to provide assisted ambulation. Health professionals (profession and years of experience) delivering ambulation will be reported. Participants will be seen once daily until discharged from physiotherapy services using defined scoring criteria [62] (see Table 4) or until discharged from hospital.

At each session the participant will be progressed sequentially through the ambulation protocol stages aiming to achieve a walking time of more than 10 min at an intensity of at least three on the Borg 10-point visual analogue scale of perceived exertion [63] and where breathing is deeper than at rest. If necessary, ambulation sessions can comprise intervals at a work/rest ratio of 1:1. Shorter, but not longer, rest times are allowable. The final achieved ambulation stage is the total amount of time walked, not including rest periods. If participants are unavailable or unable to achieve ambulation for more than 1 min, the assisted ambulation session will be attempted again later in the day. Reasons will be recorded where participants are unable to ambulate or do not achieve a minimum of 10 min walking. Physiotherapists and AHAs will be provided with protocol prompt cards and trained by the site investigator.

At the first ambulation session participants will be provided with a walking aid if required, an abdominal support pillow for use during coughing, and a brief reminder to perform DB&C exercises as described within the information booklet provide pre-operatively. If a participant has forgotten his/her booklet, a new one will be provided. Participants will be encouraged to ambulate frequently to aid in the prevention of PPCs and encouraged to seek assistance from a nurse if necessary and to

**Table 3** LIPPSMAck POP ambulation protocol

| | |
|---|---|
| Stage 1 (Safety) | Sit over edge of bed/sit in chair minimum of 2 min |
| Stage 2 (Safety) | March on spot 0–1 min |
| Stage 3 (Ambulation) | March on spot/walk away from bedside 1–3 min |
| Stage 4 (Ambulation) | March on spot/walk away from bedside 3–6 min |
| Stage 5 (Ambulation) | Walk away from bedside 6–10 min |
| Stage 6 (Ambulation) | Walk away from bedside 10–15 min |
| Stage 7 (Ambulation) | Walk away from bedside >15 min |

**Table 4** Discharge from physiotherapy scoring tool [62]

| Mobility | Score |
|---|---|
| Reached pre-operative ambulation status | 3 |
| Requires supervision, status has plateaued | 2 |
| Requires assistance, status is improving | 1 |
| Unable to ambulate | 0 |
| Breath sounds | |
| Reached pre-operative levels and within expectations for that patient | 3 |
| Slightly decreased breath sounds or presence of a few added sounds | 2 |
| Markedly abnormal breath sounds and/or significant added sounds | 1 |
| Secretion clearance | |
| Able to clear secretions independently OR at pre-operative status | 3 |
| Requires assistance to clear secretions | 1 |
| $SpO_2$% (on room air or pre-op oxygen levels) | |
| $SpO_2 \geq 92$ % (no respiratory condition) OR $SpO_2 \geq 88$ % (existing respiratory condition) | 3 |
| $SpO_2 < 92$ % (no respiratory condition) OR $SpO_2 < 88$ % (existing respiratory condition) | 2 |
| Respiratory rate (at rest and during activity) | |
| Within normal expectations | 3 |
| Outside acceptable range for the individual | 2 |
| Total score (min 6, max 15) | |
| A score ≥14 = discharge from physiotherapy | |

walk with their visitors. There will be no further provision of DB&C, PEP devices, incentive spirometers, or NIV by physiotherapists or AHAs.

Additional ambulation occasions outside physiotherapy assisted sessions or other ward staff encouraging patients to perform respiratory exercises will not be measured or controlled, as this would not be feasible. Both are considered standard ward care for both control and intervention group participants. However, if a participant is provided with an incentive spirometer or PEP device, this will be immediately removed. The break to protocol and duration of access to device will be recorded.

All other aspects of patient care, including pre-operative preparation, general anaesthesia, intraoperative ventilation parameters, fluid delivery, prophylactic antibiotic prescription, pain management, use of lines and drains, general nursing care, and discharge planning, will be provided at the discretion of nurses and physicians according to routine clinical practice at each participating centre.

### Blinding

Pre-admission clinic nurses and physiotherapists aware of group allocation will not have contact with participants post-operatively. A trial participation sticker (excluding group allocation) will be placed in the medical record. All post-operative ward staff, physiotherapists, PPC assessors, doctors, surgeons, nurses, discharge planners, data analysts, and statisticians will be blinded to group allocation. If a treatment group participant informs the assessor of their pre-operative education session, this will be noted and reported.

It is anticipated that patients will consider the pre-operative physiotherapy assessment and provision of a booklet an acceptable 'sham' treatment. This will be measured by interviewing a convenience sample of 30 consecutive participants via a semi-structured interview on their fifth post-operative day, or on the day of discharge, whichever comes first. They will be asked which group they believed they had been allocated to and, to test fidelity of the intervention over the control, what they remembered from their pre-operative physiotherapy session. The success of participant and therapist blinding will be tested and reported by requiring post-operative physiotherapists, AHAs, and assessors to guess group allocation for each of these 30 participants.

### Withdrawal from trial

Participants will be withdrawn for either of the following: (i) failure to progress to surgery within the first 3 months of PAC attendance or (ii) withdrawal of consent. All withdrawals and reasons will be reported.

### Primary outcome

The primary outcome is the development of a PPC within the first 14 post-operative hospital days. PPCs will be diagnosed with the Melbourne Group Scale (MGS) diagnostic scoring tool, which is reliable and valid following UAS and thoracic surgery [5, 8] and has high inter-rater reliability [64]. This tool has eight clinical criteria: four factors relating to symptoms and four to diagnostic markers (Table 5). A PPC will be diagnosed when four or more factors are present from midnight to midnight on one post-operative day.

Participants will be assessed prospectively and daily for a PPC by a blinded assessor until the seventh post-operative day. Thereafter, additional PPC assessments are performed only as clinically suspected until day 14 when there are signs or symptoms of respiratory system deterioration reported within the medical record. To reduce the potential for missing data, retrospective collection of PPC data from the daily medical record will be permitted when a patient or assessor is unavailable for PPC assessment. The proportion of retrospective assessments will be reported. Components will be collected via the patient's medical record and pathology/radiology databases. Diagnostic components (chest X-ray (CXR), white cell count (WCC), sputum microbiology) are

**Table 5** MGS PPC diagnostic criteria with modifications*

| Diagnosis confirmed when four or more of the following are present: |
|---|
| Clinical factors |
| • New abnormal breath sounds on auscultation different to pre-operative assessment |
| • Production of yellow or green sputum different to pre-operative assessment |
| • Pulse oximetry oxygen saturation ($SpO_2$) <90 % on room air on more than one consecutive post-operative day |
| • Raised maximum oral temperature >38 °C more than one consecutive day |
| Diagnostic factors |
| • Chest radiograph report of collapse/consolidation. *When a CXR has been taken but no report is available, a ward medical officer or a senior respiratory physiotherapist with more than 10 years' experience will be asked to report |
| • An unexplained WCC greater than $11 \times 10^9$/L |
| • Presence of infection on sputum culture report |
| • Physician's diagnosis of *pneumonia, URTI, or an undefined chest infection, or prescription of an antibiotic for a respiratory infection |

* modification made to original criteria

recorded only if results are available. All medical officers are masked to group allocation and these diagnostic tests are ordered only as clinically indicated, and not routinely for the purposes of the LIPPSMAck POP trial.

For this trial, modifications (* in Table 5) have been made to diagnostic criteria to ensure that respiratory therapy will not be withheld longer than necessary from patients who may have developed a PPC. A CXR can be verbally reported by a blinded senior respiratory physiotherapist or ward physician, rather than awaiting a radiologist report. When three factors (out of a possible eight) in the MGS PPC tool are present, the blinded assessor or ward physiotherapist will contact the surgical ward doctor and discuss the option of further diagnostic testing to rule in or out a PPC. Additionally, these patients will be assessed twice daily to monitor clinical criteria for any deterioration.

A positive diagnosis of a PPC will be confirmed by a blinded senior physiotherapist, and the participant will then receive respiratory treatment as determined by the ward physiotherapist.

### Secondary trial outcomes

Secondary outcomes (Fig. 2) are:

1) Days of hospital length of stay (LOS). This is defined as the continuous time spent in any type of inpatient hospital service (acute care, sub-acute rehabilitation, and time at another hospital) from the day of admission to the day of discharge to a community dwelling
2) ICU LOS in days;
3) Unplanned ICU admission at any time point during the acute stay;
4) Pneumonia, defined as the presence of new CXR infiltrates along with at least two of the following criteria: temperature >38 °C, dyspnoea, cough and purulent sputum, altered respiratory auscultation, and WCC >14,000/ml or leukopenia <3000/ml [65] on any day within the first 14 post-operative hospital days;
5) Time in hours from end of operation to time able to achieve ambulation greater than 1 min;
6) Time in days from end of operation to post-operative day able to achieve ambulation greater than10 min;
7) Time in days to discharge from physiotherapy service (Table 4) [62];
8) Time in days to readiness for discharge from hospital as defined by standardised scoring criteria [66];
9) Hospital costs for the UAS admission episode of care. This will be supplied by the participating centres' or health departments' costing data for each participant's admission episode.
10) Patient-reported complications at 6 to 8 weeks following day of surgery using a standardised semi-structured interview; and
11) HRQoL using the SF-36 and functional capacity using SAQ [58, 67] at 6 to 8 weeks following day of surgery.

Post-hospital discharge follow-up of self-reported complications, SF-36, and functional capacity will be via phone interview with a site investigator at 6 weeks from the date of surgery. If patients are unable to be contacted by phone for a period of five consecutive working days, a standardised cover letter, questionnaires, and self-addressed return paid envelope will be posted to the participant. Forms not returned within 2 weeks of posting will be considered lost to follow-up for the post-discharge secondary outcomes.

### Data collection

#### Pre-operative variables

To measure baseline characteristics the following variables will be collected directly from the patient or the medical record: centre of recruitment, age, gender, height (cm), weight (kg), body mass index ($kg/cm^2$), planned surgical procedure, category (hepatobiliary/upper gastrointestinal, colorectal, renal and urology, vascular, or other) and reason for the procedure, physical health status according to the American Society of Anaesthesiologists (ASA) and rated by the attending anaesthetist at the PAC (score 1 to 5), chemotherapy during the preceding 6 weeks, presence of a nasogastric tube before operation, respiratory status (auscultation signs and patient report of a daily productive cough), cough strength and presence of sputum (patient is

| | | STUDY PERIOD | | | | | |
|---|---|---|---|---|---|---|---|
| | | Eligibility | Enrolment & Allocation | Post-allocation | | | Close-out |
| | | $-t_1$ | 0 | $t_1$ - $t_7$ | $t_8$ – $t_{14}$ | $t_{15}$ | $t_{16}$ |
| | TIMEPOINT | *Listed for elective surgery* | *Pre-Admission clinic* | *POD 1 to POD 7* | *POD 8 to POD 14* | *Hospital D/C* | *6-8 weeks following date of surgery* |
| ENROLMENT: | Enrolment | | X | | | | |
| | Eligibility screen | X | | | | | |
| | Informed consent | | X | | | | |
| | Random allocation | | X | | | | |
| INTERVENTIONS: | *CONTROL: Assessment + booklet* | | X | | | | |
| | *INTERVENTION: Preoperative education and DB&C training* | | X | | | | |
| *VARIABLES:* | *Demographics, medical history, Functional Comorbidity Index, RAPA, Grip strength* | | X | | | | |
| | *Intraoperative variables* | | | X | | | |
| | *Postoperative variables* | | | X ◄——► X | | | |
| *OUTCOMES:* | *PPC* | | | X ◄——► X | | | |
| | *Pneumonia, ICU admission and LOS, Total LOS* | | | X ◄——————► X | | | |
| | *Time to ambulate >1min, and >10min Days to d/c from physiotherapy service* | | | X ◄——► X | | | |
| | *HRQOL SF-36 and SAQ* | | X | | | | X |
| | *Patient reported complications* | | | | | | X |

**Fig. 2** LIPPSMAck POP participant timeline and schedule of events. Describes LIPPSMAck POP participant timeline and schedule of procedures. Abbreviations: POD postoperative day, D/C discharge, DB&C deep breathing and coughing, RAPA Rapid Assessment of Physical Activity, PPC postoperative pulmonary complication, ICU intensive care unit, LOS length of stay, HRQOL health-related quality of life, SAQ Specific Activity Questionnaire

asked to cough forcibly, the physiotherapist makes a subjective scoring of strength, effectiveness, and presence of sputum), sputum class (mucoid, mucopurulent, purulent) and colour using a validated colour chart tool [68] of any observed or patient reported regularly produced bronchial secretions, patient-reported history of a chest infection in the previous 14 days and if antibiotics had been prescribed, smoking history (non-smoker, current smoker, or ex-smoker having ceased more than 8 weeks preoperatively), smoking pack years (1 pack year = 20 cigarettes per day for 1 year), years since smoking cessation, $SpO_2$ (%) on room air, heart rate (beats per minute), comorbidities as documented in the medical record (history of stroke or any other type of debilitating neurological disease, diabetes, arthritis, osteoporosis, asthma, COPD or other type of chronic respiratory disease, history of an acute myocardial infarct or angina, peripheral vascular disease, upper gastrointestinal disease such as reflux or gastric ulceration, current depressive illness or anxiety/panic disorder, visual or hearing impairment), patient's self-report if the listed comorbidities significantly limit their walking on a day-to-day basis, Functional Comorbidity Index score [69], HRQoL with the SF-36, patient-reported estimated maximum metabolic equivalent (MET) physical activity using a self-rated physical Specific Activity Questionnaire (SAQ) [58], patient-reported measure of physical activity status using the Rapid Assessment of Physical Activity (RAPA) questionnaire and categorised to sedentary, under active, under active regular light activities, under active regular, and active [57], patient-reported maximum walking time along flat ground at comfortable walking pace, any limiting factor for mobilisation, and maximum grip strength as measured on the dominant hand using a calibrated hand dynamometer (Jamar Plus+; Sammons Preston, Rolyon, Bolingbrook, IL) performed with patients seated with shoulders adducted, elbows flexed to 90°, and forearms in the neutral position. The dynamometer handle position will be set to the second position for all tests [70], and three tests will be performed with verbal encouragement with the best test result recorded.

### Intra-operative variables

The following variables will be collected from the anaesthetic record, operation report, and medical record: duration of anaesthesia during surgery in minutes; mechanical ventilation parameters including mode of ventilation, level of pressure/volume control, and PEEP; average $FiO_2$ during surgery; type and amount of intraoperative fluid delivered (ml/kg/h); numbers of blood

transfusion units; prophylactic antibiotic delivery (medication and dosage); incision type (midline, unilateral subcostal, bilateral subcostal, transverse, combined thoracotomy, other). If there are multiple incisions used, the patient's incision is categorised according to the closest abdominal incision to the thorax.

### Post-operative variables

Post-operative data will be collected daily for 14 days or until discharge from hospital, whichever occurs first: time in days from the pre-operative physiotherapy session to the operation; PPC risk stratification (low or high) using a defined risk calculation tool [5]; location (ICU, surgical ward, other) and duration in days at each location; days of analgesia and type (epidural, constant opioid infusion, patient controlled analgesia (PCA), patient controlled epidural analgesia (PCEA), oral, local pain infusion, or other); unplanned ICU/HDU admission and length of total ICU/HDU stay; length in days of total hospital stay; hours of mechanical ventilation; fluid delivery in the first 24 h (ml/kg/h); days and type of vasopressor use; hours and type of NIV use; days and types of oxygen therapy use; days, type, and indication for use for antibiotics; days and types of all drains and lines; day and diagnosis of a prolonged post-operative ileus using a standardised criteria [71] of 2 or more of the following factors in a 24-h period including nausea/vomiting, inability to tolerate normal diet, absence of flatus, abdominal distension, radiologic confirmation, and physician diagnosis of ileus.

Early ambulation parameters will be collected, including: time in hours from end of surgery until time to ambulation >1 min; post-operative day walked longer than 10 min; maximum rating of perceived exertion during ambulation at each session; maximum ambulation stage attained at each session (Table 2); number of assisted ambulation occasions; reasons for a patient being unable to participate in an ambulation session.

### Sample size

Sample size was calculated using inference for proportions comparing two independent samples with a 0.05 two-sided significance level and will have 80 % power to detect a 10 % absolute difference in PPC between Pre-Op (estimated at 10 %) and an education booklet (estimated at 20 %) when the sample size is 398. This is further increased by 11 % to account for attrition, resulting in a final sample size of 441.

### Data management

Data will be collected from participants using a standardised electronic case report form (CRF) and stored in participating centres' password protected electronic hard drives. To ensure data quality the CRF has been designed with extensive use of data entry limitation rules and on-screen prompts to ensure correct data entry. Primary and secondary outcome data entry fields will be highlighted and required for completion of each participant's data set. Automated weekly prompts will remind site investigators to complete any missing data points.

All site investigators will be trained directly by the principal investigator on correct administration of the trial. Site investigators will be required to perform random covert audits of data collected by trial personnel during the trial for reliability and correctness against the medical record. Once each participant's data set is completed, it is de-identified, entered into a central database, and maintained securely by the principal investigator. All data, consent forms, and relevant correspondence will be stored according to Australian and New Zealand privacy laws and archived at trial sites for a minimum of 7 years. There are no industrial contractual arrangements in relation to the de-identified data. On completion of the trial, the database will be made available for independent analysis or as an appendix in the publishing journal if requested.

### Statistical methods

The prognostic strength and size of imbalances to potential confounding baseline variables between groups will be assessed. Adjustment covariates will be selected by backward stepwise regression from covariates that may have the potential for clinically significant alterations in effect sizes. These include: history of a respiratory comorbidity, smoking history, self-reported physical activity levels, age, BMI, length in time of operation, operation category (upper gastrointestinal, colorectal, urological, other), ICU admission immediately following the procedure, incision type and location [72], intra-operative ventilation strategies [4, 73], fluid delivery [74], blood transfusions [75], mode of post-operative analgesia [76], and use of prophylactic antibiotics [50].

All outcomes are to be analysed using intention-to-treat. The absolute and relative rates of PPC in the trial groups will be estimated using multivariate robust random effects Poisson generalised linear regression to allow assessment of binary outcomes with or without adjustment for potential confounding variables (incidence rates and rate ratios, 95 % confidence intervals, *P*-values). Treatment centre will be treated as a fixed variable in the multi-level models. In addition, the effect of time from the end of surgery/anaesthesia to commencement of symptoms of PPC will be compared using Cox proportional hazards regression with and without covariate adjustment (hazards ratio, 95 % confidence intervals, *P*-values). Graphic representation of this analysis will be performed using the Kaplan-Meier method.

Binomial secondary outcomes, including pneumonia, unplanned ICU admission, and patient reported complications, will be analysed using mixed effects Poisson

regression. Secondary outcomes with irregular distributions, including length of time periods (ICU and total post-operative LOS, time to ambulation for 1 and 10 min, and time to discharge from assisted ambulation physiotherapy service), HRQoL, and functional capacity, will be evaluated for group differences using mixed effects ordered logistic regression, with mean time (95 % CI) estimated for descriptive purposes using mixed effects linear regression, with or without log transformation depending on distribution. Hospital costs associated with the interventions will be compared using mixed effects linear regression. Log transformation of highly skewed cost data will be performed.

An intention-to-protocol sensitivity analysis will be performed by excluding from the analysis any participant who did not undergo the anticipated scheduled upper abdominal surgery defined as a 5-cm incision or longer above, or extending above, the umbilicus. For example, this will include those participants who were scheduled for open surgery yet went on to only have a laparoscopic procedure or where the open incision remained wholly below the umbilicus.

The sensitivity of the outcome estimates to missing data will be evaluated using multiple imputation (Stata command syntax mi). All analyses will be performed using Stata version 13 or later (StataCorp, College Station, TX, USA).

### Data monitoring

The steering committee consists of the principal investigator and three academic supervisors who contribute to design and revision of the study protocol. The principal investigator is responsible for study administrative management and communication with local investigators, and for assisting participating centres with trial conduct, record keeping, and data management. An independent Data and Safety Monitoring Board (DSMB) consisting of a senior academic, staff anaesthetist, and biostatistician monitors the ethics of the study in accordance with the Declaration of Helsinki, overseeing safety and conduct of the study. This study compares two education-based treatment strategies that are highly unlikely to be related to serious adverse events (SAEs), though local investigators at participating centres remain responsible for reporting SAEs directly attributable to the intervention or control to the DSMB for review and consideration for referral to the institutional ethics review board.

### Duration and timeline

All 441 patients will be recruited by October 2015. Data collection will be completed, analysed, and the manuscript prepared for submission by March 2016. The final manuscript will be written in accordance with the CONSORT extensions for a pragmatic trial using a non-pharmacological intervention.

## Discussion

Studies in major UAS that have used the same PPC diagnostic tool as our group have reported a PPC rate of 13–18 % across all types of UAS [5, 6] with a specific rate of approximately 40 % in high-risk patients [8, 9]. Due to high incidence rates and costs of PPCs to patients and health care systems, there is great interest in their prevention.

Several clinical trials have compared a variety of different types and combinations of interventions to prevent PPCs. Trials demonstrating improvements in PPC rates have used multimodal interventions, so it is difficult to determine which component is effective in reducing PPCs, or indeed, if it is necessary to provide the whole 'package of care' to gain a significant benefit. This may influence resource provision, as providing the full package of therapy exactly as studied to gain the reported reduction on PPC rates may not be feasible, could be costly, and, indeed, may not be necessary in its entirety. Previous clinical trials have demonstrated that a single pre-operative education session can reduce PPC incidence to as low as 6 %, compared to a no-treatment control group rate of 27 %, $P < 0.001$ [47, 48], though assessors were un-blinded and potential confounders were not reported. Further, these trials were conducted 10–15 years ago, and changes in surgical and perioperative care have been significant in this time. The potential to significantly reduce the incidence of a high impact complication such as a post-operative respiratory complication with a low-cost and easily provided intervention of a single pre-operative physiotherapy session is appealing. It may not be 'how much' physiotherapy that is important, but rather 'when' that physiotherapy is provided. Unfortunately, conclusive evidence to support this hypothesis is lacking.

The LIPPSMAck POP trial is the first randomised controlled study powered and designed to investigate whether Pre-Op education and training reduces the incidence of PPCs. This RCT has been specifically designed to address previous methodological shortcomings in clinical trials investigating this intervention. Eligible participants are all patients listed for elective upper abdominal surgery and are representative of the heterogeneous nature of patients listed for these procedures. To ensure generalisability of results, the intervention will be delivered pragmatically and reflect current service delivery in Australia and New Zealand. Pre-operative education will be provided by a range of physiotherapists with different experience levels, including supervised students. The intervention and control has been designed and standardised to be provided by a physiotherapist of any experience level.

The active control of being assessed by a physiotherapist and receiving an identical subjective and objective

interview and booklet, was chosen instead of a no-treatment comparator to specifically control for the Hawthorne effect. The LIPPSMAck POP trial standardises assisted early ambulation services and removes all physiotherapy coached respiratory therapy and provision of lung expansion devices post-operatively. We have not attempted to control for ambulation initiated by the participant or lung expansion exercises provided by nursing or medical staff and, in practice, this would be extremely difficult to achieve. However, with effective random allocation and blinding of post-operative staff members, it is reasonable to expect that patients in both the control and the intervention group will have an equal chance of having similar exposure to these factors. Regarding other known confounders such as pain management strategies, fluid administration, and intraoperative ventilation strategies, we have not attempted to standardise these due to the feasibility of doing so across three sites. Instead, the impact of potential perioperative confounders will be evaluated during statistical analysis and reported.

The primary outcome, PPC, will be measured by assessors masked to group allocation; all post-operative ward staff responsible for the delivery of all physiotherapy, medical, nursing, and general care and discharge planning will also be masked. The success of blinding procedures will be measured and reported. In modern health care delivery it is also important to consider the impact of an intervention on patient reported quality of life and not just on objective clinical outcomes [77]. It is hypothesised that if Pre-Op physiotherapy education is effective in reducing the incidence of a PPC, this may improve post-surgical recovery. Improvements in recovery may influence HRQoL following discharge from hospital, particularly physical functioning domains, as has been demonstrated previously [59]. LIPPSMAck POP will be measuring 6-week post-discharge patient reported complications, HRQoL, and functional capacity to estimate the potential effect that PPCs may have on these outcomes.

In conclusion, the LIPPSMAck POP trial is an investigator-initiated, bi-national, multi-centre, pragmatic, double-blinded, randomised controlled trial, powered and rigorously designed to test the hypothesis that pre-operative physiotherapy education prevents post-operative pulmonary complications in patients following major upper abdominal surgery.

## Trial status

The trial is ongoing and is actively enrolling.

### Abbreviations

AHA: Allied Health Assistant; ASA: American Society of Anaesthesiologists; COPD: chronic obstructive pulmonary disease; CRF: case report form; CXR: chest X-ray; DB&C: deep breathing and coughing; D/C: discharge; ERAS: Enhanced Recovery After Surgery; $FiO_2$: fraction of inspired oxygen; HDU: high dependency unit; HRQoL: health-related quality of life; ICU: intensive care unit; LOS: length of stay; MET: metabolic equivalent; MGS: Melbourne Group Scale; NIV: non-invasive ventilation; PAC: Pre-Admission Clinic; PCA: patient controlled analgesia; PCEA: patient controlled epidural analgesia; PEP: positive expiratory pressure; PEEP: positive end-expiratory pressure; POD: post-operative day; PPC: post-operative pulmonary complication; RAPA: Rapid Assessment of Physical Activity; RPE: rating of perceived exertion; SAQ: Specific Activity Questionnaire; SF-36: 36-Item Short Form Health Survey; $SpO_2$: pulse oximetry oxygen saturation; UAS: upper abdominal surgery; URTI: upper respiratory tract infection; WCC: white cell count.

### Competing interests

The authors declare that they have no competing interests.

### Authors' contributions

IB conceived and designed the study, drafted and revised the protocol, and is co-ordinating the trial. LB, ES, JR, DE, and LD revised the study design and protocol. IR planned the statistical analysis and is responsible for data management. JR is responsible for data acquisition, protocol adherence, and trial co-ordination. IB prepared the manuscript and is the corresponding author. All authors read and contributed intellectually important content and approved the final manuscript.

### Funding source

This study is an investigator-initiated trial funded by research grants from the Clifford Craig Medical Research Trust, Launceston, Australia ($60,000 AUD), the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia ($50,000 AUD), Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand ($20,000 NZD), and sponsorship of the Department of Health and Human Services, Tasmania, to fund the Principal Investigator for the period of the trial ($150,000 AUD).

### Sponsors

The Department of Health and Human Services, Tasmania, and the Waitemata District Health Board have sponsored the trial through the employment of the Principal Investigator, Local Investigators, and all clinical staff related to the trial. No funding bodies or sponsors have contributed to trial design, data collection, or management, and publications relating to the trial can be submitted without permission or requiring approval.

### Other

IB wishes to thank the following physiotherapists for their intellectual contribution in critically reviewing the initial versions of the LIPPSMAck POP protocol: Dr Rebecca Lane, Ms Kimberley Haines, and Dr Julio Fiore, Jr. We wish to thank the University of Tasmania medical students (Dr Janice Tang, Dr Michael Kwok, and Dr Haoyuan Lim), who worked as blinded assessors and data collectors for the trial. We also wish to thank all local investigators, physiotherapy department managers, research assistants, physiotherapists, allied health assistants, and pre-admission staff at the participating centres.

### Author details

[1]Physiotherapy Department, Launceston General Hospital, Charles St, Launceston, Tasmania 7250, Australia. [2]Department of Physiotherapy, Melbourne School of Health Sciences, University of Melbourne, Parkville, Victoria 3010, Australia. [3]Division of Allied Health, Western Health, Furlong Road, St Albans, Victoria 3021, Australia. [4]Department of Physiotherapy, Western Health, 160 Gordon St, Footscray, Victoria 3011, Australia. [5]Department of Physiotherapy, School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand. [6]Physiotherapy Department, North Shore Hospital, Waitemata District Health Board, North Shore City, Auckland 0622, New Zealand. [7]School of Health Sciences, University of Tasmania, Locked Bag 1320, Launceston, Tasmania 7250, Australia. [8]Clifford Craig Medical Research Trust, Launceston General Hospital, Charles Street, Launceston, Tasmania 7250, Australia.

Received: 14 July 2015 Accepted: 27 November 2015
Published online: 15 December 2015

## References


1. Brooks-Brunn J. Predictors of postoperative pulmonary complications following abdominal surgery. Chest. 1997;111564–71.
2. AIHW. Procedures Cubes 2011–2012: National Hospital Morbidity Database. 2013. http://www.aihw.gov.au/hospitals-data/procedures-data-cubes/#ardrglink. Accessed 7 September 2014.
3. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. Lancet. 2008;372(9633):139–44.
4. PROVHILO group, High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. Lancet. 2014;384(9942):495–503.
5. Scholes RL, Browning L, Sztendur EM, Denehy L. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. Aust J Physiother. 2009;55(3):191–8.
6. Browning L, Denehy L, Scholes RL. The quantity of early upright mobilisation performed following upper abdominal surgery is low: an observational study. Aust J Physiother. 2007;53(1):47–52.
7. Mackay MR, Ellis E, Johnston C. Randomised clinical trial of physiotherapy after open abdominal surgery in high risk patients. Aust J Physiother. 2005;51(3):151–9.
8. Haines KJ, Skinner EH, Berney S. Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: an observational cohort study. Physiotherapy. 2013;99(2):119–25.
9. Parry S, Denehy L, Berney S, Browning L. Clinical application of the Melbourne risk prediction tool in a high-risk upper abdominal surgical population: an observational cohort study. Physiotherapy. 2014;100(1):47–53.
10. Silva Y, Li S, Rickard M. Does the addition of deep breathing exercises to physiotherapy-directed early mobilisation alter patient outcomes following high-risk open upper abdominal surgery? Physiotherapy. 2013;99(3):187–93.
11. Reeve JC, Nicol K, Stiller K, McPherson KM, Birch P, Gordon IR, et al. Does physiotherapy reduce the incidence of postoperative pulmonary complications following pulmonary resection via open thoracotomy? A preliminary randomised single-blind clinical trial. Eur J Cardiothorac Surg. 2010;37(5):1158–66.
12. Pasquina P, Walder B. Prophylactic respiratory physiotherapy after cardiac surgery: systematic review. BMJ. 2003;327(7428):1–6.
13. Arozullah A. Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery. Ann Intern Med. 2001;135(10):847–57.
14. O'Donohue Jr W. Postoperative pulmonary complications. When are preventive and therapeutic measures necessary? Postgrad Med. 1992;91(3):167–70.
15. Duggan M, Kavanagh B. Pulmonary Atelectasis A pathogenic perioperative entity. Anesthesiology. 2005;102(4):838–54.
16. Tusman G, Böhm SH, Warner DO, Sprung J. Atelectasis and perioperative pulmonary complications in high-risk patients. Curr Opin Anesthesiol. 2012;25(1):1–10.
17. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol. 2010;24(2):157–69.
18. Konrad FX, Schreiber T, Brecht-Kraus D, Georgieff M. Bronchial mucus transport in chronic smokers and nonsmokers during general anesthesia. J Clin Anesth. 1993;5(5):375–80.
19. Gamsu G, Singer MM, Vincent HH, Berry S, Nadel J. Postoperative impairment of mucous transport in the lung. Am Rev Respir Dis. 1976;114(4):673–9.
20. Bilgi M, Goksu S, Mizrak A, Cevik C, Gul R, Koruk S, et al. Comparison of the effects of low-flow and high-flow inhalational anaesthesia with nitrous oxide and desflurane on mucociliary activity and pulmonary function tests. Eur J Anaesthesiol. 2011;28(4):279–83.
21. Kim SH, Na S, Choi J-S, Na SH, Shin S, Koh SO. An evaluation of diaphragmatic movement by M-mode sonography as a predictor of pulmonary dysfunction after upper abdominal surgery. Anesth Analg. 2010;110(5):1349–54.
22. Ford G, Whitelaw W, Rosenal T, Cruse P, Guenter C. Diaphragm function after upper abdominal surgery in humans. Am Rev Respir Dis. 1983;127:431–6.
23. Blaney F, Sawyer T. Sonographic measurement of diaphragmatic motion after upper abdominal surgery: a comparison of three breathing manoeuvres. Physiother Theory Pract. 1997;13(3):207–15.
24. Kulkarni S, Fletcher E, McConnell A, Poskitt K, Whyman M. Pre-operative inspiratory muscle training preserves postoperative inspiratory muscle strength following major abdominal surgery–a randomised pilot study. Ann R Coll Surg Engl. 2010;92(8):700–5.
25. Barbalho-Moulim MC, Miguel GPS, Forti EMP, Campos FA, Costa D. Effects of preoperative inspiratory muscle training in obese women undergoing open bariatric surgery: respiratory muscle strength, lung volumes, and diaphragmatic excursion. Clinics. 2011;66(10):1721–7.
26. Bellinetti LM, Thomson JC. Respiratory muscle evaluation in elective thoracotomies and laparotomies of the upper abdomen. J Bras Pneumol. 2006;32(2):99–105.
27. Cheifetz O, Lucy SD, Overend TJ, Crowe J. The effect of abdominal support on functional outcomes in patients following major abdominal surgery: a randomized controlled trial. Physiother Can. 2010;62(3):242–53.
28. Fagevik Olsén M, Josefson K, Wiklund M. Evaluation of abdominal binder after major upper gastrointestinal surgery. Adv Physiother. 2009;11(2):104–10.
29. Smith M, Ellis E. Is retained mucus a risk factor for the development of postoperative atelectasis and pneumonia? Implications for the physiotherapist. Physiother Theory Pract. 2000;16:69–80.
30. Lång M, Niskanen M, Miettinen P, Alhava E, Takala J. Outcome and resource utilization in gastroenterological surgery. Br J Surg. 2001;88(7):1006–14.
31. Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S. A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. Physiother Res Int. 2001;6(4):236–50.
32. Thompson DA, Makary MA, Dorman T, Pronovost PJ. Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. Ann Surg. 2006;243(4):547–52.
33. Canet J, Gallart L. Postoperative respiratory failure: pathogenesis, prediction, and prevention. Curr Opin Crit Care. 2014;20(1):56–62.
34. Scholes R, Denehy L, Sztendur E, Browning L. A survey of Australian physiotherapy management of patients having abdominal surgery. Journal of Physiotherapy. e-supplements, 2005, APA 9th National Cardiothoracic Group Biennial Conference S26 (abstract). http://www.journalofphysiotherapy.com/pb/assets/raw/Health%20Advance/journals/jphys/2005%20APA%209th%20National%20Cardiothoracic%20Group%20Biennial%20Conference.
35. do Nascimento Junior P, Módolo NS, Andrade S, Guimarães MM, Braz LG, El Dib R. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. Cochrane Database Syst Rev. 2014;(2). Art. No.: CD006058. doi: 10.1002/14651858.CD006058.pub3.
36. Zhang X-Y, Wang Q, Zhang S, Tan W, Wang Z, Li J. The use of a modified, oscillating positive expiratory pressure device reduced fever and length of hospital stay in patients after thoracic and upper abdominal surgery: a randomised trial. J Physiother. 2015;61(1):16–20.
37. Ferreyra GP, Baussano I, Squadrone V, Richiardi L, Marchiaro G, Del Sorbo L, et al. Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. Ann Surg. 2008;247(4):617–26.
38. Makhabah DN, Martino F, Ambrosino N. Peri-operative physiotherapy. Multidiscip Respir Med. 2013;8(1):1–6.
39. Cassidy MR, Rosenkranz P, McCabe K, Rosen JE, McAneny D. I COUGH: reducing postoperative pulmonary complications with a multidisciplinary patient care program. JAMA Surg. 2013;148(8):740–5.
40. Pasquina P, Tramèr MR, Granier J-M, Walder B. Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: a systematic review. Chest J. 2006;130(6):1887–99.
41. Orman J, Westerdahl E. Chest physiotherapy with positive expiratory pressure breathing after abdominal and thoracic surgery: a systematic review. Acta Anaesthesiol Scand. 2010;54(3):261–7.
42. Ireland CJ, Chapman TM, Mathew SF, Herbison GP, Zacharias M. Continuous positive airway pressure (CPAP) during the postoperative period for prevention of postoperative morbidity and mortality following major abdominal surgery. Cochrane Database Syst Rev. 2014;(8). Art. No.: CD008930. doi: 10.1002/14651858.CD008930.pub2.
43. Bourn J, Conway J, Holgate S. The effect of post-operative physiotherapy on pulmonary complications and lung function after upper abdominal surgery. Eur Respir J. 1991;4:325s.
44. Denehy L. Ph.D. thesis: the physiotherapy management of patients following upper abdominal surgery. Melbourne: University of Melbourne; 2001.
45. Condie E, Hack K, Ross A. An investigation of the value of routine provision of postoperative chest physiotherapy in non-smoking patients undergoing elective abdominal surgery. Physiotherapy. 1993;79:547–52.
46. Castillo R, Haas A. Chest physical therapy: comparative efficacy of preoperative and postoperative in the elderly. Arch Phys Med Rehabil. 1985;66(6):376–9.

47. FagevikOlsén M, Hahn I, Nordgren S, Lonroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. Br J Surg. 1997;84(11):1535–8.
48. Samnani SS, Umer MF, Mehdi SH, Farid FN. Impact of preoperative counselling on early postoperative mobilization and its role in smooth recovery. International Scholarly Research Notices. 2014;2014:1–4. http://dx.doi.org/10.1155/2014/250536.
49. Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. Clin Nutr. 2010;29(4):434–40.
50. Gustafsson U, Scott M, Schwenk W, Demartines N, Roulin D, Francis N, et al. Guidelines for perioperative care in elective colonic surgery: enhanced recovery after surgery (ERAS®) society recommendations. World J Surg. 2013;37(2):259–84.
51. Partridge J, Harari D, Martin F, Dhesi J. The impact of pre-operative comprehensive geriatric assessment on postoperative outcomes in older patients undergoing scheduled surgery: a systematic review. Anaesthesia. 2014;69(s1):8–16.
52. Gupta A, Gupta N. Setting up and functioning of a preanaesthetic clinic. Indian J Anaesth. 2010;54(6):504.
53. Mata J, Cabrera S, Valldeperas M, Fernández S, Aguilar J, Atanassoff P. A national survey on current practice of preanaesthetic assessment in elective surgery patients in Spain. Rev Esp Anestesiol Reanim. 2012;59(6):299–305.
54. Browning L. Phd thesis: Early mobilisation following upper abdominal surgery in Australian public hospitals: University of Melbourne; 2007.
55. Fischer JP, Wes AM, Wink JD, Nelson JA, Braslow BM, Kovach SJ. Analysis of risk factors, morbidity, and cost associated with respiratory complications following abdominal wall reconstruction. Plast Reconstr Surg. 2014;133(1):147–56.
56. Doig GS, Simpson F. Understanding clinical trials: emerging methodological issues. Intensive Care Med. 2014;40(11):1755–7.
57. Topolski TD, LoGerfo J, Patrick DL, Williams B, Walwick J, Patrick MB. The Rapid Assessment of Physical Activity (RAPA) among older adults. Prev Chronic Dis. 2006;3(4):1–8.
58. Rankin SL, Briffa TG, Morton AR, Hung J. A specific activity questionnaire to measure the functional capacity of cardiac patients. Am J Cardiol. 1996;77:1220–3.
59. Dowson HM, Ballard K, Gage H, Jackson D, Williams P, Rockall TA. Quality of life in the first 6 weeks following laparoscopic and open colorectal surgery. Value Health. 2013;16(2):367–72.
60. Gustafsson UO, Hausel J, Thorell A, Ljungqvist O, Soop M, Nygren J. Adherence to the enhanced recovery after surgery protocol and outcomes after colorectal cancer surgery. Arch Surg. 2011;146(5):571–7.
61. Dias C, Plácido T, Ferreira M, Guimarães F, Menezes S. Incentive spirometry and breath stacking: effects on the inspiratory capacity of individuals submitted to abdominal surgery. Braz J Phys Ther. 2008;12(2):94–9.
62. Brooks D, Parsons J, Newton J, Dear C, Silaj E, Sinclair L, et al. Discharge criteria from perioperative physical therapy. Chest J. 2002;121(2):488–94.
63. Abadie B. Effect of viewing the RPE scale on the ability to make ratings of perceived exertion. Percept Mot Skills. 1996;83(1):317–8.
64. Agostini P, Naidu B, Cieslik H, Rathinam S, Bishay E, Kalkat M, et al. Comparison of recognition tools for postoperative pulmonary complications following thoracotomy. Physiotherapy. 2011;97(4):278–83.
65. Sopena N, Sabrià M. Multicenter study of hospital-acquired pneumonia in non-ICU patients. Chest J. 2005;127(1):213–9.
66. Fiore Jr JF, Bialocerkowski A, Browning L, Faragher IG, Denehy L. Criteria to determine readiness for hospital discharge following colorectal surgery: an international consensus using the Delphi technique. Dis Colon Rectum. 2012;55(4):416–23.
67. Myers J, Bader D, Madhavan R, Froelicher V. Validation of a specific activity questionnaire to estimate exercise tolerance in patients referred for exercise testing. Am Heart J. 2001;142(6):1041–6.
68. Murray M, Pentland J, Turnbull K, MacQuarrie S, Hill A. Sputum colour: a useful clinical tool for non-cystic fibrosis bronchiectasis. Eur Respir J. 2009;34:361–4.
69. Groll D, To T, Bombardier C, Wright J. The development of a comorbidity index with physical function as the outcome. J Clin Epidemiol. 2005;58(6):595–602.
70. Trampisch US, Franke J, Jedamzik N, Hinrichs T, Platen P. Optimal Jamar dynamometer handle position to assess maximal isometric hand grip strength in epidemiological studies. Journal Hand Surg. 2012;37(11):2368–73.
71. Vather R, Trivedi S, Bissett I. Defining postoperative ileus: results of a systematic review and global survey. J Gastrointest Surg. 2013;17(5):962–72.
72. Bickenbach KA, Karanicolas PJ, Ammori JB, Jayaraman S, Winter JM, Fields RC, et al. Up and down or side to side? A systematic review and meta-analysis examining the impact of incision on outcomes after abdominal surgery. Am J Surg. 2013;206(3):400–9.
73. Severgnini P, Selmo G, Lanza C, Chiesa A, Frigerio A, Bacuzzi A, et al. Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function. Anesthesiology. 2013;118(6):1307–21.
74. Corcoran T, Rhodes JEJ, Clarke S, Myles PS, Ho KM. Perioperative fluid management strategies in major surgery: a stratified meta-analysis. Anesth Analg. 2012;114(3):640–51.
75. Nobili C, Marzano E, Oussoultzoglou E, Rosso E, Addeo P, Bachellier P, et al. Multivariate analysis of risk factors for pulmonary complications after hepatic resection. Ann Surg. 2012;255(3):540–50.
76. Peyton PJ, Myles PS, Silbert BS, Rigg JA, Jamrozik K, Parsons R. Perioperative epidural analgesia and outcome after major abdominal surgery in high-risk patients. Anesth Analg. 2003;96(2):548–54.
77. Brundage M, Bass B, Davidson J, Queenan J, Bezjak A, Ringash J, et al. Patterns of reporting health-related quality of life outcomes in randomized clinical trials: implications for clinicians and quality of life researchers. Qual Life Res. 2011;20(5):653–64.



Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

BioMed Central

## 5.3 Supplementary material

### Script order of educational items

Explain why they are seeing a physiotherapist.

> "We help you to recover following your operation. We help you get your physical strength back and importantly help you to prevent getting pneumonia after this operation."

Explain risk of pneumonia

- Up to 50% (1 in 2) of patients get a respiratory complication following these types of operations.
- Give individualised risk (high – "at least 1 in 3" or low "as high as 1 in 5")

Explain that it is preventable

- This can be reduced to less than 1 in 10 if they get walking as soon as possible and do breathing exercises **immediately** after surgery.

  "I'm going to teach you how to do these breathing exercises today. Your job will be to start do them as soon as you wake up after the operation."

Explain why it is possible to get pneumonia after surgery

- Presence of dust (mainly skin flakes) and bacteria (attached to skin flakes) in the air
- Unavoidable to breathe it in with every breath.
- It is normal to breathe in about 250,000 bits of bacteria every day.
- Biological daily fact for all humans. We have 24 hours to clear it out or we get a chest infection
- Explain mucociliary clearance using diagram in booklet.
- Explain how the 'mucous factories' and 'the hairs' work to create a conveyor belt.
- This 'conveyor belt' when functioning well clears airways of bacteria within 4-6 hours
- Why is it important for them to know this before surgery?
- Anaesthetic drugs switch the mucociliary "conveyor belt" off
- It remains off until the patient gets out of bed and active following the operation, switching the conveyor belt back on.
- So, from the moment they become unconscious till the moment they are up and walking after the operation, mucous is stagnating and the bacteria are breeding in their lungs
- That is why we make such an effort to assist people to walk within 24 hours of the operation
- BUT, no matter how hard we try, there are more often than not many reasons why it is just not possible for this to happen (low blood pressure, pain, etc)

- This often means that many people remain in bed for more than 24 hours after the operation.
- Any bacteria in their lungs are effectively stuck in there and multiplying as their "conveyor belt" is still off.
- SO, need to do breathing exercises from the moment they wake up from the operation to the moment they get moving out of bed
- This will clear the bacteria out during this time spent in bed and protect the lungs from pneumonia during the time that their lungs are the most vulnerable.

Teach breathing exercises as per the booklet

- Include end inspiratory sniffs at the end of each DB. Call it a "sniff stack". Breathe in to TLC. Hold breath briefly then perform 2-3 inspiratory sniffs on top of TLC to "jack" up the lungs even further. Hold this now for 5 seconds. Let the air out in a rush – like a huff – to facilitate expiratory flow to move mucous.
- Remind patients that they need to do these from the moment they wake up and until they are ambulant and that they may not be reminded to do this by anyone.

Give memory cues

- Every time nurses do the hourly obs (BP, temp, pain) patient to do 20 reps.

Ask them to practise before surgery to get into the 'swing' of how to do them.

**Self-administered physical activity questionnaire (Rankin et al 1996)**

## SELF-ADMINISTERED PHYSICAL ACTIVITY QUESTIONNAIRE (SAQ)

**Can you complete the following activities at a normal rate?**
***Circle* YES *or* NO**

| | | | * |
|---|---|---|---|
| a. | Walk down a flight of stairs unassisted and without stopping? | YES | NO |
| b. | Carry an 8kg weight (e.g. a load of wet washing) up 8 steps? | YES | NO |
| c. | Do moderate gardening like weed or rake the leaves? | YES | NO |
| d. | Walk briskly around an oval? | YES | NO |
| e. | Carry at least 10kg (e.g. a suitcase) up 8 steps? | YES | NO |
| f. | Carry objects that weigh at least 35kg (e.g. an 11 year old child)? | YES | NO |
| g. | Do outdoor work like split wood or dig in the garden? | YES | NO |
| h. | Participate in moderate activities like walk at a normal pace (4km/hr) or play golf and carry the clubs? | YES | NO |
| i. | Participate in vigorous activities like swimming (crawl), jogging (8km/hr), cycling (17km/hr) or singles tennis? | YES | NO |
| j. | Do moderate work around the house like vacuum, sweep floors, or carry groceries? | YES | NO |
| k. | Do heavy work around the house like strip and make the bed, hang out washing, or wash the car? | YES | NO |
| l. | Push an electric or petrol mower on level ground? | YES | NO |
| m. | Dress without stopping because of symptoms? | YES | NO |

* If you answered "NO" to any of the above questions, what stops you doing these activities? (e.g. shortness of breath, angina, recent surgery etc.)

## HOW TO CALCULATE $VO_2$ USING SELF ADMINISTERED ACTIVITY QUESTIONNAIRE (SAQ) SCORE:

**Step 1:** Instruct patient to complete SAQ

**Step 2:** Determine the individual, highest MET value for that patient to calculate their SAQ according to the following table: *e.g. if the patients highest scoring question was question* **e.** *then their SAQ=7.00*

| *Can you complete the following without symptoms?* | *MET value* |
|---|---|
| **m.** Dress without stopping because of symptoms? | 2.00 |
| **j.** Do moderate work around the house like vacuum, sweep floors, or carry groceries? | 2.50 |
| **a.** Walk down a flight of stairs unassisted and without stopping? | 3.00 |
| **k.** Do heavy work around the house like strip and make the bed, hang out washing, or wash the car? | 3.25 |
| **c.** Do moderate gardening like weed or rake the leaves? | 4.25 |
| **l.** Push an electric or petrol mower on level ground? | 4.50 |
| **h.** Participate in moderate activities like walk at a normal pace (4km/hr) or play golf and carry the clubs? | 4.75 |
| **d.** Walk briskly around an oval? | 5.00 |
| **g.** Do outdoor work like split wood or dig in the garden? | 5.50 |
| **b.** Carry an 8kg weight (e.g. a load of wet washing) up 8 steps? | 6.00 |
| **e.** Carry at least 10kg (e.g. a suitcase) up 8 steps? | 7.00 |
| **f.** Carry objects that weigh at least 35kg (e.g. an 11 year old child)? | 7.50 |
| **i.** Participate in vigorous activities like swimming (crawl), jogging (8km/hr), cycling (17km/hr) or singles tennis? | 9.00 |

*MET = metabolic equivalent*

**Step 3:** Record the patient's age in years, height in centimetres and weight in kilograms.

**Step 4:** To calculate $VO_2$; substitute these values into the following equation:

$$VO_2 = 2.36(SAQ) + 0.35(HEIGHT\ cm) - 0.19(AGE\ yrs) - 0.16(WEIGHT\ kg) - 33.89$$

## PPC risk calculator (Scholes et al 2009)

Tasmania

# POST-OPERATIVE PULMONARY COMPLICATION (PPC) RISK ASSESSMENT

U.R.N.

SURNAME ..... D.O.B .....

OTHER NAMES ..... SEX

ADDRESS ..... MARITAL STATUS

..... REL.

LABEL

## UAS PPC RISK PREDICTION MODEL

**Step 1:** Upper abdominal surgery (UAS) is defined as "*an incision above or extending above the umbilicus*". To predict the risk of the development of post-operative pulmonary complications (PPC) following UAS; you must access the patient's admission notes and operation report. According to your assessment findings; tick the corresponding value in each of the following five categories:
**(tick one box in each category only)**

**1. Duration of Anaesthetic**

| | |
|---|---|
| ☐ < 60 mins | $b_1 = 23.265$ |
| ☐ 60-119mins | $b_1 = 2.046$ |
| ☐ 120-179 mins | $b_1 = 1.953$ |
| ☐ 180-239 mins | $b_1 = 0.214$ |
| ☐ 240-299 mins | $b_1 = 0.176$ |
| ☐ ≥ 300mins | $b_1 = 0.000$ |

**2. Surgical Category**

| | |
|---|---|
| ☐ Hepatobilary & Upper GI | $b_2 = 1.191$ |
| ☐ Colorectal & Lower GI | $b_2 = 2.225$ |
| ☐ Renal & Urology | $b_2 = 2.740$ |
| ☐ Vascular | $b_2 = 20.797$ |
| ☐ Other | $b_2 = 0.000$ |

**3. Diagnosis of Respiratory co morbidity**

| | |
|---|---|
| ☐ Yes | $b_3 = -0.591$ |
| ☐ No | $b_3 = 0.000$ |

**4. Current Smoker**

| | |
|---|---|
| ☐ Yes | $b_4 = -0.999$ |
| ☐ No | $b_4 = 0.000$ |

**5. $VO_2$ max score as calculated from pre-op questionnaire**

| | |
|---|---|
| ☐ $VO_2$ < 19.37ml.kg.min | $b_5 = -0.962$ |
| ☐ $VO_2$ ≥ 19.37ml.kg.min | $b_5 = 0.000$ |

Automatically score <19.37ml.kg.min if no pre-op questionnaire performed

**Step 2:** Select the corresponding "b" value to your tick from ***each*** category and enter into this equation:

$$\textbf{SCORE} = 0.490 + b_1 + b_2 + b_3 + b_4 + b_5 = \_\_\_\_\_$$

**Step 3:** Circle calculated risk and post-operative respiratory physiotherapy input

**SCORE ≤ 2.023 HIGH RISK OF PPC** **SCORE > 2.023 LOW RISK OF PPC**

# CHAPTER 6

# Treatment fidelity and impact of preoperative physiotherapy before major abdominal surgery

## 6.1 Author contributions

IB was responsible for trial concept, design and co-ordination, securing funding, recruitment of participants, manuscript preparation and submission. DE-A and NZ were responsible for scoring, analysing, and interpreting the interviews. IR was responsible for statistical design and analysis. LD, LB, and ES were responsible for trial oversight and manuscript review. All authors read and approved the final manuscript.

This study was supported by competitive research grants from the Clifford Craig Foundation, Launceston, Australia; the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia; and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand.

## 6.2 Published manuscript

Boden I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy*. 2018 Jun;104(2):194-202. doi:10.1016/j.physio.2017.08.008.

© 2018. This manuscript version is made available under the CC-BY-NC-ND 4.0 and is available for reproduction in this thesis and can be posted on the University of Melbourne dissertation repository DOI links back to the formal publication on ScienceDirect.

This chapter contains content which is unchanged from the accepted paper.

Further details are provided as thesis appendices (Interview scoring template (Appendix VIII) and standards of reporting qualitative research checklist (Appendix IX)).

ELSEVIER

Physiotherapy

Physiotherapy 104 (2018) 194–202

# Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study

Ianthe Boden [a,b,c,*], Doa El-Ansary [b], Nadia Zalucki [a], Iain K. Robertson [c,d], Laura Browning [b,e], Elizabeth H. Skinner [b], Linda Denehy [b]

[a] Physiotherapy Department, Launceston General Hospital, P.O. Box 1963, Launceston, 7250, TAS, Australia
[b] Department of Physiotherapy, School of Health Sciences, The University of Melbourne, Alan Gilbert Building, 161 Barry Street, Carlton, 3053, VIC, Australia
[c] Clifford Craig Foundation, Launceston General Hospital, P.O. Box 1963, Launceston, 7250, TAS, Australia
[d] School of Health Sciences, University of Tasmania, Locked Bag 1320, Launceston, 7250, TAS, Australia
[e] Division of Allied Health, Western Health, Furlong Road, St Albans, 3021, VIC, Australia

**Abstract**

**Objectives** To (1) assess memorability and treatment fidelity of pre-operative physiotherapy education prior to elective upper abdominal surgery and, (2) to explore patient opinions on pre-operative education.

**Design** Mixed-methods analysis of a convenience sample within a larger parallel-group, double-blinded, randomised controlled trial with concealed allocation and intention-to-treat analysis.

**Setting** Tertiary Australian hospital.

**Participants** Twenty-nine patients having upper abdominal surgery attending pre-admission clinic within six-weeks of surgery.

**Intervention** The control group received an information booklet about preventing pulmonary complications with early ambulation and breathing exercises. The experimental group received an additional face-to-face 30-minute physiotherapy education and training session on pulmonary complications, early ambulation, and breathing exercises.

**Outcome measures** Primary outcome was proportion of participants who remembered the taught breathing exercises following surgery. Secondary outcomes were recall of information sub-items and attainment of early ambulation goals. These were measured using standardised scoring of a semi-scripted digitally-recorded interview on the 5th postoperative day, and the attainment of early ambulation goals over the first two postoperative days.

**Results** Experimental group participants were six-times more likely to remember the breathing exercises (95%CI 1.7 to 22) and 11-times more likely (95%CI 1.6 to 70) to report physiotherapy as the most memorable part of pre-admission clinic. Participants reported physiotherapy education content to be detailed, interesting, and of high value. Some participants reported not reading the booklet and professed a preference for face-to-face information delivery.

**Conclusion** Face-to-face pre-operative physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity.

Trial Registration: ACTRN-12613000664741.
© 2017 Chartered Society of Physiotherapy. Published by Elsevier Ltd. All rights reserved.

*Keywords:* Pre-operative care; Elective surgery; Clinical trial; Respiratory therapy; Patient education; Treatment fidelity

* Corresponding author at: Physiotherapy Department, Launceston General Hospital, P.O. Box 1963, Launceston, 7250, TAS, Australia.
*E-mail addresses:* ianthe.boden@ths.tas.gov.au (I. Boden), d.el-ansary@unimelb.edu.au (D. El-Ansary), nadia.zalucki@ths.tas.gov.au (N. Zalucki), iain.robertson@utas.edu.au (I.K. Robertson), laura.browning@wh.org.au (L. Browning), drlizzieskinner@gmail.com (E.H. Skinner), l.denehy@unimelb.edu.au (L. Denehy).

https://doi.org/10.1016/j.physio.2017.08.008
0031-9406/© 2017 Chartered Society of Physiotherapy. Published by Elsevier Ltd. All rights reserved.

## Introduction

A postoperative pulmonary complication (PPC) is the most common complication following upper abdominal surgery (UAS) [1], increasing mortality [2] and hospital costs [3]. Preventing PPC is a key component of acute-care physiotherapy [4]. Breathing exercises can reverse respiratory pathophysiological effects of anaesthesia and surgery [5], although their overall effectiveness to prevent PPC is uncertain [6]. This paradox may possibly be due to inadequate dose-response or delayed initiation following surgery [7]. The first physiotherapy session is commonly more than 30 hours after surgery [8], which may be too late as 15% of PPC have occurred within this time [2,8]. Conceivably, timeliness of initiation and dose frequency could improve if patients are educated and trained *before* surgery to perform hourly breathing exercises immediately following surgery. Pre-operative education is strongly recommended within Enhanced Recovery After Surgery guidelines [9] although little evidence exists demonstrating that pre-operative education is understood by patients, translates into behavioural change, and results in improved postoperative outcomes.

Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) is a randomised controlled trial [10] rigorously testing the hypothesis that pre-operative physiotherapy education and training prevents PPC following UAS. The intervention is a behavioural intervention. A positive outcome could only be expected if the intervention is differentiable from standard care, is memorable, and adhered to by the patient [11]. This is referred to in the literature as treatment fidelity [12].

Treatment fidelity has four components [13]: (i) *Integrity*; was the treatment delivered as intended? (ii) *Differentiation*; did two treatments differ from one another as intended? (iii) *Receipt*; does the patient understand the treatments provided and are they equipped to perform them as intended?; and (iv) *Enactment*; does the patient enact the learnt skills and perform the intervention as intended?

We designed a nested study within LIPPSMAck-POP to test three treatment fidelity components of pre-operative physiotherapy education and training: differentiation, receipt, and enactment. The primary research questions were:

1. How memorable is physiotherapy education when provided within a multi disciplinary pre-admission clinic?
2. Is there a difference in recall of information when delivered by a physiotherapist compared to a booklet alone?
3. Does pre-operative education affect early postoperative ambulation performance?

A secondary aim was to conduct a preliminary exploration of patients' opinions on pre-operative information delivery.

## Method

### *Design*

This mixed-methods study was designed as a concurrent, nested, parallel-group, blinded (patient, assessor, analyst), randomised-controlled study within the larger LIPPSMAck-POP trial [10]. A convenience sample of consecutive LIPPSMAck-POP participants were concurrently recruited to participate in the mixed-methods study. Written informed consent was obtained for both trials.

Participants attended a multi disciplinary pre-admission clinic within six-weeks of surgery at an Australian government-funded tertiary regional hospital. Participants were seen by a nurse, surgeon, anaesthetist, physiotherapist, and, if required, a stomal therapist. Following surgery, mixed-methods trial participants were interviewed using semi-scripted open-ended questions at their bedside on the fifth postoperative day, or on day of hospital discharge, whichever occurred first. As opioid analgesia could affect mental clarity [14], interviews were deferred until this was ceased.

Interview questions were purposively developed for this trial by the lead author using expert clinical knowledge obtained from 16 years of educating and assisting abdominal surgery patients in postoperative recovery. Questions were designed to assess ability to recall and distinguish physiotherapy education from other health–professional interactions at pre-admission clinic. Questions progressively probed for degree of recall (repetition and dosage) and purpose for the prescribed breathing exercises. To prevent biasing interview responses, interviewers were unknown to participants, wore plain clothes without any physiotherapy professional identifying features, and introduced themselves as from the Department of Surgery requesting an interview about the participant's experience at pre-admission clinic.

Interviews were digitally recorded then transcribed verbatim by an independent assistant. Content was verified for accuracy, de-identified and then analysed via quantitative and qualitative methods by two physiotherapists not previously involved in the trial. Participants, postoperative physiotherapists, nursing and medical staff, interviewers, transcribers, and data analysts were masked to pre-operative group allocation.

### *Characteristics of participants and research staff*

#### *Participants*

Inclusion and exclusion criteria are published elsewhere [10]. An additional mixed-methods study *a-priori* exclusion criterion was inability to be interviewed postoperatively.

#### *Therapists, interviewers, and analysts*

All researchers were female. Pre-operative interventions were delivered by a postgraduate qualified physiotherapist with 16-years acute-care experience or a fourth-year phys-

iotherapy student. Postoperatively, two research assistants with acute-care experience interviewed participants. Quantitative categorising, scoring, and qualitative analyses of the transcribed interviews were performed by two independent researchers purposively selected to include a physiotherapist with surgical experience and another with expertise outside surgery.

*Interventions*

Interventions are described thoroughly elsewhere [10]. Briefly, all participants received a standardised physiotherapy assessment and information booklet (e-Supplement). The experimental group received an additional 30-minute education session about the effect of anaesthesia and UAS on muco-ciliary clearance, lung volumes, and individualised risk of PPC. The importance of participating in an early postoperative ambulation program and performing self-directed breathing exercises was emphasised as a means to prevent PPC. Participants were coached in at least three repetitions of the prescribed breathing exercises. Postoperatively a standardised early ambulation program (Box 1) [10] was delivered once daily to all participants starting the day after surgery by ward physiotherapists masked to pre-operative group allocation.

*Outcome measures*

*Quantitative*

Primary outcome was proportion of participants who remembered the breathing and coughing exercises provided pre-operatively (treatment receipt). Secondary outcomes were; proportion of participants who could recall pre-operative physiotherapy education sub-items (early ambulation, lung physiology, preventing pneumonia) and memorability of pre-operative physiotherapy information in context of other health-professional information provided at pre-admission clinic (treatment differentiation). To determine these outcomes, interview responses were categorised and counted using standardised quantitative scoring schema purposively devised for this study (see Supplementary Appendix A). Treatment enactment was estimated by attainment of early ambulation goals: (1) proportion of participants ambulant past Stages 3 and 6 of the ambulation protocol (Box 1) on the first postoperative day; and, (2) median stage achieved on the first and second postoperative day. Ambulation attainment was recorded daily by treating physiotherapists on standardised case report forms.

*Qualitative*

Qualitative data were derived from the transcripts of the recorded interviews using three rounds of inductive thematic analysis with triangulation [15]. The first round was independent data evaluation by the second and third authors who, following familiarisation with data, coded each interview into concepts. Similar concepts were colour-coded then collapsed into key themes. Supportive quotes were extracted to support each theme. These authors met for second round analysis to review and discuss original findings and reach consensus on themes. The first three authors then met to review final themes and analysis. The first author acted as arbiter where consensus was not met.

**Box 1: LIPPSMAck POP ambulation protocol [10].**

| Stage | Definition |
|---|---|
| Stage 1 (Safety) | Sit over edge of bed/sit in chair minimum of 2 minutes |
| Stage 2 (Safety) | March on spot 0 to 1 minute |
| Stage 3 (Ambulation) | March on spot/walk away from bedside 1 to 3 minutes |
| Stage 4 (Ambulation) | March on spot/walk away from bedside 3 to 6 minutes |
| Stage 5 (Ambulation) | Walk away from bedside 6 to 10 minutes |
| Stage 6 (Ambulation) | Walk away from bedside 10 to 15 minutes |
| Stage 7 (Ambulation) | Walk away from bedside >15 minutes |

Frequency: Once daily starting as soon as possible on the first postoperative day.
Intensity: Minimum 3/10 on the Borg visual analogue scale.
Duration: Patient effort dependent with no time limit.
Delivered by a physiotherapist until patient attains Stage 3 or greater. Next session delivered by an Allied Health Assistant if safe to do so.
Each session patient is progressed sequentially through the stages with a goal to attain Stage 6 (10 to 15 minutes) or greater.
Rest periods (interval training) were allowable. Once rest time exceeded the preceding to work time (work to rest ratio became greater than 1:1) that ambulation session was considered finished.
Patients were discharged from the assisted ambulation service according to a standardised discharge criteria assessed daily.

*Data analysis*

*Quantitative data*

Sociodemographic and clinical data were analysed using descriptive statistics. Sample selection bias and representativeness was assessed by comparing descriptive data of interviewed participants to: (1) those excluded or lost-to-follow-up from the mixed-methods trial; (2) all other LIPPSMAck-POP participants. Categorised interview responses were compared between-groups (control vs experimental) using unadjusted relative risk estimated by mixed-effects general linear Poisson modelling. Where zero events occurred Fisher's exact test was used. Between-group differences in early ambulation attainment on the first post-

operative day were estimated using simple risk-ratio tables tested with Fisher's two-tailed exact test. Median ambulation stages achieved were analysed with ordered logistic regression. Analyses were performed intention-to-treat using commercially available software.[1]

*Statistical power*

Literature on grading treatment fidelity is limited [16]. Expert opinion considers high treatment fidelity as >80% of patients enacting health information and low fidelity as <50% [12]. To determine this required a total sample of 28 patients (one-sided, power 80%, alpha 0.05). A sample >20 is sufficient to determine certainty in qualitative analysis within mixed-methods design [17].

## Results

*Flow of participants*

From November 2013 and March 2014, 55 eligible consenting LIPPSMAck-POP participants attending pre-admission clinic were randomised to the experimental or control group. Following surgery, 31 participants were eligible for inclusion in the additional mixed-methods study. Two participants (6.5%) were missed by research staff and lost to follow-up, leaving 29 participants who were interviewed and data analysed. No participant was discharged home earlier than the fifth postoperative day. Five participants (control group n = 2, intervention group n = 3) were interviewed after the fifth postoperative day due to opioid-based analgesia; these participants had a mean day of interview of 6.7 days (SD 1.2).

*Baseline characteristics*

There was between-group imbalance in two baseline characteristics. The control group had older participants and were all educated pre-operatively by the senior physiotherapist (Table 1). There were no baseline differences between interviewed participants and those excluded or lost to follow-up (e-Supplement, Table 1S), suggesting that selection bias was unlikely. The mixed-methods sample differed from other LIPPSMAck-POP participants by having more senior physiotherapist interventions (86% vs 64%) and none residing in a metropolitan location (0% vs 19%) (e-Supplement, Table 1S).

*Quantitative results*

*Primary outcome*

Participants receiving pre-operative physiotherapy education and training were six-times more likely to remember the breathing and coughing exercises compared to those receiving a booklet alone (94% vs 15%; RR 6.1, 95%CI 1.7 to 22) (Table 2). A 94% recall rate indicates a very high treatment receipt.

*Secondary outcomes*

Both groups remembered meeting a physiotherapist at pre-admission clinic (RR 1.4, 95%CI 0.6 to 3.1). However, experimental group participants were 11-times more likely (RR 11, 95%CI 1.4 to 80.7) to report physiotherapy information as the most memorable part of the entire pre-admission clinic (Table 3) and were more likely to recall education content sub-items compared to those that received a booklet only (Table 2). A greater proportion of the experimental group ambulated longer than one-minute on the first postoperative day (100% vs 69%) although this effect was small (RR 1.4 95%CI 1.01 to 2.08). No difference in other ambulation outcomes was found (Table 4).

*Qualitative results*

Patients' views about pre-operative information were synthesized into two themes and five sub-themes.

*Theme 1: information delivery*

*Character qualities of physiotherapist.* Participants commented on the pleasant nature of the physiotherapist they interacted with at pre-admission clinic. Some commented that the information was more readily received because of this friendliness.

*"The girl who did it was very friendly and explained it to me very well." (E68)*

*Detail of information.* Experimental group participants expressed appreciation in the degree of detail provided by the physiotherapist with many finding it fascinating and intriguing. Because of this, they reported it easy to remember and differentiable from other information provided that day. Participants liked the use of pictures and this assisted in information recall.

*"Just interesting, she went into what happens in your lungs and the little hairs and how they do their little Mexican wave, that really intrigued me that. And how I need to keep that working because the stuff from clogging up from there, and so the deep breathing exercises were important for that reason, to keep pneumonia at bay. I suppose you seem to focus on the things that sort of stick out, and the more mundane stuff that you're up to speed with, you put that aside and think, well I know that." (E83)*

*"Just the way she explained things and she did a little diagram in the little booklet she gave me. That sort of thing, so just reviewing that over the period between then and when I came in for my op was helpful cos I could then remember much of what she said. I tend to sort of deal a bit in pictures in my*

[1] Stata Version 14.1, StataCorp, College Station, USA.

Table 1
Baseline characteristics of participants.

| Characteristic | Embedded mixed-methods study participants (n = 29) | |
|---|---|---|
| | Experimental (n = 16) | Control (n = 13) |
| Age (yr), median (IQR) | 58 (48 to 66) | 70 (64 to 76)[a] |
| Male, n (%) | 11 (69) | 9 (69) |
| Residential location, n (%) | | |
| Metropolitan | 0 (0) | 0 (0) |
| Regional | 8 (50) | 8 (62) |
| Rural/remote | 8 (50) | 5 (38) |
| Surgery type, n (%) | | |
| Colorectal | 6 (38) | 8 (62) |
| Upper gastrointestinal | 6 (38) | 3 (23) |
| Urology/other | 4 (25) | 2 (15) |
| Expertise of pre-operative physiotherapist/student | | |
| Senior, n (%) | 12 (75) | 13 (100) |
| Student, n (%) | 4 (25) | 0 (0)[a] |
| Days from pre-operative physiotherapy to day of surgery, median (IQR) | 6 (2 to 13) | 6 (2 to 30) |
| Length of hospital stay, days, median (IQR) | 8 (8 to 10) | 9 (8 to 15) |

IQR—interquartile range.
[a]Denotes characteristic imbalanced between groups.

Table 2
Recall of specific information items from pre-operative physiotherapy session.

| Outcome, n (%) | Groups | | Relative risk between groups | | |
|---|---|---|---|---|---|
| | Experimental (n = 16) | Control (n = 13) | Experimental relative to control | | |
| | | | RR | 95% CI | P-value |
| Recall of breathing and coughing exercises | 15 (94) | 2 (15) | 6.1 | 1.7 to 22 | <0.001 |
| Breathing exercises | 13 (81) | 2 (15) | 5.3 | 1.4 to 19 | <0.001 |
| Early ambulation | 12 (75) | 2 (15) | 4.9 | 1.3 to 18 | 0.001 |
| Lung physiology, mucociliary clearance | 8 (50) | 0 (0) | | | 0.003 |
| Coughing | 8 (50) | 1 (8) | 6.5 | 0.9 to 45 | 0.015 |
| Preventing pneumonia | 5 (31) | 0 (0) | | | 0.028 |
| Nothing | 0 (0) | 5 (38) | | | 0.006 |
| The research project | 1 (6) | 5 (38) | 0.2 | 0.0 to 1.2 | NS |
| Booklet | 8 (50) | 4 (31) | 1.6 | 0.6 to 4.2 | NS |

Table 3
Memorability of the pre-operative physiotherapist encounter.

| Outcome, n (%) | Groups | | Relative risk between groups | | |
|---|---|---|---|---|---|
| | Experimental (n = 16) | Control (n = 13) | Experimental relative to control | | |
| | | | RR | 95% CI | P-value |
| Participants reporting that physiotherapy information was the most memorable from all provided at pre-admission clinic | 13 (81) | 1 (8) | 10.6 | 1.6 to 70 | <0.001 |
| Participants who remembered meeting a physiotherapist | 15 (94) | 9 (69) | 1.6 | 0.6 to 3.1 | 0.08 |

POD = postoperative day, IQR = inter-quartile range.

*mind so. . ..she went into a bit of detail and so on and that helped me to remember, and these days the memory's not as good as it used to be." (E83)*

*Mode of delivery.* Many patients admitted to not reading the booklet with some saying they received so much written literature it was difficult to differentiate one booklet from another. Additionally, a number of participants reported diffi-

Table 4
Early mobilisation outcomes achieved on postoperative days 1 and 2.

| Outcome | Groups | | Difference between groups | | |
|---|---|---|---|---|---|
| | Experimental | Control | Experimental relative to control | | |
| | (n = 16) | (n = 13) | RR or OR | 95% CI | P-value |
| Proportion that mobilised > 1 minute on POD1, n (%) | 16 (100) | 9 (69) | 1.44[a] | 1.01 – 2.08 | 0.03 |
| Proportion that mobilised > 10 minutes on POD1, n (%) | 4 (25) | 4 (31) | 0.81[a] | 0.25 – 2.64 | 1.0 |
| Mobilisation stage (0 – 7) achieved on POD1, median (IQR) | 4.5 (1.5) | 3 (4) | 2.53[b] | 0.54 – 11.9 | 0.24 |
| Mobilisation stage (0 – 7) achieved on POD2, median (IQR) | 5 (1.5) | 5 (2.5) | 3.20[b] | 0.77 – 13.32 | 0.11 |

POD = postoperative day, IQR = inter-quartile range.
[a] Relative risk between groups.
[b] Odds ratio between groups.

culty reading and preferred personal delivery of information with pictorial content.

*"I had a lot of literature. I believe that there would be a lot of good readers around. . . there'd be a lot of people that are good listeners. . .and there's a lot of people that have only got to see it once and they can remember it. . .Yeah. And if you sorta see it, you. . .this is me. But if I read it, well. . ..I wasn't very good educated at school so. . .. I'm not a reader. . .(but) if I see something I say well gee that's going to help if I do this. . .It helps me a lot."* (C77)

*"No, can't remember what was in that booklet. But I still do have it. Got it in me bag. Yeah. I think it helped that I met one-on-one with her. Like it would have been no good if I just got a bit of paper in the mail saying you know this and this and this. . . meeting face-to-face was a lot better.(E101)*

*Theme 2: impact of information between groups*

*Information overload.* A number of control group participants felt overwhelmed during a long pre-admission clinic and attributed this to not being able to remember information.

*"And I had five hours in that pre-op. . .as you can appreciate there's that much that happens up here, a lot goes straight over your head. . .and a lot's forgotten." (C77)*

*"You have so much to take in, you know, in a few hours, and really. . .you're in a state of shock."(C97)*

*Value of information.* Experimental group participants placed high value on the respiratory and early ambulation education and appreciated that they could have a role in their postoperative recovery.

*"(Pneumonia) that was the one thing I really didn't want to have. . .I thought the whole process of giving you that information and making sure that you're aware that these are the steps you need to take post-surgery to make sure that you get up and get going and aid your recuperation. . .it's very important" (E51)*

## Discussion

This randomised-controlled, triple-blinded, mixed-methods study finds that face-to-face physiotherapy education and training prior to UAS has fidelity in the domains of treatment receipt, differentiation, and enactment. Pre-operative education leads to significantly better postoperative information recall and a small improvement in ambulation on the first postoperative day when compared to patients who received information via a booklet alone. The pre-operative physiotherapy education was highly memorable standing out from all other pre-admission clinic information. Qualitative results attribute this to the personal delivery of detailed, interesting, and practical information that patients place high value upon. Patients rate pre-operative counselling and avoiding infection as the two most important strategies for improving recovery after UAS [18], preferring personalised delivery of detailed information [19] which meets their need for control over their disease and surgery [20]. These factors tend to be underestimated by health-professionals [21]. The high memorability and fidelity of pre-operative physiotherapy could be because it successfully met components desired by patients. This then strengthens self-efficacy via adult-learning principles enabling a person to enact positive health behaviours [22].

Although we measured a significant effect, the 95% confidence intervals are wide. To attain more certainty requires a larger sample. This was not feasible with our chosen research method within finite resources. A semi-scripted recorded interview was chosen to measure our main outcome as this was considered least likely to introduce reporting bias and obtain true unsolicited information recall. Likert-scale or multiple-choice questionnaires, although less resource intensive, could prompt recall through the formatting nature of questions. The semi-scripted interview and quantitative scoring schema were not tested nor validated prior to use in this trial so there is a possibility that measurement error and reporting bias could exist due to the unknown measurement properties of this tool. Further research is required to determine an accurate, sensitive, and cost-effective method to assess information attainment in surgical populations.

Research in pre-operative education [23–25] is limited by methodological flaws, such as non-randomisation and uncontrolled interventions. Controlling for Hawthorne effects is vital, as physiotherapist character quality can independently improve clinical outcomes [26]. To control for the patient-therapist relationship all participants in our study were met by a physiotherapist. Most participants, including control participants, remembered meeting a physiotherapist and commented on her friendliness highlighting the importance of having an active control arm in physiotherapy trials. In our trial the superior recall rate is most likely dependent on the type and mode of information provided rather than on the personality of the therapist who provided it. It is also possible that the training component of the intervention, which we could not control for, may provide an additional Hawthorne effect and could explain a degree of the memorability of the intervention.

To the authors' knowledge, this study is singular in this field to have rigorously assessed for selection bias, representativeness within a larger population, and baseline comparability. Our mixed-methods sample had more senior physiotherapist's interventions and rural residents compared to the larger LIPPSMAck-POP population. It may be possible that educational attainment is superior when delivered by an experienced physiotherapist although there is no published literature that supports this. Another factor that could influence recall of pre-operative information is health literacy. Rural area residents may have lower health literacy than city residents. Although we did not measure this formally, a number of participants reported poor reading skills. 60% of Australian adults have inadequate health literacy [27]. In our study, information attainment through written material alone was inadequate with most participants reporting that they did not read the booklet and were given too many written materials. Patients find written materials complex to understand and difficult to remember without oral explanation [25]. Booklet information could be adequate for people with high health literacy levels although this remains to be determined.

Within the mixed-methods study there was a 12 year mean age difference which could favour the experimental group if older age reduces ability to recall information. However, age is an insensitive estimate of cognition. A majority of community-dwelling adults do not have significant memory decline between the ages of 60 and 80 [28]; however, cognitive decline accelerates over a 10 year period following a single surgical episode or following diagnosis of a mild cognitive impairment [29]. Our study could have been strengthened with assessment of cognitive function and incidence of surgery within the preceding decade.

Our primary aim was to measure treatment fidelity (receipt, differentiation, and enactment) of pre-operative physiotherapy education. Although there were strong effects to receipt and differentiation, there was only a small difference in our proxy measure of treatment enactment; early ambulation. This measure was used as it was concurrently measured within LIPPSMAck-POP. Early ambulation following UAS has many performance barriers [8]. Patient knowledge and motivation may be one of them. Pre-operative early ambulation education has been shown to improve ambulation performance [30]. Our intervention focused predominantly on respiratory information and breathing exercises to prevent pneumonia and contained a small component about early ambulation. The information about early ambulation may not have been sufficiently strong enough to engender a large postoperative response. A more sensitive measure of treatment enactment for our study would have been to specifically measure breathing exercise adherence. We could have recorded performance with a diary; however, the expectation that patients could complete an entry each time they performed them, especially when emerging from anaesthetic is unreasonable and unreliable. A diary could also act as a reminder of pre-operative information and confound the independent recall of information being tested. A more reliable measurement of breathing exercise adherence requires future exploration. Another reason we may not have found a difference in early ambulation performance was that it was provided by blinded physiotherapists using a standardised protocol. Our findings could be a measure of standardisation success rather than a lack of treatment effect.

Another domain of treatment fidelity, integrity (how consistently the information was delivered), was purposively not assessed. Tightly controlled protocols may improve reliability, however, as physiotherapists deliver information with varying styles, tone, and, authority, LIPPSMAck-POP was deliberately pragmatic in design. The delivered information was guided by a semi-scripted list although degrees of freedom in personalisation and answering patient questions were allowed. This improves generalisability to other physiotherapists as providers of this type of education.

This study finds that physiotherapy education and training prior to UAS is a high fidelity intervention. Pre-operative physiotherapy education and training provides highly memorable information about the risk of a PPC and the self-directed breathing exercises and early ambulation program that may prevent it. These exercises were recalled by almost all patients who received them directly from a physiotherapist, whereas, information delivered solely via a booklet was inadequate with a recall rate of just 15%. Results of this nested mixed-methods study will inform interpretation of LIPPSMAck-POP primary results. It remains to be determined if this memorable high fidelity pre-operative physiotherapy intervention translates into a clinically relevant reduction in PPC.

## Acknowledgements

We thank Kate Sullivan and Bronte Biggins-Tosch for conducting the patient interviews, Susan Kaye for transcribing the interviews, and we thank all participants for their time and involvement.

**Key messages**

- A single 30-minute face-to-face physiotherapy education and training session at a multi disciplinary outpatient clinic prior to elective upper abdominal surgery has high treatment fidelity and stands out from all other health professional interactions.
- An information booklet is not sufficient to provide information on early ambulation and breathing exercises to be performed following elective upper abdominal surgery.
- This paper provides novel evidence that pre-operative physiotherapy education and training is remembered and enacted following surgery. This memorable, high fidelity intervention could prevent postoperative pulmonary complications.

*Ethical approval*: The Tasmanian Health Research Ethics Committee approved this study (HREC-H0011911). All participants gave written informed consent before data collection began.

*Funding*: Clifford Craig Foundation and the University of Tasmania; virtual Tasmanian Academic Health Precinct Grant.

*Conflict of interest*: None declared.

*Provenance*: Not invited, peer reviewed.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2017.08.008.

## References

[1] Hemmes SN, de Abreu MG, Pelosi P, Schultz MJ, Severgnini P, Hollmann MW, *et al*. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. Lancet 2014;384:495–503.

[2] Neto AS, Hemmes SN, Barbas CS, Beiderlinden M, Fernandez-Bustamante A, Futier E, *et al*. Incidence of mortality and morbidity related to postoperative lung injury in patients who have undergone abdominal or thoracic surgery: a systematic review and meta-analysis. Lancet Respir Med 2014;2:1007–15.

[3] Eappen S, Lane BH, Rosenberg B, Lipsitz SA, Sadoff D, Matheson D, *et al*. Relationship between occurrence of surgical complications and hospital finances. JAMA 2013;309:1599–606.

[4] Hanekom SD, Brooks D, Denehy L, Fagevik-Olsén M, Hardcastle TC, Manie S, *et al*. Reaching consensus on the physiotherapeutic management of patients following upper abdominal surgery: a pragmatic approach to interpret equivocal evidence. BMC Med Inform Decis Mak 2012;12:5, http://dx.doi.org/10.1186/1472-6947-12-5.

[5] Grams ST, Ono LM, Noronha MA, Schivinski CIS, Paulin E. Breathing exercises in upper abdominal surgery: a systematic review and meta-analysis. Braz J Phys Ther 2012;16:345–53.

[6] Pasquina P, Tramèr MR, Granier J-M, Walder B. Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: A systematic review. Chest 2006;130:1887–99.

[7] Hedenstierna G, Edmark L, Perchiazzi G. Postoperative lung complications: have multicentre studies been of any help? Br J Anaesth 2015;114:541–3.

[8] Haines KJ, Skinner EH, Berney S. Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: an observational cohort study. Physiotherapy 2013;99:119–25.

[9] Gustafsson U, Scott M, Schwenk W, Demartines N, Roulin D, Francis N, *et al*. Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery after Surgery (ERAS®) Society recommendations. World J Surg 2013;37(2):259–84.

[10] Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, *et al*. The LIPPSMAck POP (lung infection prevention post surgery-major abdominal-with pre-operative physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. Trials 2015;16:1–15.

[11] Miller WR, Rollnick S. The effectiveness and ineffectiveness of complex behavioral interventions: impact of treatment fidelity. Contemp Clin Trials 2014;37:234–41.

[12] Borrelli B. The assessment, monitoring, and enhancement of treatment fidelity in public health clinical trials. J Public Health Dent 2011;71:S52–63.

[13] Bellg AJ, Borrelli B, Resnick B, Hecht J, Minicucci DS, Ory M, *et al*. Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. Health Psychol 2004;23:443–51.

[14] van der Sluis PJ, Buisman PL, Meerdink M, Wouter B, van Etten B, de Bock GH, *et al*. Risk factors for postoperative delirium after colorectal operation. Surgery 2017;161(3):704–11.

[15] Chapman A, Hadfield M, Chapman C. Qualitative research in healthcare: an introduction to grounded theory using thematic analysis. J R Coll Phys Edinb 2015;45:201–5.

[16] Mowbray CT, Holter MC, Teague GB, Bybee D. Fidelity criteria: development, measurement, and validation. Am J Eval 2003;24:315–40.

[17] Onwuegbuzie AJ, Collins KM. A typology of mixed methods sampling designs in social science research. Qual Rep 2007;12:281–316.

[18] Hughes M, Coolsen MM, Aahlin EK, Harrison EM, McNally SJ, Dejong C, *et al*. Attitudes of patients and care providers to enhanced recovery after surgery programs after major abdominal surgery. J Surg Res 2015;193:102–10.

[19] Stern C, Lockwood C. Knowledge retention from preoperative patient information. Int J Evid Based Healthc 2005;3:45–63.

[20] Hall M, Migay A-M, Persad T, Smith J, Yoshida K, Kennedy D, *et al*. Individuals' experience of living with osteoarthritis of the knee and perceptions of total knee arthroplasty. Physiother Theory Pract 2008;24:167–81.

[21] Keulers B, Scheltinga M, Houterman S, Van Der Wilt G, Spauwen P. Surgeons underestimate their patients' desire for preoperative information. World J Surg 2008;32:964–70.

[22] Epton T, Harris PR, Kane R, van Koningsbruggen GM, Sheeran P. The impact of self-affirmation on health-behavior change: a meta-analysis. Health Psychol 2015;34:187–96.

[23] McDonald S, Page MJ, Beringer K, Wasiak J, Sprowson A. Preoperative education for hip or knee replacement. Cochrane Libr 2014:CD003526, http://dx.doi.org/10.1002/14651858.CD003526.pub3.

[24] Waller A, Forshaw K, Bryant J, Carey M, Boyes A, Sanson-Fisher R. Preparatory education for cancer patients undergoing surgery: a systematic review of volume and quality of research output over time. Patient Educ Couns 2015;98:1540–9.

[25] Johansson K, Nuutila L, Virtanen H, Katajisto J, Salanterä S. Preoperative education for orthopaedic patients: systematic review. J Adv Nurs 2005;50:2 12–23.
[26] Buining EM, Kooijman MK, Swinkels IC, Pisters MF, Veenhof C. Exploring physiotherapists' personality traits that may influence treatment outcome in patients with chronic diseases: a cohort study. BMC Health Serv Res 2015;15:558.
[27] Australian Bureau of Statistics. Health literacy, Australia.2008. cat. no. 4233.0. Canberra: ABS; 2008.
[28] Caselli RJ, Dueck AC, Osborne D, Sabbagh MN, Connor DJ, Ahern GL, *et al.* Longitudinal modeling of age-related memory decline and the APOE ε4 effect. N Engl J Med 2009;361:255–63.
[29] Patel D, Lunn A, Smith A, Lehmann D, Dorrington K. Cognitive decline in the elderly after surgery and anaesthesia: results from the Oxford Project to Investigate Memory and Ageing (OPTIMA) cohort. Anaesthesia 2016;71:1144–52.
[30] Samnani SS, Umer MF, Mehdi SH, Farid FN. Impact of preoperative counselling on early postoperative mobilization and its role in smooth recovery. Int Sch Res Notices 2014:1–5.

Available online at www.sciencedirect.com
ScienceDirect

## 6.3 Supplementary material

Published online as supplementary information for the published manuscript
https://www.sciencedirect.com/science/article/abs/pii/S0031940617300871

**Box.1**: Postoperative interview

Hi, my name is _____; I'm from the Department of Surgery and would like to ask you some questions about the preparation you received from the hospital before you came in for your operation.

I know that before your operation you came in to the Pre-Operative Assessment Unit where you were seen by an anaesthetist, nurses, surgical staff and a physiotherapist.

What pieces of information you received that day really stand out in your memory?

Do you remember meeting (*insert name here*), the physiotherapist?

What do you remember about the information that (*insert name here*) gave you that day?

You were provided with a booklet at this session, tell me what you remember about the information in that booklet.

Thinking back to the information (*insert name here*) gave you, tell me what remember about walking after your operation.

Tell me what you remember about deep breathing and coughing exercises. How many deep breaths in a row are you supposed to do and how often should you do them?

Tell me why these things are important.

Do you think way you received the information helped you to remember it?

As you know, being part of this trial means you either received the normal amount of information or a lot more information when you met the physiotherapist at the Pre-Operative Assessment Clinic before your surgery. Which do you think you received?

Why do you think that?

**Table 6** Characteristics of participants in embedded mixed-methods study, those recruited for mixed-methods study then excluded or lost to follow-up, and all other LIPPSMAck POP participants

| Characteristic | Groups | | |
|---|---|---|---|
| | Embedded mixed-methods study participants (n = 29) | Excluded/lost to follow-up from embedded study (n = 24) | All other LIPPSMAck POP participants (n = 379) |
| Age (*yr*), median (IQR) | 64 (53 to 71) | 68 (57 to 75) | 66 (55 to 74) |
| Male, n (%) | 20 (69) | 15 (63) | 231 (61) |
| Caucasian, n (%) | 29 (100) | 23 (96) | 364 (96) |
| Residential location, n (%) | | | |
| Metropolitan | 0 (0)* | 0 (0) | 72 (19) |
| Regional | 16 (55) | 10 (42) | 159 (42) |
| Rural/remote | 13 (45) | 14 (58) | 148 (39) |
| Surgery type, n (%) | | | |
| Colorectal | 14 (48) | 12 (48) | 187 (49) |
| Upper gastrointestinal/hepatobiliary | 9 (31) | 4 (17) | 93 (25) |
| Urology/other | 6 (21) | 8 (32) | 99 (26) |
| Control / Intervention, n (%) / n (%) | 13 (45) / 16 (55) | 15 (62) / 9 (38) | 186 (49) / 193 (51) |
| Expertise of preoperative physiotherapist | | | |
| Senior, n (%) | 25 (86)* | 20 (83) | 241 (64) |
| Junior, n (%) | 4 (14) | 4 (17) | 138 (36) |
| Days from preoperative physiotherapy to day of surgery, median (IQR) | 6 (2 to 20) | 6 (3 to 24) | 9 (3 to 17) |
| Length of hospital stay (*days*), mean (SD) | 13 (15) | 12 (10) | 11 (11) |

IQR – interquartile range, *denotes characteristic imbalanced between groups

# CHAPTER 7

# The LIPPSMAck-POP trial.

## 7.1 Author contributions

As outlined in the preface IB conceived and designed the study, coordinated the trial, prepared the first draft of the manuscript, and was responsible for the final manuscript. IB and IKR did the statistical analysis. IB, EHS, LB, JR, IKR, DS, and LD analysed and interpreted the data. All authors revised all manuscript drafts and approved the final manuscript.

This study was supported by competitive research grants from the Clifford Craig Foundation, Launceston, Australia; the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia; and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand.

## 7.2 Published manuscript

Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, Robertson IK, Story D, Denehy L. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ*. 2018 Jan 24;360:j5916. doi:10.1136/bmj.j5916.

This is an open-access journal. This chapter contains content which is unchanged from the accepted paper.

Further details are provided as thesis appendices (Human Research Ethics Committee letters of approval (Appendix III), participant information and consent forms (Appendix IV), information booklet (Appendix V), and data collection forms (Appendix VI).

RESEARCH

OPEN ACCESS

# Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial

Ianthe Boden,[1,2] Elizabeth H Skinner,[2,3] Laura Browning,[2,3] Julie Reeve,[4,5] Lesley Anderson,[5] Cat Hill,[6] Iain K Robertson,[7,8] David Story,[9] Linda Denehy[10,11]

For numbered affiliations see end of article.

Correspondence to: I Boden ianthe.boden@ths.tas.gov.au

Additional material is published online only. To view please visit the journal online.

Cite this as: *BMJ* 2018;360:j5916 http://dx.doi.org/10.1136/bmj.j5916

Accepted: 12 December 2017

**ABSTRACT**

OBJECTIVE

To assess the efficacy of a single preoperative physiotherapy session to reduce postoperative pulmonary complications (PPCs) after upper abdominal surgery.

DESIGN

Prospective, pragmatic, multicentre, patient and assessor blinded, parallel group, randomised placebo controlled superiority trial.

SETTING

Multidisciplinary preadmission clinics at three tertiary public hospitals in Australia and New Zealand.

PARTICIPANTS

441 adults aged 18 years or older who were within six weeks of elective major open upper abdominal surgery were randomly assigned through concealed allocation to receive either an information booklet (n=219; control) or preoperative physiotherapy (n=222; intervention) and followed for 12 months. 432 completed the trial.

INTERVENTIONS

Preoperatively, participants received an information booklet (control) or an additional 30 minute physiotherapy education and breathing exercise training session (intervention). Education focused on PPCs and their prevention through early ambulation and self directed breathing exercises to be initiated immediately on regaining consciousness after surgery. Postoperatively, all participants received standardised early ambulation, and no additional respiratory physiotherapy was provided.

MAIN OUTCOME MEASURES

The primary outcome was a PPC within 14 postoperative hospital days assessed daily using the Melbourne group score. Secondary outcomes were hospital acquired pneumonia, length of hospital stay, utilisation of intensive care unit services, and hospital costs. Patient reported health related quality of life, physical function, and post-discharge complications were measured at six weeks, and all cause mortality was measured to 12 months.

RESULTS

The incidence of PPCs within 14 postoperative hospital days, including hospital acquired pneumonia, was halved (adjusted hazard ratio 0.48, 95% confidence interval 0.30 to 0.75, P=0.001) in the intervention group compared with the control group, with an absolute risk reduction of 15% (95% confidence interval 7% to 22%) and a number needed to treat of 7 (95% confidence interval 5 to 14). No significant differences in other secondary outcomes were detected.

CONCLUSION

In a general population of patients listed for elective upper abdominal surgery, a 30 minute preoperative physiotherapy session provided within existing hospital multidisciplinary preadmission clinics halves the incidence of PPCs and specifically hospital acquired pneumonia. Further research is required to investigate benefits to mortality and length of stay.

TRIAL REGISTRATION

Australian New Zealand Clinical Trials Registry ANZCTR 12613000664741.

**WHAT IS ALREADY KNOWN ON THIS TOPIC**

Pulmonary complications are among the most serious negative outcomes after upper abdominal surgery and are associated with high mortality and costs

Trials have indicated that these complications might be prevented by preoperative physiotherapy education and breathing exercise instructions alone

This evidence is limited by methodological weaknesses and poor generalisability within the context of modern advances in perioperative surgical practice

**WHAT THIS STUDY ADDS**

This trial provides strong evidence that a single preoperative physiotherapy session that educates patients on the reason and necessity to do breathing exercises immediately after surgery halves the incidence of postoperative respiratory complications

The number needed to treat to avoid postoperative pulmonary complications, including hospital acquired pneumonia, is 7 (95% confidence interval 5 to 14)

## Introduction

Upper abdominal surgery is the most frequent major surgical procedure performed in developed countries.[1] A postoperative pulmonary complication (PPC) is the most common serious complication after this type of surgery.[2] The reported incidence is between 10% and 50% of patients.[2-12] The variability in reported PPC rates after upper abdominal surgery can be explained by the differing patient risk profiles studied and PPC definitions utilised. A PPC is strongly associated with increased mortality, morbidity, and healthcare costs.[3-6] Pulmonary complications (including pneumonia and severe atelectasis) are caused by postoperative pathophysiological reductions in lung volumes, respiratory muscle function, mucociliary clearance, and pain inhibition of respiratory muscles.[13] Breathing exercises may prevent PPCs by reversing these problems, although evidence is inconclusive.[14] Findings may be limited by confounding combinations

of both preoperative and postoperative interventions. Timing may be a key factor in reversing postoperative atelectasis.[15] The time point of initiation of breathing exercises could be improved if patients were educated and trained before surgery to perform their breathing exercises immediately after surgery, rather than waiting for the first physiotherapy session, which is commonly not provided until the day after surgery.[16]

Preoperative education and breathing exercise training alone is reported to be associated with a 75% relative risk reduction and absolute risk reduction of 20% in PPCs,[17 18] although this effect could be exaggerated by methodological biases of single centre trials, non-masked assessors, and low risk surgical cohorts. Non-reporting of PPC risk factors and non-standardisation of early ambulation and physiotherapy are additional confounders that limit conclusions. Additionally, preoperative education to prevent PPCs has not been tested in the context of recent advances in perioperative management, such as minimally invasive surgery or enhanced recovery after surgery pathways,[19] or where preoperative education is provided at outpatient clinics many weeks before surgery and by physiotherapists of different experience levels; both confounders of typical current practice at public and private hospitals.

The Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) trial tested the hypothesis that preoperative education and breathing exercise training delivered within six weeks of surgery by physiotherapists reduces the incidence of PPCs after upper abdominal surgery. We tested this pragmatically with physiotherapists of varying levels of experience providing the intervention within existing multidisciplinary preadmission clinics and within the context of modern advances in perioperative management.

## Methods

The trial was a pragmatic, international, multicentre, patient and assessor blinded, parallel group, randomised placebo controlled trial, powered for superiority and conducted at three Australian and New Zealand public hospitals. Site institutional review boards and ethics committees approved the study, and an independent data safety and monitoring board (see appendix) oversaw the trial's safety and ethical conduct. Full details of the trial's rationale, design, protocol, and interventions are published elsewhere.[20]

### Participants

Eligible patients were English speaking adults 18 years or older who were awaiting elective upper abdominal surgery that required general anaesthesia, a minimum overnight hospital stay, and a 5 cm or longer incision above, or extending above, the umbilicus, and who attended an outpatient preadmission assessment clinic. We excluded patients if they were current hospital inpatients, required organ transplants, required abdominal hernia repairs, were unable to ambulate for more than one minute, and were unable to participate in a single physiotherapy preoperative session within six weeks of surgery. Site investigators screened preadmission clinics daily and invited eligible patients to participate in the trial. Written informed consent was gained before randomisation.

### Randomisation

Preoperative physiotherapists randomly assigned consecutive participants to either intervention (information booklet plus preoperative physiotherapy education and training) or control (information booklet alone) using sequentially numbered sealed opaque envelopes containing allocation cards wrapped in aluminium foil. An independent administrator who took no further part in the trial preprepared these envelopes. Randomisation occurred before the preoperative physiotherapy assessment. Patient details were marked on envelopes to record that randomisation was in order of recruitment. The allocation sequence was determined by a web based computer generated blocked random number table (1:1), which was unavailable to trial staff until completion of the trial.

### Masking

Site investigators and preoperative physiotherapists aware of group allocation had no contact with patients postoperatively. The patients, postoperative physiotherapists, hospital staff, and statisticians were unaware of group assignment. We assessed the success of patient masking in a convenience sample of 29 consecutive participants[21] (see appendix). Primary and secondary outcome assessors were masked to group allocation and not involved in postoperative clinical management. Data were entered into locked electronic databases. These were unsealed for initial analysis after the final participant had reached the six week follow-up. Databases were resealed until the final 12 month follow-up.

### Interventions and procedures

At participating centres, as per accepted standard care, patients listed for upper abdominal surgery are required to attend a hospital multidisciplinary outpatient clinic for presurgical evaluation within six weeks of surgery. At these clinics patients are seen by a nurse, anaesthetist, doctor, and, if required, a stomal therapist. Consenting eligible patients were entered into the trial and provided with an additional physiotherapy session at these clinics.

The preadmission physiotherapy session for control and intervention participants consisted of a standardised physical and subjective assessment.[20] The physiotherapist gave participants an information booklet containing written and pictorial information about PPCs and potential prevention with early ambulation and breathing exercises. Within this booklet, breathing exercises were prescribed and consisted of two sets of 10 slow deep breaths followed by three coughs, to be performed hourly and starting



doi: 10.1136/bmj.j5916 | BMJ 2018;360:j5916 | the bmj

immediately after surgery. No physiotherapy related information other than that contained within the booklet was provided to control participants. Physicians and nurses at the preadmission clinic provided information to participants at their discretion and this was expected to contain the standard amount of education, information, and preparation from these other professions.

Participants randomised to the intervention group received an additional single 30 minute education and breathing exercise coaching session with the physiotherapist immediately after the standardised physiotherapy assessment and delivery of the booklet. During this session, participants were educated about the possibility of PPCs after surgery and given an individualised risk assessment.[7] The effect of anaesthesia and abdominal surgery on mucociliary clearance and lung volumes was explained. Consequences of bacterial stagnation in the lungs were highlighted, utilising the booklet's diagram of mucociliary clearance. The participants were informed that although PPCs were preventable with early ambulation it was often not possible to ambulate at the intensity and duration thought to prevent PPCs until the first or second postoperative day. The participants were educated that self directed breathing exercises were vital to protect their lungs during this inactivity phase and to commence them immediately on regaining consciousness and to continue them hourly until fully ambulant. The physiotherapist then trained the intervention participants on how to perform the prescribed breathing exercises, as detailed in the booklet, and they were coached for at least three repetitions. To help patients remember to perform the exercises hourly in the postoperative period, memory cues were provided. Pragmatically, when we were unable to provide interventions face to face, the booklet was mailed to patients and assessment and education were provided by telephone.

Eleven physiotherapists with varying levels of experience provided the preoperative interventions. The physiotherapists included students, new graduates, senior physiotherapists, through to a physiotherapist with 15 years of acute surgical practice and extensive experience in patient education. To ensure consistency in delivery, all physiotherapists viewed an audiovisual recording of the most experienced physiotherapist providing a preoperative intervention and were provided with a semi-scripted guide to the education session.

From the first postoperative day both control and intervention participants received a physiotherapy directed standardised assisted early ambulation programme[20] (see appendix). Ward physiotherapists assessed the participants daily using standardised criteria[22] (see appendix) and discharged the participants from the assisted ambulation service once a threshold score was met. At the first ambulation session, ward physiotherapists provided participants with a walking aid if needed, an abdominal support pillow for use during coughing, and a brief reminder to perform the breathing exercises as described within the information booklet provided preoperatively. Other than the daily assisted ambulation programme and the brief breathing exercise reminder on the first postoperative day, no additional respiratory physiotherapy was provided to either control or intervention participants. Site investigators monitored and reported divergence from this protocol. If nursing staff provided respiratory devices (eg, incentive spirometry or positive expiratory pressure devices), site investigators removed these and recorded the incidence (see appendix). If a participant was diagnosed as having the primary PPC endpoint, a site investigator informed the ward physiotherapist, and respiratory physiotherapy was subsequently delivered at the attending physiotherapist's discretion. No attempt was made to standardise the way medical or nursing staff encouraged participants to perform breathing exercises as this was considered unfeasible and not reflective of pragmatic ward practice. All other aspects of perioperative patient care, including the type of anaesthesia, postoperative analgesia, surgical techniques, and postoperative clinical care were provided at the discretion of the anaesthesia and surgical teams and according to routine clinical practice at each centre.

### Outcome measures

The primary outcome was incidence of a PPC within 14 postoperative days, or hospital discharge, whichever came sooner. Assessors masked to group allocation assessed participants prospectively and daily until the seventh postoperative day. From the seventh postoperative day additional assessments were performed only as clinically suspected until day 14 when signs or symptoms of respiratory system deterioration were reported in the medical record. Participants were screened using a standardised validated diagnostic tool[7-10 18 20] consisting of eight symptomatic and diagnostic criteria (see box 1). A PPC was diagnosed when four or more of these eight criteria were present at any time from midnight to midnight each postoperative day.

Secondary outcomes included pneumonia,[23] defined as the presence of new chest infiltrates on radiography with at least two of the following criteria: temperature >38°C, dyspnoea, cough and purulent sputum, altered respiratory auscultation, and leukocytosis >14 000/mL or leucopenia <3000/mL within the first 14 hospital days, length of hospital stay (acute and subacute inclusive), readiness for hospital discharge[24] within the first 21 hospital days, number of days in an intensive care or high dependency unit, all cause unplanned admissions to an intensive care or high dependency unit, and hospital costs. Additional secondary outcomes measured at six weeks were self reported health related quality of life and physical function using the SF-36 version 2[25] and specific activity questionnaire,[26] hospital readmissions, and self reported complications that required medical review (respiratory, thromboembolic event, cardiac, gastrointestinal, wound infection, fatigue, or

**Box 1: Postoperative pulmonary complication diagnostic tool: Melbourne group score**

Diagnosis confirmed when four or more criteria are present in a postoperative day:

- New abnormal breath sounds on auscultation different from in the preoperative assessment
- Production of yellow or green sputum different from in the preoperative assessment
- Pulse oximetry oxygen saturation ($SpO_2$) <90% on room air on more than one consecutive postoperative day
- Maximum oral temperature >38°C on more than one consecutive postoperative day
- Chest radiography report of collapse or consolidation
- An unexplained white cell count greater than $11\times10^9$/L
- Presence of infection on sputum culture report
- Physician's diagnosis of pneumonia, lower or upper respiratory tract infection, an undefined chest infection, or prescription of an antibiotic for a respiratory infection

weakness). Following newly published meta-analysis data showing a strong association between mortality and PPCs,[4] we added a further secondary outcome of 12 month all cause mortality one year into the trial. Assessors masked to group assignment retrieved these data for all participants from government databases.

To assess standardisation of postoperative ambulation we measured hours from surgery until participants were ambulant with a physiotherapist for longer than one minute, days until ambulant for longer than 10 minutes, and days until discharged from assisted ambulation.

## Statistical analysis

### *Sample size*

The study was powered based on two rationales: absolute risk reduction in PPCs of 20% as reported by previous trials of preoperative education,[17 18] and a PPC rate of 38% (95% confidence interval 26% to 52%) at the primary participating institution identified by retrospective audit of consecutive patients requiring upper abdominal surgery (n=50, unpublished data, 2008). For the purposes of this trial, conservative goals (minimum 10% absolute risk reduction from a 20% baseline PPC risk) were set considering time passed since previous audits and trials, known improvements in perioperative care during this time, and methodological limitations of previous research. A priori we estimated a sample of 398 patients would have 80% power to detect a significant difference between groups (P=0.05, two sided) with an 11% inflation to account for drop-outs, non-compliance, and uncertainty of baseline risk, providing a final sample size of 441.

### *Baseline comparability and adjustment factors*

Results were adjusted using backwards stepwise regression for specific baseline covariates considered a priori[20] to affect primary outcome. These prespecified covariates were respiratory comorbidity, smoking history, physical activity, age, obesity, duration of operation, surgical category, incision type, admission to intensive care, intraoperative ventilation, fluid delivery, blood transfusions, postoperative analgesia mode, and prophylactic antibiotics.

### *Analysis of primary and secondary outcomes*

To estimate primary outcome efficacy and binomial secondary outcomes we used multivariate robust random effects Poisson generalised linear regression. We compared the time effect of day the PPC was diagnosed (to day 14) and mortality (to 12 months) between groups using Cox proportional hazards regression with or without adjustment for covariates and graphically illustrated using Kaplan-Meier methods. Analysis of hospital length of stay and readiness for hospital discharge (to 21 days) was prespecified[20] using mixed effects ordered logistic regression. However, as these time points are truncated in patients who died, we also performed a sensitivity analysis using Cox proportional hazards regression with or without adjustment for covariates, where deaths were treated as censored times without failure.

For all outcomes we estimated differences in effect size between groups on an intention-to-treat basis. We recruited patients with an anticipated surgical procedure complying with the trial protocol. At times this planned procedure was changed intraoperatively to lower abdominal or laparoscopic surgery. We also performed a prespecified per protocol analysis excluding participants operated on through an incision wholly below the umbilicus or by laparoscope alone.[20] These participants were not provided with assisted ambulation physiotherapy as this was not standard care at participating sites for this patient cohort. In these participants we therefore did not assess days to discharge from assisted ambulation. We excluded from all analyses those participants who failed to progress to surgery or withdrew their consent.

### *Exploratory analyses*

We performed exploratory post hoc sensitivity adjusted analyses of the per protocol population to determine the effect of specific covariates (experience grade of treating physiotherapist—experience less than five years versus experience more than five years; surgical group—upper gastrointestinal/hepatobiliary, colorectal, renal/urology, preoperative respiratory complication risk score,[7] age, and sex) across all primary and major secondary outcomes. These covariates were selected to assist in hypothesis generation according to known factors influencing the incidence of PPCs and the successful provision of an education based intervention.

The statistical analysis plan was prespecified[20] and we used STATA (version 14.1) for all analyses.

## Patient involvement

Qualitative studies report that patients rate preoperative counselling and the avoidance of infection as the two most important strategies for improving recovery after upper abdominal surgery,[27] preferring personalised delivery of detailed information.[28] This meets patients' need for control over their disease and surgery.[29] However, health professionals tend to underestimate these factors.[30] Before designing the current study, the corresponding author invited patients who had



doi: 10.1136/bmj.j5916 | *BMJ* 2018;360:j5916 | the bmj

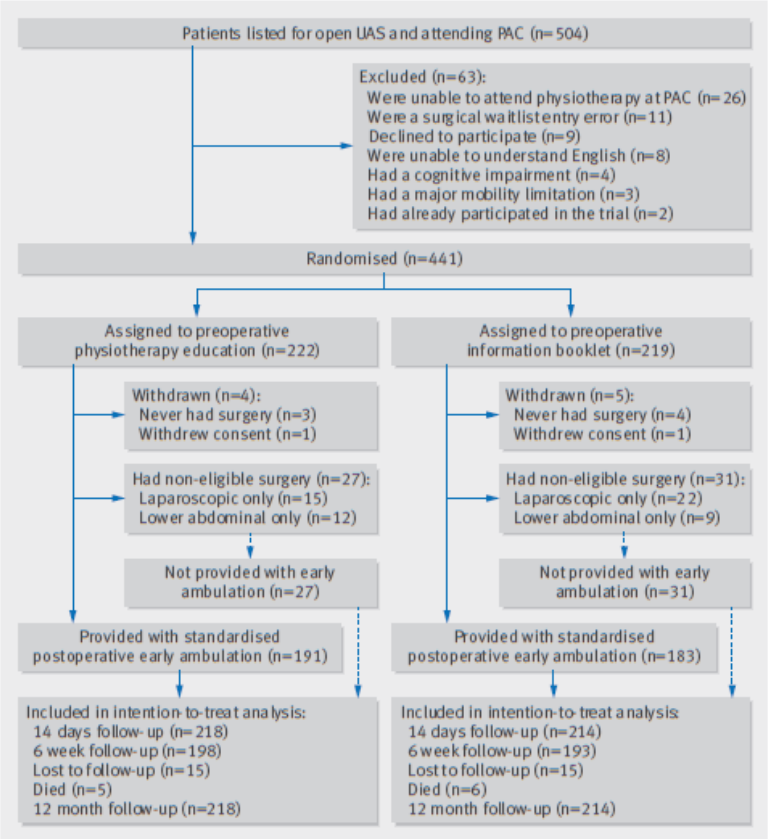



**Fig 1 | Flow of patients through trial. UAS=upper abdominal surgery. PAC=preadmission clinic**

abdominal surgery within six months at the primary participating site to participate in a focus group. These patients reviewed the information booklet intended to be provided to all trial participants and were asked to comment on the type of information about respiratory complications, breathing exercises, and postoperative physiotherapy and recovery they would have liked to have been provided with before their own surgery. Within the first six months of the trial we interviewed a convenience sample of participants in the week after their surgery.[21] This was to explore further participants' opinions on preoperative education and to assess the feasibility of delivering a memorable and impactful preoperative intervention that had the potential to change behaviour. At the primary participating centre the consent form contained a section where participants could elect to receive a newsletter where updates on the trial would be provided and results disseminated.

## Results

From June 2013 to August 2015, we assessed 504 patients listed for elective upper abdominal surgery for eligibility. Of these, 441 met the inclusion criteria and were randomly assigned to receive either an information booklet (n=219; control) or preoperative physiotherapy (n=222; intervention). Nine (2%) patients were withdrawn from the trial, leaving 432 (98%) included for primary analysis (fig 1). Tables 1 and 2 list the baseline and clinical characteristics of the participants.

### Primary outcome

Overall, 85 of the 432 participants (20%) were diagnosed as having a PPC. Intention-to-treat unadjusted results showed statistically significantly fewer PPCs in the physiotherapy group (27/218, 12%) compared with control group (58/214, 27%); (absolute risk reduction 15%, 95% confidence interval 7% to 22%, P<0.001; table 3). The incidence of PPCs remained halved (hazard ratio 0.48, 95% confidence interval 0.30 to 0.75, P=0.001) in the intervention group when adjustments were made for baseline imbalances in three of the prespecified covariates—age, respiratory comorbidity, surgical procedure (table 3, fig 2), with a number needed to treat of 7 (95% confidence interval 5 to 14).

### Secondary outcomes

The incidence of hospital acquired pneumonia was halved in the physiotherapy group in the adjusted analyses (table 3), with a number needed to treat of 9 (95% confidence interval 6 to 21). No differences were detected in the other secondary measures of hospital length of stay, readiness for hospital discharge, unplanned readmissions or length of stay in intensive care, hospital readmissions at six weeks, and all ambulation attainment measures (table 3 and appendix). No adverse events were attributable to the preoperative physiotherapy education sessions or to the assisted ambulation protocol. Detailed modelling of specific costs and health economics supporting this clinical efficacy report will be published later.

Five participants (1%) died during the primary hospital stay. Four participants (two each in both groups) acquired a PPC in the first three postoperative days, progressing to respiratory sepsis, multi-organ failure, and then death. The fifth death occurred in a participant who developed a PPC on the 11th postoperative day and later died of a thromboembolic event. A PPC within the first 14 postoperative days was associated with increased mortality at all time points after surgery (unadjusted 12 month mortality: 24% (20/85) in participants with PPCs *v* 6% (20/347) without PPCs; P<0.001; adjusted data figure 1S: appendix). No difference in all cause mortality between groups was seen at six weeks and 12 months, although a sustained separation between groups favouring the intervention group starting at four months was evident (adjusted hazard ratio 0.78, 95% confidence interval 0.41 to 1.48, P=0.45; fig 3a).

### Sensitivity analyses

Planned per protocol sensitivity analysis removing participants who had lower abdominal and laparoscopic surgery found strengthening of effect in the primary and most secondary outcomes in favour of physiotherapy (see appendix). After surgery, 15 (3%)

**Table 1 | Baseline demographic and clinical characteristics of the study population. Values are numbers (percentages) unless stated otherwise**

| Characteristics | Preoperative physiotherapy (n=218) | Information booklet (n=214) |
|---|---|---|
| Median (interquartile range) age (years) | 63.4 (51.5-71.9) | 67.5 (56.3-75.3) |
| Men | 132 (61) | 134 (61) |
| Mean (SD) body mass index | 28.5 (5.9) | 28.3 (6.2) |
| Body mass index >35 | 25 (12) | 30 (14) |
| ASA physical health status: | | |
| 1-2 | 150 (69) | 124 (58) |
| 3-4 | 67 (31) | 90 (42) |
| Comorbidities: | | |
| Respiratory disease | 42 (19) | 55 (26) |
| Diabetes mellitus | 33 (15) | 41 (19) |
| Cancer | 148 (68) | 148 (69) |
| Cardiac disease | 26 (12) | 34 (16) |
| Median (interquartile range) functional comorbidity index | 2 (1-5) | 2 (1-4) |
| **Preoperative respiratory status** | | |
| Chronic daily sputum typology: | | |
| Mucoid | 44 (20) | 46 (22) |
| Mucopurulent or purulent | 28 (13) | 20 (9) |
| Recent chest infection* | 12 (6) | 5 (2) |
| Smoking status: | | |
| Never smoked | 76 (35) | 71 (33) |
| Former smoker† | 93 (43) | 86 (40) |
| Current smoker‡ | 49 (21) | 57 (27) |
| Mean (SD) average pack years | 18.1 (23.7) | 20.6 (24.7) |
| **Preoperative strength and activity levels** | | |
| Mean (SD) handgrip strength (kg) | 35.1 (11.4) | 33.8 (10.9) |
| Mean (SD) estimated $VO_2$max§ (mL/kg/min) | 16.1 (6.9) | 15.3 (7.0) |
| Mean (SD) self reported maximum METS§ | 6.5 (2.0) | 6.3 (2.1) |
| **Provision of interventions** | | |
| Physiotherapist experience grade: | | |
| Student | 31 (14) | 30 (14) |
| Recent graduate | 47 (22) | 54 (25) |
| Senior | 16 (7) | 11 (5) |
| Specialist respiratory | 124 (57) | 119 (56) |
| Provided by telephone | 18 (8) | 24 (11) |
| Median (interquartile range) days from preoperative physiotherapy to surgery | 8 (3-16) | 9 (4-20) |
| **Surgical category and procedure** | | |
| Colorectal: | 108 (50) | 101 (47) |
| Hemicolectomy | 33 (15) | 37 (17) |
| Anterior and anteroposterior resection | 33 (15) | 36 (17) |
| Hartmann's (including reversals) | 13 (6) | 9 (4) |
| Other bowel resections | 29 (13) | 19 (9) |
| Hepatobiliary/upper gastrointestinal: | 49 (22) | 59 (28) |
| Oesophagectomy/gastrectomy | 12 (6) | 21 (10) |
| Liver surgery | 17 (8) | 14 (7) |
| Whipples/pancreadectomy | 13 (6) | 12 (6) |
| Other | 7 (3) | 12 (6) |
| Renal/urology/other: | 61 (28) | 54 (24) |
| Nephrectomy | 35 (16) | 31 (14) |
| Cystoprostatectomy/cystectomy | 9 (4) | 7 (3) |
| Adrenalectomy/pyeloplasty | 5 (2) | 9 (4) |
| Other | 12 (6) | 7 (3) |
| Incision type: | | |
| Midline laparotomy | 109 (50) | 103 (48) |
| Bilateral or unilateral subcostal | 40 (18) | 38 (18) |
| Transverse abdominal | 33 (15) | 34 (16) |
| Abdominal+thoracotomy | 6 (3) | 7 (3) |
| Other upper abdominal incision | 3 (1) | 1 (0) |
| Laparoscopic or lower abdominal | 27 (12) | 31 (14) |
| Length of procedure (mins): | | |
| <120 | 21 (10) | 15 (7) |
| 120-179 | 40 (18) | 40 (19) |
| 180-239 | 62 (28) | 64 (30) |
| 240-299 | 37 (17) | 36 (17) |

(Continued)



doi: 10.1136/bmj.j5916 | *BMJ* 2018;360:j5916 | the bmj

**Table 1 | (Continued)**

| Characteristics | Preoperative physiotherapy (n=218) | Information booklet (n=214) |
|---|---|---|
| ≥300 | 58 (27) | 59 (28) |
| **Intraoperative management** | | |
| Mechanical ventilation: | | |
| Mean (SD) $F_IO2$ | 0.54 (0.14) | 0.56 (0.13) |
| Median (interquartile range) PEEP (cm $H_2O$) | 5 (5-6) | 5 (4-6) |
| Mean (SD) tidal volume (mL/kg) | 6.2 (1.3) | 6.2 (1.3) |
| Mean (SD) intraoperative fluid delivery (mL/kg/hr) | 9.1 (4.5) | 9.0 (4.6) |
| Type of intraoperative fluid: | | |
| Crystalloid | 213 (98) | 202 (94) |
| Colloid | 5 (2) | 1 (0) |
| No of transfusion units: | | |
| 1-2 | 7 (3) | 6 (3) |
| >2 | 2 (1) | 4 (2) |
| Intraoperative epidural | 47 (22) | 44 (21) |
| **Postoperative management** | | |
| Immediate postoperative location: | | |
| Surgical ward | 124 (57) | 115 (54) |
| ICU | 94 (43) | 99 (46) |
| ICU with mechanical ventilation | 21 (10) | 23 (11) |
| Mean (SD) fluid delivery postoperative day 1 (mL/kg/min) | 1.4 (0.8) | 1.5 (1.1) |
| Antibiotic delivery before PPC, discharge from hospital, or day 14, whichever came first: | | |
| Prophylactic during surgery | 212 (97) | 209 (98) |
| All types of β lactamase inhibitor | 191 (88) | 183 (86) |
| Penicillins and 1st-2nd generation cephalosporins | 186 (85) | 180 (84) |
| 3rd generation cephalosporins/macrolides | 16 (7) | 20 (9) |
| Other | 33 (15) | 35 (16) |
| Analgesia management: | | |
| Oral | 210 (96) | 211 (99) |
| Patient controlled intravenous | 159 (73) | 178 (83) |
| Patient controlled epidural | 22 (10) | 20 (9) |
| Continuous epidural | 45 (21) | 38 (18) |
| Continuous infusion pump | 26 (12) | 26 (12) |

ASA=American Society Anaesthesiologists score where 1 is a normal healthy patient, 2 is a patient with mild systemic disease, 3 is a patient with severe systemic disease, 4 is a patient with severe systemic disease that is a constant threat to life, and 5 is a moribund patient who is not expected to survive; $VO_2$=rate of oxygen consumption; METS=metabolic equivalents; $FIO_2$=Fraction of inspired oxygen; PEEP=positive end expiratory pressure; ICU=intensive care unit; PPC=postoperative pulmonary complications.
*Reported cough with new yellow/green sputum and symptoms of malaise, fever, or dyspnoea within two weeks of preoperative assessment.
†Ceased smoking more than eight weeks before preoperative assessment.
‡Smoked tobacco regularly within eight weeks of assessment.
§Derived from specific activity questionnaire.

**Table 2 | Postoperative clinical events and complications between groups**

| | No (%) | |
|---|---|---|
| Clinical events or complications | Preoperative physiotherapy (n=218) | Information booklet (n=214) |
| Blood volume complications: | | |
| Hypovolemia | 26 (12) | 26 (12) |
| Fluid overload | 7 (3) | 4 (2) |
| Surgical complications: | | |
| Surgical lacerations | 22 (10) | 12 (6) |
| Haemorrhage | 16 (7) | 13 (6) |
| Wound dehiscence | 5 (2) | 8 (4) |
| Anastomosis leaks | 3 (1) | 2 (1) |
| Infection type: | | |
| Wound | 22 (10) | 25 (10) |
| Urinary tract | 12 (6) | 18 (8) |
| All others | 16 (7) | 20 (9) |
| Sepsis | 8 (4) | 14 (7) |
| Other events: | | |
| Delirium | 17 (8) | 22 (10) |
| Re-intubation | 8 (4) | 11 (5) |
| Cardiac event | 11 (5) | 7 (3) |
| Fall | 0 (0) | 2 (1) |
| Other specific respiratory events: | | |
| Pneumothorax | 11 (5) | 8 (4) |
| Pleural effusion | 10 (5) | 11 (5) |
| Pulmonary embolisms | 3 (1) | 4 (2) |
| Acute respiratory failure | 5 (2) | 12 (6) |

**Table 3 | Primary and secondary outcomes. Values are numbers (percentages) unless stated otherwise**

| Intention to treat | Preoperative physiotherapy (n=218) | Information booklet (n=214) | Adjusted analysis HR, OR, IRR (95% CI) | Adjusted analysis P value | Unadjusted analysis HR, OR, IRR (95% CI) | Unadjusted analysis P value |
|---|---|---|---|---|---|---|
| **Primary outcome** | | | | | | |
| PPC | 27 (12) | 58 (27) | 0.48 (0.30 to 0.75) | 0.001 | 0.43 (0.27 to 0.67) | <0.001 |
| **Secondary outcomes** | | | | | | |
| Pneumonia | 18 (8) | 42 (20) | 0.45 (0.26 to 0.78) | 0.005 | 0.40 (0.23 to 0.69) | <0.001 |
| Hospital utilisation: | | | | | | |
| Median (interquartile range) length of hospital stay (days)* | 8 (6-11) | 9 (7-13) | 0.85 (0.61 to 1.19) | 0.35 | 0.77 (0.56 to 1.07) | 0.13 |
| Sensitivity analysis† | | | 1.12 (0.94 to 1.34) | 0.22 | 1.19 (0.99 to 1.43) | 0.06 |
| Ready for hospital discharge (days): | | | | | | |
| Median (interquartile range)* | 6 (5-10) | 7 (5-11) | 0.85 (0.61 to 1.18) | 0.33 | 0.77 (0.56 to 1.08) | 0.13 |
| Sensitivity analysis† | | | 1.07 (0.90 to 1.28) | 0.45 | 1.15 (0.96 to 1.38) | 0.14 |
| Median (interquartile range) ICU length of stay (days) | 1.3 (2.9) | 1.5 (2.7) | 0.97 (0.67 to 1.42) | 0.89 | 0.83 (0.57 to 1.18) | 0.29 |
| Unplanned ICU readmissions | 15 (7) | 19 (9) | 0.93 (0.47 to 1.85) | 0.84 | 0.78 (0.39 to 1.53) | 0.46 |
| Hospital readmission at six weeks | 36/197 (18) | 33/199 (17) | 1.14 (0.71 to 1.84) | 0.59 | 1.10 (0.69 to 1.77) | 0.69 |
| Mobility‡: | | | | | | |
| Median (interquartile range) time from operation to ambulation >1 min (hours) | 23 (20-44) | 22 (20-39) | 1.03 (0.82 to 1.30) | 0.81 | 1.08 (0.86 to 1.37) | 0.50 |
| Median (interquartile range) postoperative day achieved >10 mins of ambulation (days) | 3 (1-5) | 3 (1-5) | 0.99 (0.83 to 1.17) | 0.90 | 1.05 (0.88 to 1.25) | 0.58 |
| Median (interquartile range) postoperative day discharged from assisted ambulation (days) | 3 (2-5) | 4 (2-5) | 1.05 (0.86 to 1.28) | 0.60 | 1.14 (0.94 to 1.39) | 0.19 |
| Patient reported complications at 6 weeks: | | | | | | |
| Any complications | 74/192 (39) | 79/197 (40) | 0.90 (0.65 to 1.24) | 0.50 | 0.89 (0.65 to 1.22) | 0.65 |
| Wound infection | 36/192 (19) | 40/197 (20) | 0.88 (0.56 to 1.39) | 0.50 | 0.92 (0.59 to 1.45) | 0.73 |
| Fatigue | 29/192 (14) | 33/197 (14) | 1.00 (0.61 to 1.66) | 0.99 | 0.90 (0.55 to 1.48) | 0.65 |
| Nausea/vomiting/gastrointestinal | 27/192 (14) | 29/197 (14) | 0.98 (0.58 to 1.67) | 0.94 | 0.96 (0.57 to 1.61) | 0.86 |
| Respiratory | 8/192 (4) | 21/197 (9) | 0.45 (0.20 to 1.03) | 0.059 | 0.39 (0.17 to 0.88) | 0.024 |
| Cardiac | 10/192 (5) | 3/197 (2) | 4.06 (1.09 to 15.1) | 0.036 | 3.42 (0.94 to 12.4) | 0.062 |
| Venothromboembolic events | 2/192 (1) | 6/197 (3) | 0.37 (0.07 to 1.85) | 0.23 | 0.34 (0.07 to 1.69) | 0.19 |
| Mean (SD) mortality: | | | | | | |
| In hospital | 3 (1.4) | 3 (1.4) | 1.72 (0.42 to 7.01) | 0.45 | 1.25 (0.26 to 5.96) | 0.78 |
| At 6 weeks | 4 (1.8) | 3 (1.4) | 1.47 (0.32 to 6.72) | 0.62 | 1.31 (0.29 to 5.83) | 0.72 |
| At 12 months | 16 (7.3) | 23 (11) | 0.78 (0.41 to 1.48) | 0.45 | 0.67 (0.35 to 1.27) | 0.22 |

PPC=postoperative pulmonary complication; ICU=intensive care unit; HR=hazard ratio; OR=odds ratio; IRR=incidence rate ratio.
Analyses are adjusted for baseline age, previous respiratory disease, and hepatobiliary/upper gastrointestinal surgery. Point estimates are HRs for all outcomes except for ORs for prespecified analysis of hospital length of stay and readiness to discharge, unplanned admission to an ICU, length of stay on an ICU, and hospital readmissions at six weeks, and IRRs for patient reported complications.
*Prespecified analysis involved a rank ordered comparison of length of stay (days), using mixed effects ordered logistic regression. OR <1.00 indicates an earlier discharge from hospital.
†Time-to-event analysis with median (interquartile range) number of days reported and estimation of HR using Cox proportion hazards regression. HR >1.00 indicates an increased likelihood of earlier discharge from hospital.
‡No mobility measures are available for patients who did not have upper abdominal surgery.

breaches to the postoperative protocol occurred (see appendix). Removal of these patients from analysis did not affect the reduction in PPCs (hazard ratio 0.48, 95% confidence interval 0.3 to 0.7). To explore variations of effect and to validate the main results, we performed further exploratory post hoc adjusted analyses of subgroup effects (experience level of preoperative physiotherapist, site, and participant age, sex, surgical category, and predicted PPC risk score) in PPCs, hospital stay, and 12 month mortality. There was a gradient in PPC reduction according to surgical category, with the greatest response to preoperative physiotherapy in colorectal surgery, then upper gastrointestinal surgery, with the least difference between groups for urology (fig 4). A similar pattern according to type of surgery was seen with length of stay and mortality (fig 5 and fig 6). PPC reduction attributable to the preoperative intervention was greatest in participants educated by an experienced physiotherapist, men, and those younger than 65 years (fig 4). In particular, education

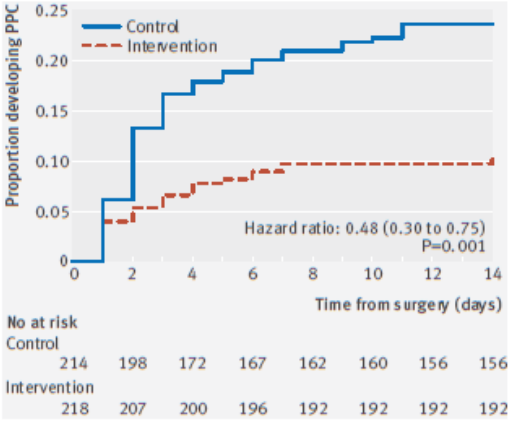



**Fig 2 | Time to diagnosis of a postoperative pulmonary complication after surgery. Data are on an intention-to-treat basis and adjusted for age, previous respiratory disease, and surgical category. PPC=postoperative pulmonary complication**



doi: 10.1136/bmj.j5916 | BMJ 2018;360:j5916 | the bmj

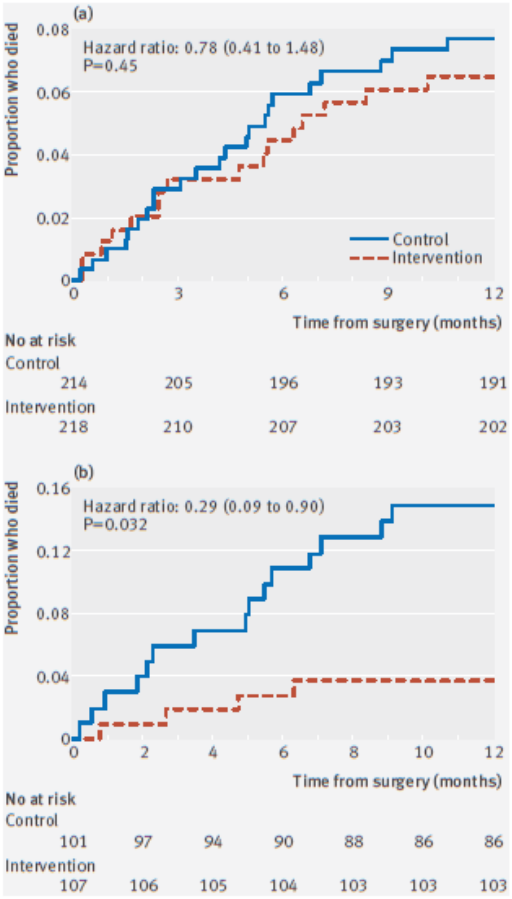



**Fig 3 | (a) 12 month mortality between groups; (b) 12 month mortality between groups in subgroup treated by experienced physiotherapists. Data are per protocol and adjusted for age, previous respiratory disease, and surgical category**

provided by experienced physiotherapists was associated with shorter length of stay (fig 5) and lower all cause 12 month mortality (adjusted hazard ratio 0.29, 95% confidence interval 0.09 to 0.90, P=0.032; fig 3b).

At the New Zealand site, the reduction in PPCs was less than at Australian sites. Exploratory between site covariate analysis found that the New Zealand site provided fewer interventions with experienced physiotherapists (0% *v* 68%, P<0.001), less intraoperative fluid (mean 5.1 *v* 9.8 mL/kg/hr, P<0.001), more epidurals (50% *v* 12%, P<0.001), and later commencement of postoperative ambulation (52 hours *v* 28 hours, P<0.001). There were no statistically significant differences between sites in the proportion of participants who had colorectal surgery, were male, or were younger than 65 years.

## Discussion

In this multicentre trial conducted in two countries we found that a single 30 minute face-to-face preoperative physiotherapy education and training session provided within six weeks of surgery halved the incidence of postoperative pulmonary complications (PPCs), including hospital acquired pneumonia, after major upper abdominal surgery compared with information provided by a booklet alone. This association was stronger in patients having colorectal surgery, those younger than 65 years, men, or where an experienced physiotherapist provided the education.

### Hypothesis of effect

Atelectasis is inevitable in the early postoperative period because of the pathophysiological effects of anaesthesia,[31] mechanical ventilation,[32] and changes in thoracoabdominal pressure.[13] Postoperative breathing exercises performed by patients might reverse this atelectasis, although breathing exercises coached by physiotherapists postoperatively appear less effective in reducing PPCs[14] compared with preoperative interventions.[17 18 33-35] One explanation for the effectiveness of preoperative physiotherapy to reduce PPCs is that the preparation, motivation, and training of patients before surgery brings the timing of breathing exercise initiation forward to immediately after regaining consciousness after surgery. Commonly in a postoperative only physiotherapy service, coaching begins on the first or second postoperative day[15]; which may be too late, as most PPCs have already occurred by this time.[4 8] Timing of initiation could be critical. Breathing exercises during the first 24 hours after surgery could prevent mild atelectasis extending to severe atelectasis, at which point breathing exercises are less effective in re-expanding non-compliant collapsed lung tissue.[15] Earlier initiation may also increase the total dose of breathing exercises. Pain, nausea, analgesia, anxiety, and persisting sedation can also compromise a patient's ability to comprehend instructions when first contact with physiotherapy is only in the postoperative phase. In this trial, a sample of intervention patients reported that preoperative physiotherapy education was memorable and engaging.[21] These patients reported that preoperative physiotherapy empowered them to treat themselves and placed high value on its role in improving their postoperative recovery.[21]

### Comparison with other studies

Our PPC reduction of an adjusted 52% relative risk reduction is less than that reported in methodologically weaker trials with limitations on generalisability.[17 18] A Pakistani trial[18] of 224 patients who were young (mean age 37), having minor surgeries, and of a reasonably healthy premorbid status, reported that preoperative education by medical registrars resulted in earlier postoperative mobilisation and a 76% relative reduction in PPCs. Similarly, a single centre Swedish trial of 368 patients[17] reported a 78% PPC risk reduction after open abdominal surgery where participants were met by experienced physiotherapists the day before surgery, taught postoperative breathing exercises, and educated about early ambulation. Despite the large effect sizes, the generalisability

| | PPCs/All cases (%) | | Hazard ratio (95% CI) | Hazard ratio (95% CI) | P value |
|---|---|---|---|---|---|
| | Preoperative physiotherapy | Booklet | | | |
| All patients | | | | | |
| Intention to treat | 27/218 (12.4) | 58/214 (27.1) | | 0.51 (0.32 to 0.80) | 0.004 |
| Per protocol | 26/191 (13.6) | 56/183 (30.6) | | 0.49 (0.30 to 0.78) | 0.003 |
| Experience level of physiotherapists | | | | | |
| Experienced | 15/107 (14.0) | 36/101 (35.6) | | 0.43 (0.23 to 0.81) | 0.03 |
| Inexperienced | 11/84 (13.1) | 20/82 (24.4) | | 0.57 (0.29 to 1.13) | 0.30 |
| Surgical category | | | | | |
| Colorectal/lower gastrointestinal | 6/92 (6.5) | 19/89 (21.3) | | 0.31 (0.12 to 0.79) | 0.06 |
| Hepatobiliary/upper gastrointestinal | 12/48 (25.0) | 26/54 (48.1) | | 0.55 (0.29 to 1.06) | 0.08 |
| Renal/vascular/other | 8/51 (15.7) | 11/40 (27.5) | | 0.65 (0.26 to 1.62) | 0.40 |
| Trial site | | | | | |
| Australia | 22/159 (13.8) | 52/154 (33.8) | | 0.47 (0.28 to 0.79) | 0.004 |
| New Zealand | 4/32 (12.5) | 4/29 (13.8) | | 0.78 (0.21 to 2.82) | 0.70 |
| Age (years) | | | | | |
| <65 | 11/102 (10.8) | 27/74 (36.5) | | 0.33 (0.16 to 0.68) | 0.01 |
| ≥65 | 15/89 (16.9) | 29/109 (26.6) | | 0.63 (0.35 to 1.15) | 0.42 |
| Sex | | | | | |
| Women | 10/76 (13.2) | 15/68 (22.1) | | 0.76 (0.34 to 1.69) | 0.51 |
| Men | 16/115 (13.9) | 41/115 (35.7) | | 0.38 (0.22 to 0.68) | 0.004 |
| Preoperative PPC risk score | | | | | |
| Low | 7/91 (7.7) | 12/70 (17.1) | | 0.44 (0.17 to 1.14) | 0.18 |
| High | 19/100 (19.0) | 44/113 (38.9) | | 0.45 (0.26 to 0.76) | 0.003 |

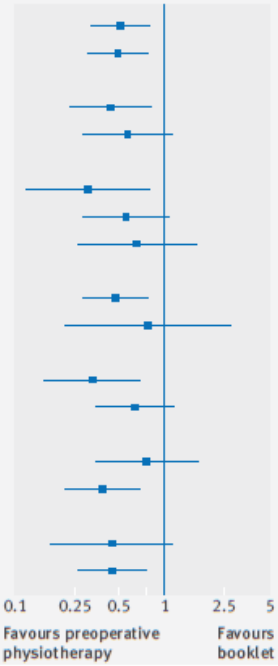



**Fig 4 | Sensitivity analysis of subgroup effects on incidence of postoperative pulmonary complications (PPCs). Data are adjusted for age, respiratory comorbidity, and upper gastrointestinal surgery**

| | Median (interquartile range)/Total | | Hazard ratio (95% CI) | Hazard ratio (95% CI) | P value |
|---|---|---|---|---|---|
| | Preoperative physiotherapy | Booklet | | | |
| All patients | | | | | |
| Intention to treat | 8 (6-11)/218 | 9 (7-13)/214 | | 1.11 (0.93 to 1.34) | 0.25 |
| Per protocol | 8 (7-12)/191 | 9 (7-15)/183 | | 1.18 (0.97 to 1.43) | 0.11 |
| Experience level of physiotherapists | | | | | |
| Experienced | 8 (7-11)/107 | 9 (7-16)/101 | | 1.33 (1.02 to 1.74) | 0.12 |
| Inexperienced | 8 (6-12)/84 | 9 (7-12)/82 | | 1.01 (0.76 to 1.35) | 0.93 |
| Surgical category | | | | | |
| Colorectal/lower gastrointestinal | 8 (6-11)/92 | 9 (7-12)/89 | | 1.23 (0.97 to 1.69) | 0.35 |
| Hepatobiliary/upper gastrointestinal | 9 (7-15)/48 | 11 (8-15)/54 | | 1.12 (0.81 to 1.57) | 0.49 |
| Renal/vascular/other | 8 (7-12)/51 | 9 (7-13)/40 | | 1.07 (0.68 to 1.69) | 0.76 |
| Trial site | | | | | |
| Australia | 8 (7-11)/159 | 9 (7-15)/154 | | 1.26 (1.01 to 1.56) | 0.11 |
| New Zealand | 8 (7-13)/32 | 10 (7-11)/29 | | 0.83 (0.52 to 1.31) | 0.83 |
| Age (years) | | | | | |
| <65 | 8 (6-11)/102 | 9 (7-12)/74 | | 1.19 (0.94 to 1.51) | 0.14 |
| ≥65 | 9 (7-13)/89 | 10 (7-17)/109 | | 1.13 (0.83 to 1.54) | 0.43 |
| Sex | | | | | |
| Women | 8 (7-12)/76 | 9 (7-13)/68 | | 0.96 (0.69 to 1.35) | 0.82 |
| Men | 8 (6-12)/115 | 10 (7-15)/115 | | 1.34 (1.06 to 1.70) | 0.05 |
| Preoperative PPC risk score | | | | | |
| Low | 8 (6-10)/91 | 8 (6-10)/70 | | 1.09 (0.78 to 1.54) | 0.61 |
| High | 9 (7-13)/100 | 10 (8-16)/113 | | 1.26 (0.99 to 1.60) | 0.06 |

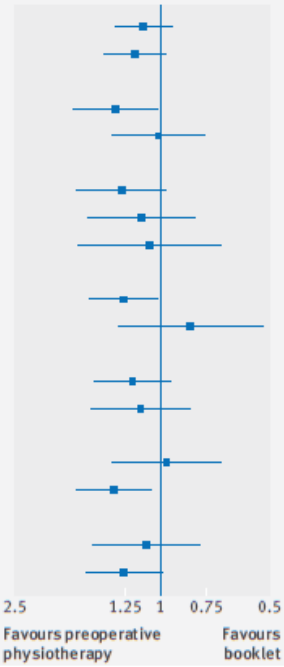



**Fig 5 | Sensitivity analysis of subgroup effects on hospital length of stay. Data are adjusted for age, respiratory comorbidity, and upper gastrointestinal surgery. PPC=postoperative pulmonary complication**



doi: 10.1136/bmj.j5916 | BMJ 2018;360:j5916 | the bmj

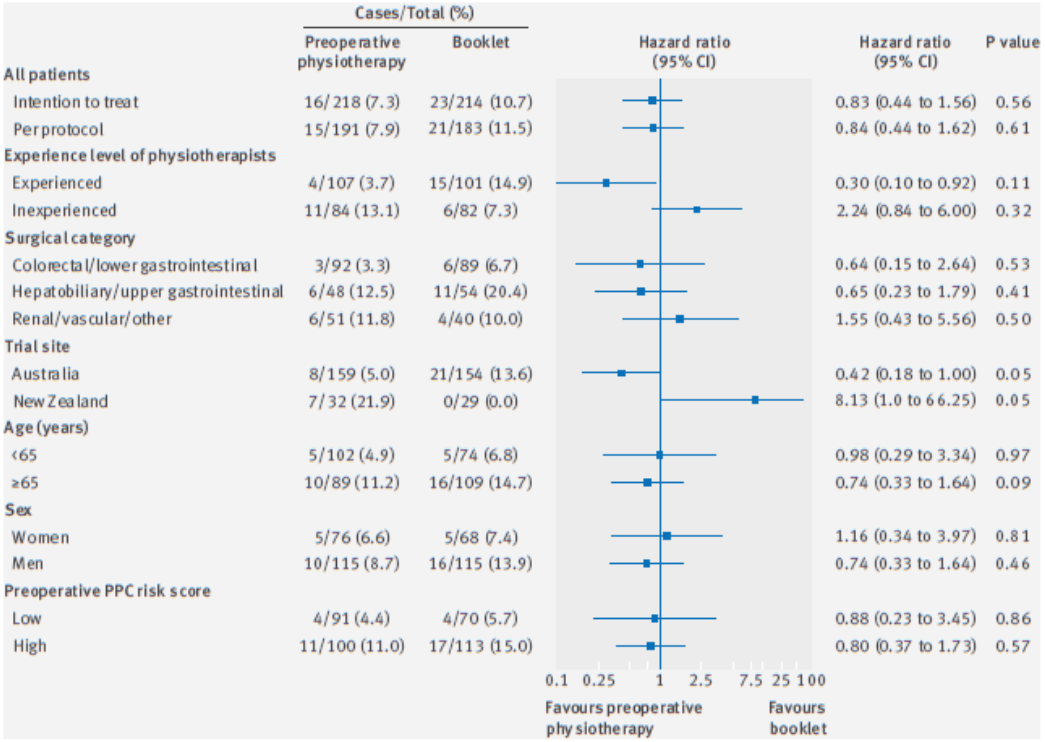



**Fig 6 | Sensitivity analysis of subgroup effects on 12 month all cause mortality. Data are adjusted for age, respiratory comorbidity, and upper gastrointestinal surgery. PPC=postoperative pulmonary complication**

and validity of these trials are reduced by the low risk populations, single centre designs, non-masked assessors, and interventions only by experienced practitioners.

Our results are important in the context of considering existing evidence for other methods to prevent PPCs. These include preoperative inspiratory muscle training, "prehabilitation," incentive spirometry, and postoperative chest physiotherapy. Considering how effective preoperative education is in independently reducing PPCs, the benefit attributed to inspiratory muscle training[36] may come from just educating the patients preoperatively on breathing exercises rather than the effect of the training device itself. Inspiratory muscle training could provide an additive effect to preoperative education, although this currently remains untested. Future research into preventing PPCs will need to standardise the provision of preoperative physiotherapy education to both treatment arms.

### Strengths of the trial

Our trial was specifically designed and powered to address methodological limitations in previous studies.

We included most types of upper gastrointestinal, colorectal, and renal procedures involving traditional full length open incision approaches or via modern minimally invasive methods where smaller length incisions are preferred. From this population, 88% of eligible patients were entered into the trial, with a 98% follow-up rate. The three participating sites were representative of the variety of public hospitals in developed countries; a small rural hospital, a medium sized regional tertiary referral hospital, and a large major metropolitan university affiliated hospital. Given this, our cohort is closely representative of the heterogeneous population having upper abdominal surgery. To further promote generalisability of results the intervention was delivered by physiotherapists of varying grades of experience and conducted within an environment reflective of modern perioperative practice where patients attend an outpatient assessment clinic weeks before surgery rather than admission the day before surgery. Assessors, postoperative physiotherapists, and participants were masked to group allocation. To our knowledge we are one of few trials to assess the success of masking (see appendix). We also recorded most known perioperative confounders, including preoperative functional status, intraoperative fluid administered, transfusions, ventilation strategies, and postoperative analgesia and antibiotic management, and we adjusted the results for baseline imbalances in variables known to influence PPCs. To establish efficacy of preoperative education alone, we standardised early mobilisation and successfully removed all postoperative chest physiotherapy modalities.

### Implications of findings

Considering the standardisation of postoperative practice, the most plausible reason for PPC reduction

in our trial is that the participants performed the breathing exercises as taught preoperatively. This cannot be proved in this study as we opted not to measure postoperative performance of breathing exercises. We considered that measuring such performance could have resulted in a Hawthorne effect by artificially reminding patients to adhere to the prescribed breathing exercises, and results would not be reflective of the pragmatic nature of the intervention. As a proxy measure of compliance, a convenience sample of 29 patients was interviewed on the fifth postoperative day, with 94% of intervention participants remembering the breathing exercises compared with just 15% in those who received the booklet alone.[21] We extrapolate that a threshold proportion of intervention participants implemented the acquired knowledge provided by the preoperative physiotherapists and performed deep breathing exercises immediately on regaining consciousness from surgery and continued to perform them at a dose necessary to reverse the respiratory pathophysiological changes from surgery, thus preventing PPCs.

Postoperative assisted ambulation in our trial was carefully standardised, as improvements in hospital length of stay are independently attributed to early mobilisation programmes after major surgery.[37] Early ambulation is also espoused as a possible intervention to prevent PPCs,[8] although this is not supported at systematic review level.[38] Our findings, in combination with those of Schaller et al,[37] suggest specificity of therapy, early ambulation to improve functional recovery,[38] and respiratory therapy to prevent PPCs. Given the current evidence, postoperative early ambulation cannot be confidently supported as the only method to prevent PPCs; rather, preoperative physiotherapy education should be considered a primary step in PPC prophylaxis for all patients awaiting upper abdominal surgery.

Observational studies associate PPC incidence with increased hospital length of stay.[3-10] In our study, despite the incidence of PPCs being halved, a statistically significant reduction in length of stay was not detected in the overall population. Possible explanations for this apparent paradox are that previously reported associative data between PPCs and length of stay is unadjusted for other factors that may influence both outcomes, such as surgical category, age, comorbidities, and other concurrent complications. The independent impact of PPCs to affect length of stay may be less than previously reported when accounting for confounding factors. Hospital stay is an outcome with complex multifactorial reasons for determination, and after abdominal surgery the standard deviation is wide. For our population the average length of stay was 11.4 (SD 11.0) days, with a range of 1 to 105 days. To determine a statistically significant difference in length of stay requires a larger sample size or meta-analysis to confirm effect. It may also be that we measured total combined acute and subacute length of stay. Specific subset effects may apply to acute length of stay only.

Despite these limitations, exploratory subgroup analysis of our population revealed that in cohorts with stronger reductions in PPCs attributable to the intervention there was also a corresponding stronger signal to a reduction in length of stay. This suggests that our length of stay findings may be limited by sample size and heterogeneous response rates rather than by a lack of effect from the intervention. Similarly, point estimates across almost all other secondary outcomes in our trial favoured the intervention group, with sensitivity analyses strengthening these relations further. Subgroups with the greatest reduction in PPCs had a consistent signal towards improved secondary outcomes favouring the intervention group. Again this may be an indication that secondary outcome results are limited by sample size rather than by a lack of effect.

Our study has repeated the reported association between PPCs and in-hospital and 30 day mortality,[3-5] and to our knowledge is the first prospective study to show an association between PPCs in the early postoperative period to 12 month all cause mortality.[39] Our trial is also the first to find a signal of improved survival attributable to an intervention that reduces the incidence of PPCs, although, considering the low event rates, our study was not adequately powered, nor was it intended to, mortality being an exploratory secondary outcome. The 12 month mortality effect size in our trial was an absolute risk reduction of 5% (12% *v* 7%). This would require more than 1000 participants to confirm the effect of preoperative physiotherapy to reduce 12 month mortality. Future studies in prophylactic interventions to prevent PPCs could consider being powered a priori to detect these small, yet arguably clinically important, differences in mortality.

### Recommendations for future research

We recommend that future research is directed towards, firstly, investigating the improved postoperative outcomes dependent on the experience level of physiotherapists providing the preoperative education; for example, is it the way an experienced physiotherapist delivers the intervention, or is it due to repetition and practice of delivering the intervention? The experienced physiotherapist provided the intervention 124 times, compared with a maximum 25 for one of the junior physiotherapists. Many practitioner dependent interventions have a learning curve, including surgery, where surgeon experience is associated with improved morbidity and mortality.[40] A similar relationship might exist in preoperative education. Preoperative education provided by two physiotherapists, including the most experienced, was found to be highly memorable and impactful for patients.[21] The treatment integrity of the education and training provided by other physiotherapists in this trial was not checked or graded. Considering the effect gradient according to experience level, further research is required to assess the repeatability of this intervention to ensure that it is provided with a similar



doi: 10.1136/bmj.j5916 | *BMJ* 2018;360:j5916 | the bmj

degree of rigour across all treating therapists. Secondly, preoperative education needs to be validated in other elective surgical populations such as cardiothoracic surgery and neurosurgery.

Considering the strong association between PPCs and mortality and the consistent findings across three trials, four countries, and 1000 patients[17 18] that preoperative education significantly reduces PPCs; we recommend that future studies should investigate additional PPC prophylactic interventions to augment preoperative physiotherapy education, particularly targeting high risk patients. The PPC rate in high risk patients in our intervention group, although halved, was still 19%. Considering the high mortality association with PPCs, more urgently needs to be done to prevent PPCs in high risk patients, over and above preoperative physiotherapy education and postoperative ambulation alone.

### Limitations of this trial

Despite concerted methodological efforts to ensure internal validity of the trial, baseline imbalances did exist between the groups. This could just be a chance bias or a failure of true randomisation. Mathematical modelling finds that even with true randomisation, there is a 72.4% probability of two or more uneven covariates between groups if 50 covariates are included. Therefore, there is a moderate to high likelihood that maldistributions between groups occurred simply by chance. It is also possible, although unlikely, that physiotherapists opened envelopes and deliberately randomised patients prone to PPCs to the control group.[41] Methods of random allocation less prone to selection bias include telephone or web based systems. We chose to use sealed envelopes as our trial was minimally funded and clinician initiated, and reliable internet access at all sites was not always ensured. Envelopes were considered the most feasible, low tech, and cost effective option to conceal the randomisation order. An independent audit of our randomisation process found no evidence of a failure in sequential allocation (see appendix). Our results were adjusted to control for prespecified confounders imbalanced at baseline; however, our trial could have been further improved by using stratified randomisation according to known confounders—for example, surgical category and respiratory comorbidity. This would have ensured equal distribution at baseline.

Several aspects of our trial also limit generalisability. We excluded non-English speakers and only conducted our trial in developed Western countries. It cannot be extrapolated that preoperative education would be effective with the use of interpreters, in a different social-cultural context, through different modes such as visual recordings or group sessions, or with health professionals other than physiotherapists.

Additionally, despite our trial being multicentred, a large proportion of participants were recruited at a single hospital in Australia. Our trial could have been strengthened with equal distribution of representation from other sites and involvement from other countries. At the New Zealand site, the reduction in PPCs was less than at Australian sites. It is possible that this was due to the difference in experience level of the preoperative physiotherapists, although the 95% confidence interval is within the bounds of PPC risk reduction at the other sites, and may rather be a function of a limited sample. The New Zealand site also had established enhance recovery after surgery pathways,[19] unlike the two Australian sites, which could explain the difference in intravenous fluid amounts, epidural usage, and the lower PPC incidence in the control group (13.8%). Despite the lower PPC baseline risk, subgroup analysis suggests that across the whole trial sample both high and low risk patients have a similar relative risk reduction of PPCs given preoperative physiotherapy education.

### Conclusions and implications for practice

Our trial provides strong evidence that preoperative education and training delivered within six weeks of open upper abdominal surgery by a physiotherapist reduces the incidence of PPCs, including hospital acquired pneumonia, within the first 14 days after surgery. Our format of preoperative physiotherapy education and training was a single 30 minute intervention with minimal potential to harm and provided within existing multidisciplinary hospital clinics that patients are already required to attend before surgery. These results are directly applicable to the tens of millions of patients listed for elective major abdominal surgery worldwide. This service could be considered for all patients awaiting upper abdominal surgery.


### AUTHOR AFFILIATIONS

[1]Department of Physiotherapy, Launceston General Hospital, Launceston, TAS, 7250, Australia
[2]Department of Physiotherapy, The University of Melbourne, Melbourne, VIC, 3010, Australia
[3]Directorate of Community Integration, Allied Health and Service Planning, Western Health, Melbourne, VIC, Australia
[4]School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand
[5]Physiotherapy Department, North Shore Hospital, Waitemata District Health Board, Auckland, New Zealand
[6]Physiotherapy Department, North West Regional Hospital, Burnie, TAS, Australia
[7]Clifford Craig Foundation, Launceston General Hospital, Launceston, TAS, Australia
[8]School of Health Sciences, University of Tasmania, Launceston, TAS, Australia
[9]Anaesthesia Perioperative and Pain Medicine Unit, Melbourne Medical School, The University of Melbourne, Melbourne, VIC, Australia
[10]Melbourne School of Health Sciences, The University of Melbourne, VIC, Australia
[11]Peter MacCallum Cancer Centre, Melbourne, VIC, Australia


We thank the LIPPSMAck POP research assistants, Kate Sullivan and Bronte Biggins-Tosch, for their dedication and thoroughness throughout the trial; the medical students at the University of Tasmania School of Medicine and Leanne Fung (MD) for working as masked assessors; all physiotherapists at the participating sites for assisting in providing the interventions and delivering the standardised postoperative ambulation protocol over the two year trial period; and the participants for their contribution to knowledge in this area.

**Contributors:** IB conceived and designed the study, coordinated the trial, prepared the first draft of the manuscript, and was responsible for the final manuscript. IB, LB, EHS, JR, and LD developed the protocol. IB, JR, CH, and LA recruited the patients and acquired the data, and were responsible for protocol adherence and managing the trial at each of the sites. IB and IKR did the statistical analysis. IB, EHS, LB, JR, IKR, DS, and LD analysed and interpreted the data. All authors revised manuscript drafts, approved the final manuscript, and contributed intellectually important content. IB is the guarantor of the paper and takes responsibility for the integrity of the work as a whole, from inception to published article.

**Funding:** This study was an investigator initiated trial funded by competitive research grants from the Clifford Craig Foundation, Launceston, Australia, the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia, and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand. Support was provided from departmental sources at each participating study centre (Launceston General Hospital, North West Regional Hospital, North Shore Hospital) and through sponsorship by the Tasmanian Health Service-North to support IB for the period of the trial. The funding sources had no controlling role in the study design, data collection, analysis, interpretation, or report writing. All authors had full access to the data on trial completion and had final responsibility for publication submission.

**Competing interests:** All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare that IB received grants from the Clifford Craig Foundation (CCF), University of Tasmania, and Waitemata District Health Board to fund participating sites for physiotherapists to provide preoperative interventions outside of current standard care and for research assistants to acquire data. JR, LA, and CH were also supported by these grants to coordinate the project at their respective sites. IKR receives a salary from the CCF to perform statistical analysis and provide study design advice for studies receiving grants from the CCF. IKR also receives information technology and library services from the University of Tasmania. Neither CCF nor the University of Tasmania have managerial authority over IKR's work.

**Ethical approval:** This study was approved by the Human Research Ethics Committee (Tasmania) Network, Tasmania, Australia (H0011911) and the Health and Disability Ethics Committee, New Zealand (14/NTA/233) and informed written consent was given by all patients.

**Data sharing:** As prespecified a priori in the LIPPSMAck POP published protocol we welcome independent statistical analysis of our findings and provide open access to our anonymised primary dataset as an appendix. Participants gave informed consent for data sharing with organisations that submit a proposal for post hoc data analysis to the LIPPSMAck POP investigators and receive ethical clearance from their host institution and an approved amendment to the original ethics approvals provided by the two source ethics committees. Following this and on request (ianthe.boden@ths.tas.gov.au), the investigators will share the extended anonymised dataset (with associated coding library). Any published peer reviewed manuscripts derived from post hoc analysis of these shared data must list the LIPPSMAck POP investigators as coauthors.

**Transparency:** The lead author (IB) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

1 Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet* 2008;372:139-44. doi:10.1016/S0140-6736(08)60878-8
2 Hemmes SN, Gama de Abreu M, Pelosi P, Schultz MJ, PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. *Lancet* 2014;384:495-503. doi:10.1016/S0140-6736(14)60416-5
3 Schultz MJ, Hemmes SN, Neto AS, et al, LAS VEGAS investigators. Epidemiology, practice of ventilation and outcome for patients at increased risk of postoperative pulmonary complications: LAS VEGAS - an observational study in 29 countries. *Eur J Anaesthesiol* 2017;34:492-507. doi:10.1097/EJA.0000000000000646
4 Neto AS, Hemmes SN, Barbas CS, et al, PROVE Network investigators. Incidence of mortality and morbidity related to postoperative lung injury in patients who have undergone abdominal or thoracic surgery: a systematic review and meta-analysis. *Lancet Respir Med* 2014;2:1007-15. doi:10.1016/S2213-2600(14)70228-0
5 Fernandez-Bustamante A, Frendl G, Sprung J, et al. Postoperative Pulmonary Complications, Early Mortality, and Hospital Stay Following Noncardiothoracic Surgery: A Multicenter Study by the Perioperative Research Network Investigators. *JAMA Surg* 2017;152:157-66. doi:10.1001/jamasurg.2016.4065
6 Fleisher LA, Linde-Zwirble WT. Incidence, outcome, and attributable resource use associated with pulmonary and cardiac complications after major small and large bowel procedures. *Perioper Med (Lond)* 2014;3:7. doi:10.1186/2047-0525-3-7
7 Scholes RL, Browning L, Sztendur EM, Denehy L. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO2max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. *Aust J Physiother* 2009;55:191-8. doi:10.1016/S0004-9514(09)70081-9
8 Haines KJ, Skinner EH, Berney S, Austin Health POST Study Investigators. Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: an observational cohort study. *Physiotherapy* 2013;99:119-25. doi:10.1016/j.physio.2012.05.013
9 Browning L, Denehy L, Scholes RL. The quantity of early upright mobilisation performed following upper abdominal surgery is low: an observational study. *Aust J Physiother* 2007;53:47-52. doi:10.1016/S0004-9514(07)70061-2
10 Parry S, Denehy L, Berney S, Browning L, Austin Health Post-Operative Surveillance Team (POST) Investigators. Clinical application of the Melbourne risk prediction tool in a high-risk upper abdominal surgical population: an observational cohort study. *Physiotherapy* 2014;100:47-53. doi:10.1016/j.physio.2013.05.002
11 Mackay MR, Ellis E, Johnston C. Randomised clinical trial of physiotherapy after open abdominal surgery in high risk patients. *Aust J Physiother* 2005;51:151-9. doi:10.1016/S0004-9514(05)70021-0
12 Silva YR, Li SK, Rickard MJ. Does the addition of deep breathing exercises to physiotherapy-directed early mobilisation alter patient outcomes following high-risk open upper abdominal surgery? Cluster randomised controlled trial. *Physiotherapy* 2013;99:187-93. doi:10.1016/j.physio.2012.09.006
13 Miskovic A, Lumb AB. Postoperative pulmonary complications. *Br J Anaesth* 2017;118:317-34. doi:10.1093/bja/aex002
14 Pasquina P, Tramèr MR, Granier J-M, Walder B. Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: a systematic review. *Chest* 2006;130:1887-99. doi:10.1378/chest.130.6.1887
15 Ball L, Bos LD, Pelosi P. High-flow nasal cannula in the postoperative period: is positive pressure the phantom of the OPERA trial? *Intensive Care Med* 2017;43:119-21. doi:10.1007/s00134-016-4627-6
16 Patman S, Bartley A, Ferraz A, Bunting C. *Physiotherapy in upper abdominal surgery – what is the current practice in Australia?* Arch Physiotherapy, 2017:7-11. https://doi.org/10.1186/s40945-017-0039-
17 Fagevik Olsén M, Hahn I, Nordgren S, Lönroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. *Br J Surg* 1997;84:1535-8. doi:10.1002/bjs.1800841111
18 Samnani SS, Umer MF, Mehdi SH, Farid FN. Impact of Preoperative Counselling on Early Postoperative Mobilization and Its Role in Smooth Recovery. *Int Sch Res Notices* 2014;2014:250536. doi:10.1155/2014/250536
19 Gustafsson UO, Scott MJ, Schwenk W, et al, Enhanced Recovery After Surgery (ERAS) Society, for Perioperative Care, European Society for Clinical Nutrition and Metabolism (ESPEN), International Association for Surgical Metabolism and Nutrition (IASMEN). Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS(®)) Society recommendations. *World J Surg* 2013;37:259-84. doi:10.1007/s00268-012-1772-0
20 Boden I, Browning L, Skinner EH, et al. The LIPPSMAck POP (Lung Infection Prevention Post Surgery-Major Abdominal-with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials* 2015;16:1-15. doi:10.1186/s13063-015-1090-6

21 Boden I, El-Ansary D, Zalucki N, et al. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy* 2017; published online 30 Aug. https://doi.org/10.1016/j.physio.2017.08.008.

22 Brooks D, Parsons J, Newton J, et al. Discharge criteria from perioperative physical therapy. *Chest* 2002;121:488-94. doi:10.1378/chest.121.2.488

23 Sopena N, Sabrià M. Neunos 2000 Study Group. Multicenter study of hospital-acquired pneumonia in non-ICU patients. *Chest* 2005;127:213-9. doi:10.1378/chest.127.1.213

24 Fiore JFJr, Faragher IG, Bialocerkowski A, Browning L, Denehy L. Time to readiness for discharge is a valid and reliable measure of short-term recovery after colorectal surgery. *World J Surg* 2013;37:2927-34. doi:10.1007/s00268-013-2208-1

25 McHorney CA, Ware JEJr, Lu JF, Sherbourne CD. The MOS 36-item Short-Form Health Survey (SF-36): III. Tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care* 1994;32:40-66. doi:10.1097/00005650-199401000-00004

26 Rankin SL, Briffa TG, Morton AR, Hung J. A specific activity questionnaire to measure the functional capacity of cardiac patients. *Am J Cardiol* 1996;77:1220-3. doi:10.1016/S0002-9149(97)89157-6

27 Hughes M, Coolsen MM, Aahlin EK, et al. Attitudes of patients and care providers to enhanced recovery after surgery programs after major abdominal surgery. *J Surg Res* 2015;193:102-10. doi:10.1016/j.jss.2014.06.032

28 Stern C, Lockwood C. Knowledge retention from preoperative patient information. *Int J Evid Based Healthc* 2005;3:45-63.

29 Hall M, Migay A-M, Persad T, et al. Individuals' experience of living with osteoarthritis of the knee and perceptions of total knee arthroplasty. *Physiother Theory Pract* 2008;24:167-81. doi:10.1080/09593980701588326

30 Keulers BJ, Scheltinga MR, Houterman S, Van Der Wilt GJ, Spauwen PH. Surgeons underestimate their patients' desire for preoperative information. *World J Surg* 2008;32:964-70. doi:10.1007/s00268-008-9581-1

31 Grabitz SD, Farhan HN, Rusdic KJ, et al. Dose-dependent protective effect of inhalational anesthetics against postoperative respiratory complications: a prospective analysis of data on file from three hospitals in New England. *Crit Care Med* 2017;45:e30-9. doi:10.1097/CCM.0000000000002015

32 Neto AS, Hemmes SN, Barbas CS, et al, PROVE Network Investigators. Association between driving pressure and development of postoperative pulmonary complications in patients undergoing mechanical ventilation for general anaesthesia: a meta-analysis of individual patient data. *Lancet Respir Med* 2016;4:272-80. doi:10.1016/S2213-2600(16)00057-6

33 Condie E, Hack K, Ross A. An investigation of the value of routine provision of postoperative chest physiotherapy in non-smoking patients undergoing elective abdominal surgery. *Physiotherapy* 1993;79:547-52doi:10.1016/S0031-9406(10)60295-7.

34 Mans CM, Reeve JC, Elkins MR. Postoperative outcomes following preoperative inspiratory muscle training in patients undergoing cardiothoracic or upper abdominal surgery: a systematic review and meta analysis. *Clin Rehabil* 2015;29:426-38. doi:10.1177/0269215514545350

35 Castillo R, Haas A. Chest physical therapy: comparative efficacy of preoperative and postoperative in the elderly. *Arch Phys Med Rehabil* 1985;66:376-9.

36 Katsura M, Kuriyama A, Takeshima T, Fukuhara S, Furukawa TA. Preoperative inspiratory muscle training for postoperative pulmonary complications in adults undergoing cardiac and major abdominal surgery. *Cochrane Database Syst Rev* 2015;(10):CD010356.

37 Schaller SJ, Anstey M, Blobner M, et al, International Early SOMS-guided Mobilization Research Initiative. Early, goal-directed mobilisation in the surgical intensive care unit: a randomised controlled trial. *Lancet* 2016;388:1377-88. doi:10.1016/S0140-6736(16)31637-3

38 Castelino T, Fiore JF Jr, Niculiseanu P, Landry T, Augustin B, Feldman LS. The effect of early mobilization protocols on postoperative outcomes following abdominal and thoracic surgery: A systematic review. *Surgery* 2016;159:991-1003. doi:10.1016/j.surg.2015.11.029

39 Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ. Participants in the VA National Surgical Quality Improvement Program. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242:326-41, discussion 341-3.

40 Schmidt CM, Turrini O, Parikh P, et al. Effect of hospital volume, surgeon experience, and surgeon volume on patient outcomes after pancreaticoduodenectomy: a single-institution experience. *Arch Surg* 2010;145:634-40. doi:10.1001/archsurg.2010.118

41 Clark L, Fairhurst C, Torgerson DJ. Allocation concealment in randomised controlled trials: are we getting better? *BMJ* 2016;355:i5663. doi:10.1136/bmj.i5663


**Supplementary appendix:** additional information

## 7.3 Supplementary material

Published online as supplementary material with published manuscript
https://www.bmj.com/content/bmj/suppl/2018/01/24/bmj.j5916.DC1/bodi041081.ww1.pdf

1. Template for Intervention Description and Replication (TIDieR) table; Table 1S
2. Ambulation protocol, Table 2S
3. Discharge from physiotherapy scoring tool, Table 3S
4. Primary and secondary outcomes; per-protocol, Table 4S
5. 12-month mortality according to PPC diagnosis: Figure 1S
6. Standardisation of ambulation protocol, Table 5S and Figure 2S
7. Methodological notes on analysis of data pertaining to durations (ie. Length of stay, time to ambulation)
8. Success of masking participants, Table 6S
9. Postoperative protocol violations, Table 7S
10. Audit of random allocation
11. Data Safety Management Board membership

## TIDieR (Hoffmann et al 2014) description of LIPPSMAck POP interventions

### Table 1S

| TIDieR criterion | Intervention | Standard care |
|---|---|---|
| Item 1. Brief name: Provide the name or a phrase that describes the intervention | Preoperative physiotherapy respiratory education and training + booklet | Preoperative information booklet alone |
| Item 2. Why: Describe any rationale, theory, or goal of the elements essential to the intervention | Postoperative breathing exercises can reverse respiratory pathophysiological effects of anaesthesia and surgery although the timing of initiation may be a key factor. Breathing exercises may be ineffective if delayed until the day after surgery when the first physiotherapy session is commonly provided. The time point of initiation and dosage of breathing exercises could be improved if patients are educated and trained before surgery to perform their breathing exercises immediately upon waking from surgery.<br><br>Our intervention is an education-based intervention aimed at educating patients about the possibility of getting a postoperative pulmonary complication, the physiological effects of anaesthesia and surgery on respiratory mucociliary clearance, the effect this has on lung bacterial stagnation, and postoperative breathing exercises required to overcome these problems and preventing the onset of postoperative pneumonia.<br><br>The aim of the intervention is to educate and motivate patients to engender a behavioural response that will result in patients starting breathing exercises immediately upon waking from surgery and for patients to continue to perform these breathing exercises independently and hourly until frequently ambulant out of bed.<br><br>The intervention also included being taught and coached how to perform the prescribed breathing exercises.<br>Memory cues were also provided to assist patient to remember to perform the hourly breathing exercises independently following surgery. | |

| | | |
|---|---|---|
| Item 3. What (materials): Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. | **Participant information materials:**<br>A booklet (as per standard care group) was provided to accompany the education and training intervention to consolidate the learnt knowledge.<br><br>**Physiotherapists training materials:**<br>To ensure consistency in delivery, physiotherapists were required to view an audio-visual recording of the most experienced physiotherapist providing a preoperative intervention and were provided with a semi-scripted guide to the education session. Physiotherapists were instructed to adhere to the overall themes and premises of information delivery as included within the protocol script and video | **Participant information materials:**<br>A booklet containing written and pictorial information regarding PPC and their potential prevention with early ambulation and breathing exercises.<br>Within this booklet, written prescribed breathing exercises are of two sets of ten slow deep breaths followed by three coughs, to be performed hourly starting immediately following surgery. |
| Item 4. What (procedures): Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities | **Preoperative phase:**<br>Standardised physical and subjective assessment and provision of booklet as per the control group.<br>Intervention participants received an additional single education and training session of approximately 30 minutes duration with a physiotherapist. Participants were given an individualized estimate of their likelihood of a PPC based on a risk prediction tool, and educated about the effect of anaesthesia, abdominal surgery, and bed-rest on mucociliary clearance and lung volumes. To ameliorate these factors and prevent bacteria stagnation the importance of participating in an early postoperative ambulation program and performing self-directed breathing exercises was emphasised.<br><br>Participants were educated on the necessity of performing self-directed breathing exercises to protect their lungs following surgery. They were instructed to perform the breathing exercises immediately from waking from the anaesthetic and then every hour during daytime waking hours until their first ambulation session, and then at any time when they were not ambulant.<br><br>The breathing exercises consisted of two sets of 10 slow-flow breaths to maximum inspiratory capacity with two to three inspiratory sniff breath stacking manoeuvres. Each breath was instructed to be held for three to five seconds. Each set of 10 breaths were followed by three coughs, or a forced expiratory technique with an | **Preoperative phase:**<br>Standardised physical and subjective assessment conducted by a physiotherapist consisting of: questioning on current health co-morbidities, mobility and functional status, smoking history, lung auscultation, subjective assessment of cough quality and strength, sputum production and colour, hand grip strength, current activity and fitness levels, and Short Form 36 to measure health related quality of life.<br><br>Participants were then provided with an education booklet. This colour booklet contained written and pictorial information about abdominal surgery, expected types of pain management, medical lines and drains, postoperative recovery process, and how to prevent postoperative respiratory complications with early ambulation and self-directed breathing exercises. The booklet included detailed written instructions to perform breathing exercises for two sets of 10 deep breaths followed by three coughs every hour during waking hours. Participants were instructed to bring the booklet to hospital for reference following the |

| | | |
|---|---|---|
| | open glottis called a "huff", with a small firm pillow pressed over on the abdominal incision to support the wound.<br><br>The physiotherapist coached each participant in at least three repetitions, and as many as required to master technique as judged by the physiotherapist. Participants were encouraged to practice these exercises prior to their operation to develop familiarity.<br><br>Patients were taught that a physiotherapist would assist them to walk as soon as possible on the first postoperative day, aiming for a duration longer than 10-minutes and at a pace causing mild breathlessness. Outside these assisted sessions, participants were advised to walk or exercise by their bedside as frequently as they are able.<br>**Postoperative phase:**<br>Standardised early ambulation program (protocol, Boden et al, *Trials*, 2015)<br><br>No coached respiratory physiotherapy | operation. The contents of the booklet were not discussed with participants in the control group.<br><br>**Postoperative phase:**<br>Standardised early ambulation program (protocol, Boden et al, *Trials*, 2015)<br><br>No coached respiratory physiotherapy |
| Item 5. Who provided: For each category of intervention provider (for example, psychologist, nursing assistant), describe their expertise, background and any specific training given | 11 physiotherapists of varying experience levels: students, new graduates, senior physiotherapists, through to a physiotherapist with 15 years of acute surgical practice and extensive experience in patient education.<br>To ensure consistency in delivery, all physiotherapists viewed an audio-visual recording of the most experienced physiotherapist providing a preoperative intervention and were provided with a semi-scripted guide to the education session. | 11 physiotherapists of varying experience levels: students, new graduates, senior physiotherapists, through to a physiotherapist with 15 years of acute surgical practice. |
| Item 6. How: Describe the modes of delivery (such as face to face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group | Face-to-face, individual sessions<br><br>Pragmatically, when interventions were unable to be provided face-to-face, the booklet was mailed and assessment and education were provided via telephone. | Face-to-face, individual sessions<br><br>Pragmatically, when assessment unable to be provided face-to-face, the booklet was mailed and assessment were provided via telephone. |
| Item 7. Where: Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features | Outpatient hospital-located multidisciplinary pre-admission clinics at three government funded, university affiliated, teaching hospitals:<br>1. Launceston General Hospital (Launceston, Tasmania, Australia), 330-bed inner-regional, primary referral hospital<br>2. North Shore Hospital (Auckland, New Zealand), 600-bed metropolitan, primary referral hospital. | Outpatient hospital-located multidisciplinary pre-admission clinics at three government funded, university affiliated, teaching hospitals:<br>1. Launceston General Hospital (Launceston, Tasmania, Australia), 330-bed inner-regional, primary referral hospital |

| | | |
|---|---|---|
| | 3. North West Regional Hospital (Burnie, Tasmania, Australia), 240-bed rural secondary referral hospital.<br><br>Elective upper abdominal surgical patients at the participating centres attend an outpatient Pre-Admission Clinic session one to six-weeks prior to their operation where they are assessed by a multi-disciplinary team consisting of, as a minimum, a registered nurse, anaesthetist, and doctor from the admitting surgical team. Information about the surgical process, pain management, postoperative drips and drains, and expected recovery process are provided as standard care. | 2. North Shore Hospital (Auckland, New Zealand), 600-bed metropolitan, primary referral hospital<br>3. North West Regional Hospital (Burnie, Tasmania, Australia), 240-bed rural secondary referral hospital.<br><br>Elective upper abdominal surgical patients at the participating centres attend an outpatient Pre-Admission Clinic session one to six-weeks prior to their operation where they are assessed by a multi-disciplinary team consisting of, as a minimum, a registered nurse, anaesthetist, and doctor from the admitting surgical team. Information about the surgical process, pain management, postoperative drips and drains, and expected recovery process are provided as standard care. |
| Item 8. When and how much: Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose | Within six-weeks of the planned surgical procedure.<br><br>The education and training session was provided once only.<br><br>If a participant's operation is delayed and the time from intervention to day of surgery becomes greater than 42 days, a physiotherapist will contact the participant by phone for a review assessment and to remind them to read the booklet as provided at the pre-admission clinic and a review of the education session and the breathing exercises repeated over the phone. | Within six-weeks of the planned surgical procedure.<br><br>The booklet was provided once only.<br><br>If a participant's operation is delayed and the time from intervention to day of surgery becomes greater than 42 days, a physiotherapist will contact the participant by phone for a review assessment and to remind them to read the booklet as provided at the pre-admission clinic. |
| Item 9. Tailoring: If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how | Participants were given an estimate of their individualized likelihood of a postoperative pulmonary complication based on an existing risk prediction tool. | None. |
| Item 10. Modifications: If the intervention was modified during the course of the | No modifications | No modifications |

| | | |
|---|---|---|
| study, describe the changes (what, why, when, how) | | |
| Item 11. How well (planned): If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them | Treatment fidelity was measured and published in full (Boden et al, *Physiotherapy*, 2017) | Treatment fidelity was measured and published in full (Boden et al, *Physiotherapy*, 2017) |
| Item 12: How well (actual): If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned | Proxy measure of adherence (memorability of delivered information) was measured and published in full (Boden et al, *Physiotherapy*, 2017) | Proxy measure of adherence (memorability of delivered information) was measured and published in full (Boden et al, *Physiotherapy*, 2017) |

## LIPPSMAck-POP ambulation protocol

### Table 2S

| | |
|---|---|
| Stage 1 (Safety) | Sit over edge of bed/sit in chair minimum of 2 minutes |
| Stage 2 (Safety) | March on spot 0-1 minute |
| Stage 3 (Ambulation) | March on spot/walk away from bedside 1-3 minutes |
| Stage 4 (Ambulation) | March on spot/walk away from bedside 3 – 6 minutes |
| Stage 5 (Ambulation) | Walk away from bedside 6 – 10 minutes |
| Stage 6 (Ambulation) | Walk away from bedside 10 – 15 minutes |
| Stage 7 (Ambulation) | Walk away from bedside > 15 minutes |

**PROTOCOL**

Provide assisted early ambulation as soon as possible on the first postoperative day.

At each session progress through each stage in sequence. Time achieved in the session is accumulative.

Aim to achieve rating of perceived exertion of greater than 3/10.

Aim to assist patient to ambulate more than 10 minutes (Stage 6 or greater).

Once patient able to ambulate past Stage 3, patient can be assisted to ambulate with a Physiotherapy Assistant, as long as safe to do so as determined by the ward physiotherapist.

Interval training is permissible to obtain target walking time. Each interval of rest time must not exceed the preceding work time. Total session time is the accumulative work time.

Provide assisted early ambulation once a day until discharged according to the discharge scoring tool.

## Standardised discharge from assisted ambulation scoring tool

### Table 3S: Discharge from Physiotherapy scoring tool[1]

| **Mobility** | **Score** |
|---|---|
| Reached preoperative ambulation status | 3 |
| Requires supervision, status has plateaued | 2 |
| Requires assistance, status is improving | 1 |
| Unable to ambulate | 0 |
| **Breath Sounds** | |
| Reached preoperative levels and within expectations for that patient | 3 |
| Slightly decreased breath sounds or presence of a few added sounds | 2 |
| Markedly abnormal breath sounds and/or significant added sounds | 1 |
| **Secretion clearance** | |
| Able to clear secretions independently OR at preoperative status | 3 |
| Requires assistance to clear secretions | 1 |
| **$SpO_2$% (on room air or pre-op oxygen levels)** | |
| $SpO_2 \geq 92\%$ (no respiratory condition) OR $SpO_2 \geq 88\%$ (existing respiratory condition) | 3 |
| $SpO_2 < 92\%$ (no respiratory condition) OR $SpO_2 < 88\%$ (existing respiratory condition) | 2 |
| **Respiratory Rate (at rest and during activity)** | |
| Within normal expectations | 3 |
| Outside acceptable range for the individual | 2 |
| **TOTAL SCORE (min 6, max 15)** | |
| **A score ≥14 = discharge from Physiotherapy** | |

$SpO_2$=pulse oximetry oxygen saturation.

[1]Brooks D, Parsons J, Newton J, et al. Discharge criteria from perioperative physical therapy. *Chest* 2002; **121**: 488-94.

## Table 4S: Per-protocol primary and secondary outcomes

| | Preoperative physiotherapy education and training (n= 191) | Information booklet (n=183) | Adjusted analysis | | Unadjusted analysis | |
|---|---|---|---|---|---|---|
| | | | HR, OR, IRR (95% CI) | p-value | HR, OR, IRR (95% CI) | p-value |
| **Primary outcome** | | | | | | |
| Postoperative pulmonary complication | 26 (14%) | 56 (31%) | HR 0.46 (0.29 to 0.73) | 0.0010 | HR 0.43 (0.27 to 0.67) | 0.0002 |
| **Secondary outcomes** | | | | | | |
| Pneumonia | 18 (8%) | 42 (20%) | HR 0.41 (0.23 to 0.73) | 0.0022 | HR 0.40 (0.23 to 0.69) | 0.0009 |
| Hospital utilisation | | | | | | |
| Hospital LOS, days | | | | | | |
| Prespecified analysis[#] | 8 (7 - 12) | 9 (7 - 15) | OR 0.75 (0.52 to 1.07) | 0.11 | OR 0.77 (0.56 to 1.07) | 0.13 |
| Alternative analysis[##] | | | HR 1.19 (0.94 to 1.34) | 0.080 | HR 1.26 (1.03 to 1.54) | 0.023 |
| Ready for hospital discharge, days | | | | | | |
| Prespecified analysis[#] | 7 (5 - 10) | 8 (5 - 13) | OR 0.74 (0.52 to 1.05) | 0.093 | OR 0.67 (0.47 to 0.95) | 0.025 |
| Alternative analysis[##] | | | HR 1.15 (0.94 to 1.39) | 0.17 | HR 1.15 (1.00 to 1.49) | 0.046 |
| ICU LOS, days | 1.4 (2.9) | 1.7 (2.9) | OR 0.92 (0.62 to 1.36) | 0.66 | OR 0.78 (0.53 to 1.14) | 0.20 |
| Unplanned ICU readmissions | 14 (7%) | 19 (10%) | OR 0.86 (0.43 to 1.74) | 0.68 | OR 0.71 (0.35 to 1.41) | 0.68 |
| Hospital readmission at 6-weeks | 34/181 (19%) | 30/178 (17%) | OR 1.16 (0.68 to 1.82) | 0.67 | OR 1.11 (0.68 to 1.82) | 0.67 |
| Mobility | | | | | | |
| Time from operation to ambulation > 1min, hours | 23 (20 - 44) | 22 (20 - 39) | HR 1.03 (0.82 to 1.30) | 0.81 | HR 1.08 (0.86 to 1.37) | 0.50 |
| Day achieved >10 mins of ambulation, days | 3 (1 – 5) | 3 (1 –5) | HR 0.99 (0.83 to 1.17) | 0.90 | HR 1.05 (0.88 to 1.25) | 0.58 |
| Discharged from physiotherapy assisted ambulation, days | 4 (2 -5) | 3 (2 - 5) | HR 1.05 (0.86 to 1.28) | 0.60 | HR 1.14 (0.94 to 1.39) | 0.19 |
| Patient reported complications at 6-weeks[+] | | | | | | |
| Any complications | 72/175 (41%) | 74/164 (45%) | IRR 0.92 (0.66 to 1.27) | 0.60 | IRR 0.91 (0.66 to 1.26) | 0.58 |
| Wound infection | 35/178 (20%) | 38/177 (21%) | IRR 0.87 (0.55 to 1.38) | 0.55 | IRR 0.92 (0.58 to 1.45) | 0.71 |
| Fatigue | 28/178 (16%) | 32/177 (18%) | IRR 0.98 (0.59 to 1.64) | 0.94 | IRR 0.87 (0.52 to 1.44) | 0.59 |
| Nausea/vomiting/gastrointestinal | 26/178 (15%) | 27/177 (15%) | IRR 0.99 (0.57 to 1.72) | 0.98 | IRR 0.96 (0.56 to 1.64) | 0.88 |
| Respiratory | 8/178 (4%) | 20/177 (11%) | IRR 0.47 (0.21 to 1.09) | 0.079 | IRR 0.40 (0.18 to 0.90) | 0.028 |
| Cardiac | 10/178 (6%) | 2/177 (1%) | IRR 6.37 (1.37 to 29.7) | 0.018 | IRR 4.97 (1.09 to 22.7) | 0.038 |
| Venothromboembolic events | 2/178 (1%) | 6/177 (3%) | IRR 0.36 (0.07 to 1.80) | 0.21 | IRR 0.34 (0.07 to 1.69) | 0.18 |
| Mortality | | | | | | |
| Death, in hospital | 3 (1.5%) | 3 (1.6%) | HR 1.74 (0.40 to 7.68) | 0.47 | HR 1.40 (0.30 to 6.60) | 0.67 |
| Death, 6-weeks | 4 (2.1%) | 3 (1.6%) | HR 1.44 (0.31 to 6.64) | 0.64 | HR 1.28 (0.29 to 5.70) | 0.75 |
| Death , 12 months | 15 (7.9%) | 21 (11.5%) | HR 0.79 (0.41 to 1.54) | 0.49 | HR 0.67 (0.35 to 1.31) | 0.24 |

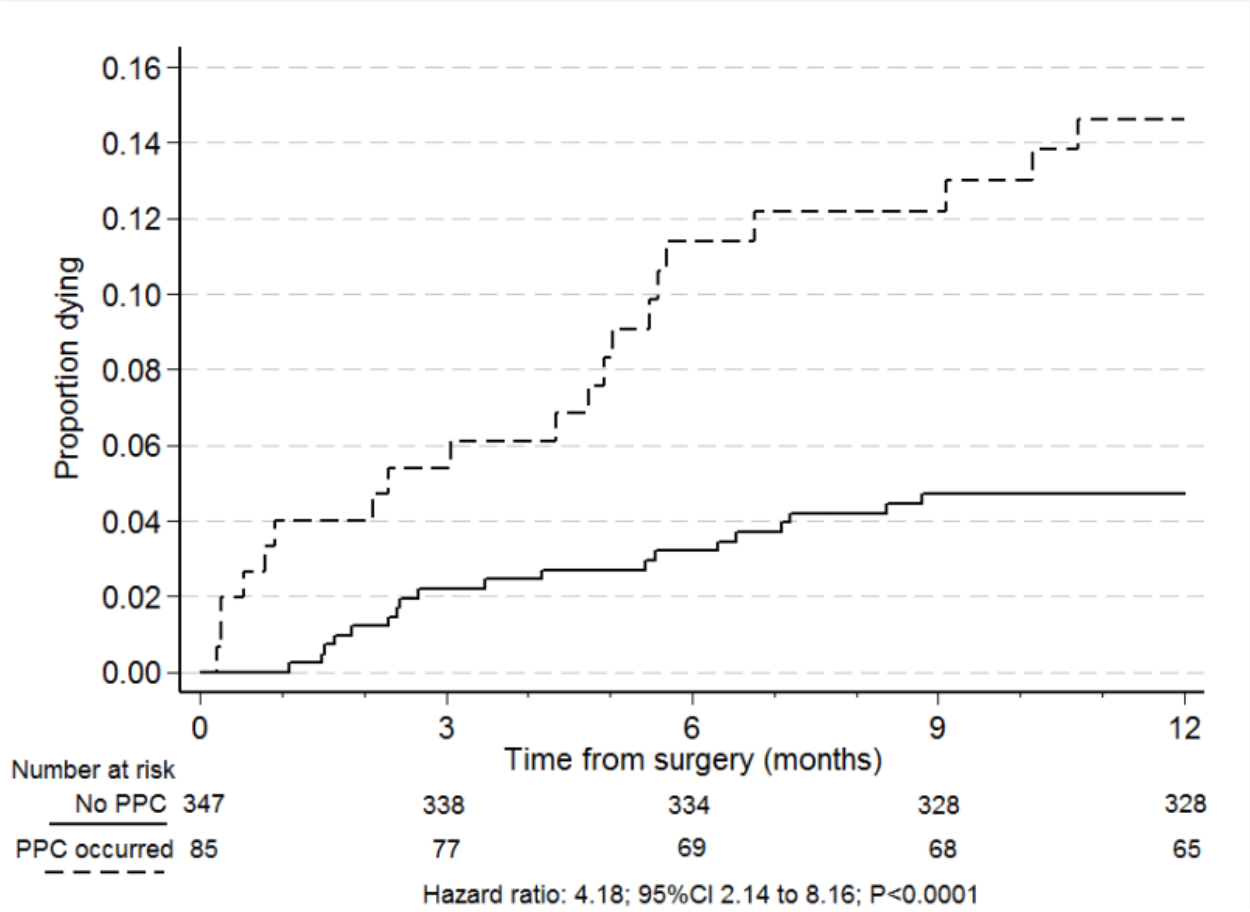
Data are n (%), mean (SD), or median (IQR). Analyses are adjusted for baseline age, prior respiratory disease, and hepatobiliary/upper gastrointestinal surgery unless specified otherwise. LOS=length of stay, ICU=intensive care unit, HR=hazard ratio, IRR=incidence rate ratio

Mean difference is intervention group value minus control group value; Point estimates are HR for the primary outcome

[#] Prespecified analysis involved a rank-ordered comparison of LOS days, using mixed effects ordered logistic regression. OR <1.00 indicates an earlier discharge from hospital

[##] Time-to-event analysis with median days (IQR) reported and estimation of HR using Cox proportion hazards regression. HR >1.00 indicates an increased likelihood of earlier discharge from hospital.

**Figure 1S: Twelve-month mortality according to diagnosis of PPC (intention-to-treat)**




Data adjusted for baseline age, respiratory comorbidity, and surgical category

## Assessment of standardisation of early ambulation provision

### Table 5S. Mobilisation stage achievement per-protocol

| | Cases | | Successes | | Failures | | Comparison: Intervention vs Control | | |
|---|---|---|---|---|---|---|---|---|---|
| | Int[1] | Cont[1] | Int | Cont | Int | Cont | RR[2] | 95%CI | p-value[3] |
| Unable to ambulate | 26 | 22 | | | | | | | |
| Stage 1 (sit over edge of bed) | 16 | 17 | 159 | 156 | 26 | 22 | 0·98 | (0·91-1·06) | 0·65 |
| Stage 2 (march 1 min) | 14 | 10 | 143 | 139 | 42 | 39 | 0·99 | (0·89-1·11) | 0·90 |
| Stage 3 (walk 1-3min) | 25 | 22 | 129 | 129 | 56 | 49 | 0·96 | (0·84-1·10) | 0·64 |
| Stage 4 (walk 3-6min) | 21 | 30 | 104 | 107 | 81 | 71 | 0·94 | (0·79-1·11) | 0·46 |
| Stage 5 (walk 6-10min) | 28 | 15 | 83 | 77 | 102 | 101 | 1·04 | (0·82-1·31) | 0·83 |
| Stage 6 (walk 10-15min) | 38 | 49 | 55 | 62 | 130 | 116 | 0·85 | (0·63-1·15) | 0·31 |
| Stage 7 (walk >15min) | 17 | 13 | 17 | 13 | 168 | 165 | 1·26 | (0·63-2·51) | 0·57 |
| Physio/patient unavailable | 11 | 7 | | | | | | | |

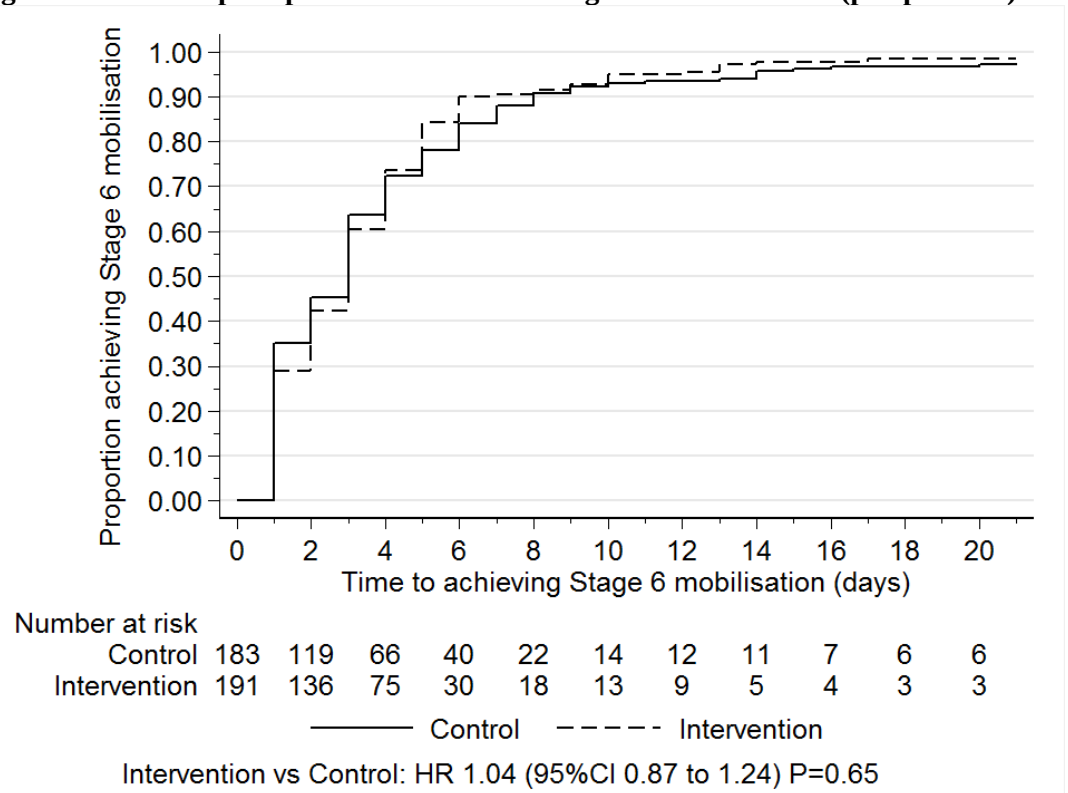
1 Int=Preoperative physiotherapy education and training, Cont= Information booklet

2 Relative risk estimated using Mantel-Haenszel method; each RR was estimated separately

3 p-value calculated using Fisher's exact test

4 Each stage was evaluated separately, with each case assigned to success or failure at that stage

### Figure 2S: Time to postoperative ambulation longer than 10 minutes (per-protocol)



## Methodological note on the analysis of duration outcomes and covariates in patient management

These data (e.g. hospital length of stay, time to ambulation >10minutes) are usually handled by estimating group means (with standard deviations and 95% confidence intervals), with or without logarithmic transformation, or using a non-parametric equivalent. This provides approximate estimates of durations that might be expected to be seen for patients with a usual successful progress to resolution of their treatment.

However, those patients whose course of recovery is not usual (e.g. those who die, are transferred to another hospital, or are managed outside the confines of the planned protocol) may not contribute data comparable to the majority of patients. A short length of stay may be a measure of success, and a long stay a measure of failure. However, a person who dies early has not had a successful course of treatment (unless you are only concerned with costs, and not cost-utility). Any outcome measure must have a progressive meaning across its range of values, and these durations do not.

The alternative is to treat the outcome being measured as a survival (time-to-event) analysis. What is measured is the time to achieve a successful outcome (e.g. the patient is discharged from hospital having recovered from their surgery). Patients who die do not achieve a successful outcome, and they contribute their accumulated time until they die, at which point they are censored from the analysis without achieving an event. Those who fall outside the trial protocol are managed in the same way. Those who are not discharged until beyond a defined follow-up period (determined by the logistics of the conduct of the trial) will also not be successful and will have a censored time-to-event; such prolonged lengths of stays will be uncommon events, and could cause sample size difficulties unless censored in some way. The statistic used is estimation of hazards ratios using Cox proportional hazards regression.

Figure 1 illustrates how this analysis would be described. Over 95% of patients achieve success (post-perative time to ambulation longer than 10 minutes). Despite a progressive loss to follow-up of patients who develop PPC unevenly in the two trial groups (recording of ambulation is less reliable in the PPC group) or who die, it is still possible to perform a numerical comparison where the measured outcome means the same thing across the range from best to worse in all patients. The Kaplan-Meier plot is a visual illustration, and the Cox proportional hazards regression is a numerical illustration, of what is going on. It is clear that the two methods and results are consistent with each other, showing little if any difference between the groups.

## Assessment of participant blinding

*Method*

A convenience sample of 29 consecutive participants were interviewed on the fifth postoperative day individually and at their bedside by an interviewer masked to group allocation. A semi-scripted interview was used and interviews recorded[1]. Participants were reminded that they were involved in a clinical trial investigating preoperative education by physiotherapists, one group where the standard amount of information was given, and the other where a lot more was provided. They were then asked to guess which group they had been allocated to. Participants were required to provide one of only two answers; "a lot more" or "the standard amount". They were unable to answer "don't know".

*Statistical methods*

The intervention group was arbitrarily provided with the label 'positive'. The control group was labelled 'negative'. A 2x2 sensitivity/specificity table was constructed based upon the participant report, with a true positive allocated with accurate identification of group allocation in a participant in the intervention group, similarly a true negative when there was accurate identification of group allocation in a participant in the control group. Using mathematical conventions, the sensitivity, specificity, and positive prediction value were calculated. Simple Chi square analysis was utilised to determine if there was a significant difference between the trial participant's accuracy levels and the assumed ideal of perfect masking set at 50% accuracy.

**Results and discussion:**

**Table 6S**

| Patient belief of group allocation | True group allocation (n=29) | |
|---|---|---|
| | Intervention | Control |
| Intervention | 11 | 5 |
| Control | 6 | 7 |
| TOTAL | 17 | 13 |

Analysis gives a sensitivity of 69% and a specificity of 54%. That is, 69% of intervention group participants believed that they had been provided with the intervention and 54% of control group participants believed that they had been provided with the control. Overall, participants had a positive predictive value of 65% to accurately determine their group allocation.

If it is assumed that a 50% positive predictive value would reflect ideal blinding, comparison with our trial value of 65% (n=29) gives a non-significant difference (p=0.25, two-tailed). It can be estimated that our participants were sufficiently blinded.

Further exploratory analysis finds no significant difference (p=0.42, two-tailed) between the intervention group and control group participants in accurately determining their group allocation.

## Protocol deviations in the postoperative period

**Table 7S:**

| | |
|---|---|
| Intervention (n=8) | 3 x coached breathing exercises<br>1 x patient had an acute myocardial infarct on POD7. Following an immediate angioplasty they were transferred to coronary care unit where a ward physiotherapist unfamiliar with the trial protocol provided two sessions on POD8.<br>1 x provided with two sessions over POD 1 and POD2.<br>1 x transferred to a medical ward on POD2 and was provided with a single session with a ward physiotherapist unfamiliar with the trial protocol.<br>1 x provided with single session on POD3 by a weekend physiotherapist unfamiliar with trial protocol<br>3 x nurse provided Bubble PEP device<br>1 x on morning of POD2. Removed that afternoon by research team.<br>1 x on morning of POD3. Removed that afternoon by research team<br>1 x on morning of POD1 (on a weekend). Removed on POD3 by research team<br>2 x additional ambulation sessions<br>1 x two sessions of ambulation provided on POD1 and POD 2<br>1 x additional session provided on POD4 |
| Control (n=7) | 3 x nurse provided PEP device<br>1 x on morning of POD2. Removed that afternoon by research team.<br>2 x on morning of POD1 (on a weekend). Removed on POD3 by research team.<br>coached breathing exercises<br>2 x additional ambulation sessions<br>1 x two sessions of ambulation provided on POD1<br>1 x two sessions of ambulation provided on POD4 and POD7<br>1 x additional advice about reason for ambulation was provided to patient by ward physiotherapist on POD2.<br>1 x patient diagnosed with a respiratory complication. No physiotherapy treatment provided for 4 days due to communication error. |

POD=postoperative day. PEP=positive expiratory pressure

## Audit of trial recruitment and random allocation

All fortnight periods during the trial were coded in temporal numerical order (n=52) and entered into a computerised random number generator. A fortnight period was randomly selected by an external auditor who assessed the accuracy of allocation based on the temporal order of patient eligibility. This audit found that all patients recruited into LIPPSMAck POP during the randomly selected time period (Monday 8th April – Friday 25th April 2014) were entered into the trial sequentially in order of presentation to the pre-admission clinic.

## Members of the Data Safety Management Board

Dr Dane Blackford[1], MD

Prof Linda Denehy[2], PhD

Dr Iain Robertson[3], PhD

Affiliations:

1. Department of Anaesthesia, Launceston General Hospital, Launceston, Tasmania, Australia
2. Department of Physiotherapy, The University of Melbourne, Victoria, Australia
3. School of Health Sciences, University of Tasmania, Newnham, Tasmania, Australia

Duties of the Data Safety Management Board were to monitor ethical conduct of trial and adjudicate adverse events possibly associated with the ambulation protocol as needed. No interim stopping rules were predetermined due to the minimal risk considered to be associated with the intervention and the control was standard care at all participating sites.

## 7.4 Response to critical appraisal of LIPPSMAck-POP trial

### 7.4.1 Background

Following publication of the LIPPSMAck-POP trial, it was selected to be scrutinised by the *Journal of Physiotherapy*, as the subject of a 'Super Critically Appraised Paper', where an editor summarises the trial and three international experts in the field are invited to provide a commentary on the trial. The authors of the paper are invited to provide a response.

### 7.4.1 Published letter

Boden I. Critically appraised paper: Preoperative physiotherapy education halved postoperative pulmonary complications in patients after upper abdominal surgery [commentary]. *J Physiother*. 2018 ;64(3):195-196.

This is an open access journal. The content is unchanged from the published letter.

Journal of Physiotherapy 64 (2018) 194

Journal of PHYSIOTHERAPY

journal homepage: www.elsevier.com/locate/jphys

Appraisal

# Critically appraised paper: Preoperative physiotherapy education halved postoperative pulmonary complications in patients after upper abdominal surgery

## Synopsis

Summary of: Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, et al. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ*. 2018;360:j5916.

***Question***: Does preoperative physiotherapy reduce postoperative pulmonary complications in adults after elective, major, open upper abdominal surgery? ***Design***: Randomised, controlled trial with concealed allocation and blinding of participants and assessors. ***Setting***: Three tertiary public hospitals in Australia and New Zealand. ***Participants***: Adults (≥ 18 years) within 6 weeks of elective upper abdominal surgery requiring general anaesthesia, a minimum overnight hospital stay, an incision ≥ 5 cm above the umbilicus, and attendance at an outpatient preadmission clinic. Key exclusion criteria were: current hospital inpatients, organ transplant recipients, abdominal hernia repairs, being unable to walk ≥ 1 minute, or unable to attend the preoperative physiotherapy session. Randomisation of 441 participants allocated 222 to the intervention group and 219 to the control group. ***Interventions***: Both groups attended the preadmission clinic and received preoperative physiotherapy comprising a standardised assessment and a booklet containing information about postoperative pulmonary complications, potential prevention with early ambulation and breathing exercises, and a prescription for deep breathing exercises starting immediately after surgery. In addition, the intervention group received a 30-minute education and breathing exercise coaching session with a physiotherapist immediately after the preoperative session. This included: details on risk of postoperative pulmonary complications, individualised risk assessment, education about the impact of surgery, instructions on breathing exercises, and memory cues. ***Outcome measures***: The primary outcome was presence of postoperative pulmonary complications within 14 postoperative days assessed daily using the Melbourne Group Scale. Secondary outcomes were: hospital-acquired pneumonia, length of hospital stay, use of intensive care services, hospital costs, health-related quality of life (at 6 weeks), and all-cause mortality (at 12 months). ***Results***: A total of 432 participants completed the trial. The incidence of postoperative pulmonary complications was halved (adjusted hazard ratio 0.48, 95% CI 0.30 to 0.75) in the intervention group compared with the control group, with an absolute risk reduction of 15% (95% CI 7 to 22) and a number needed to treat of seven (95% CI 5 to 14). No significant differences in other secondary outcomes were detected. ***Conclusion***: In adults undergoing upper abdominal surgery, adding a single preoperative physiotherapy session, which comprised education and breathing exercise coaching, to a standardised assessment and delivery of information on postoperative physiotherapy via a booklet halved the incidence of postoperative pulmonary complications.

**Provenance**: Invited. Not peer reviewed.

**Nora Shields**
*School of Allied Health, La Trobe University, Australia*

https://doi.org/10.1016/j.jphys.2018.04.008

1836-9553/© 2018 Published by Elsevier B.V. on behalf of Australian Physiotherapy Association. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

## Commentary

The positive effects of breathing exercises on the recovery of wounded soldiers was reported in 1915.[1] The need to prevent postoperative pulmonary complications was well noted in the 1950s, and the role of chest physiotherapy in the prevention of postoperative pulmonary complications was first acknowledged in 1954.[2] The association between postoperative pulmonary complications, mortality and length of hospital stay has led to a multitude of reports on a variety of interventions, and been the pathophysiological basis for the prevention of postoperative pulmonary complications after thoracic and abdominal surgery.

The Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) trial is the first multicentre, international, randomised, controlled trial to investigate the effect of the 'quality' of preoperative physiotherapy intervention on postoperative pulmonary complications. This well-designed study by Boden and colleagues addressed many of the factors that confound postoperative pulmonary complication data, and demonstrated that a control group that received an information booklet provided preoperatively, together with postoperative physiotherapy management, had a postoperative pulmonary complication rate of 27%. However, the addition of a 30-minute preoperative physiotherapy consultation, clearly targeting breathing and coughing technique, with an emphasis on breathing technique immediately after regaining consciousness, reduced the incidence of postoperative pulmonary complications by 50%. Further, this study also suggested that the experience of the physiotherapist conducting the preoperative session may influence the intervention outcome. This study conveyed an important message that preoperative physiotherapy should target not only optimal breathing technique, but also empower the patient to conduct self-directed breathing techniques as early as practicable after surgery. The appreciation that prevention of postoperative pulmonary complications relies upon the principle of maintenance of alveoli and airway patency, rather than the re-expansion of collapsed alveoli, is easily understood but may be clinically neglected.

The fidelity of the communication between the physiotherapist and the patient affects the outcome of the intervention. It is our role as physiotherapists to deliver optimal care to our patients. This study provides objective evidence that the calibre of preoperative respiratory instructions and immediacy of postoperative implementation directly impacts postsurgical patient recovery.

**Provenance**: Invited. Not peer reviewed.

**Alice Jones**
*Discipline of Physiotherapy, Faculty of Health Sciences, The University of Sydney, Sydney, Australia*

## References

1. MacMahon C. *Lancet*. 1915;186:769–770.
2. Thoren L. *Acta Chir Scand*. 1954;107:193–205.

https://doi.org/10.1016/j.jphys.2018.04.006

1836-9553/© 2018 Australian Physiotherapy Association. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Journal of Physiotherapy 64 (2018) 195–196

Journal of PHYSIOTHERAPY

journal homepage: www.elsevier.com/locate/jphys

## Commentary

Surgery is a stressor that causes large physiological changes ranging from tissue trauma, immobility, and systemic effects, to psychological distress. After upper abdominal surgery, patients present with respiratory changes, including atelectasis, diaphragm dysfunction and reduced lung volumes. This leads to postoperative hypoventilation, which is associated with a high risk of pulmonary complications. Preoperative physiotherapy interventions, including exercise training[1] and breathing therapy strategies,[2] aim to increase alveolar stability and mobilise secretions. These interventions usually take around 20 minutes to complete. Several protocols having been tested but none have been found to reduce postoperative pulmonary complications.[3]

I commend the authors for this well designed and reported trial that satisfied all possible criteria of the PEDro scale, and recruited a large number of patients. The intervention included patient education about postoperative pulmonary complications and training patients how to perform breathing exercises. The intervention was provided either face to face or by telephone. The simple intervention halved the incidence of postoperative pulmonary complications, including pneumonia, within 14 postoperative hospital days and the effect was maintained at 12 months. It seems amazing how such a simple intervention was more effective than other interventions previously described and delivered directly to patients while in hospital. The effect could be explained by the fact that most patients were well educated and seen within 6 weeks before surgery. Another consideration is that most patients (around 70%) had cancer and it is possible that these patients were motivated to take greater care of their health postoperatively. In many developing countries, it might be difficult to implement this type of intervention because of a lack of routine preadmission clinics. However, this trial will encourage clinicians to re-consider their preoperative care.

**Provenance**: Invited. Not peer reviewed.

**Celso RF Carvalho**
*Department of Physical Therapy, School of Medicine, University of São Paulo, São Paulo, Brazil*

### References

1. Pouwels S, et al. *Int J Surg*. 2014;12:134–140.
2. Carvalho CRF, et al. *Braz J Phys Ther*. 2011;15:160–165.
3. Lunardi AC, et al. *Chest*. 2015;148:1003–1010.

https://doi.org/10.1016/j.jphys.2018.04.004

## Commentary

The trial results point towards an effective intervention in which a single 30-minute preoperative coaching session from a physiotherapist on breathing exercises can halve the incidence of postoperative pulmonary complications after upper abdominal surgery. However, there were several imbalances in the randomised groups that might explain some of the effect. The intervention group: was younger; had lower American Society of Anaesthesiology scores; had fewer respiratory, diabetes and cardiac co-morbidities; had fewer current smokers and had a lower pack-year history. Additionally, the intervention group reportedly had higher preoperative handgrip strength and estimated $VO_2$max. Further, less upper gastrointestinal/hepatobiliary surgeries were performed in the intervention group. Are any of these large enough to create an unbalanced risk profile between intervention and control groups, and therefore cast doubt on the results? Probably not in isolation, but collectively? The investigators undertook adjustments to their results for some baseline variables considered to potentially affect the primary outcome, but it is speculative whether this was sufficient. What is known is that presently, preadmission education by physiotherapists for those undergoing upper abdominal surgery is not usual care in Australian and New Zealand hospitals.[1] Therefore, for clinical practice change to occur, results have to pass the 'water cooler test'. It intuitively seems too good to be true that such a minimal-risk preoperative intervention of 'shock and awe' education on risks of postoperative pulmonary complications along with coaching on simple breathing exercises would have the profound impact of halving complications in the upper abdominal surgery cohort. Implementation challenges could occur if decision-makers were not fully convinced by or committed to the results. Anecdotally, physiotherapy preoperative assessment and education of those undergoing 'at-risk' surgery, such as cardiac, lung lobectomy and upper abdominal surgery, was prevalent in the later part of the 20th century[2] but funding for preoperative education, in the absence of evidence, has long been directed elsewhere. This trial is generating much conversation, but needs replicating across jurisdictions before the water cooler chatter can settle and practice change ensues.

**Provenance**: Invited. Not peer reviewed.

**Shane Patman**
*School of Physiotherapy, The University of Notre Dame Australia, Perth, Australia*

### References

1. Patman S, et al. *Arch Physiother*. 2017;7:11.
2. Reeve J, et al. *N Z J Physiother*. 2016;44:33–49.

https://doi.org/10.1016/j.jphys.2018.04.007

## Commentary

Strong claims require strong evidence. The Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) is the latest and most robust trial (PEDro 9/10) demonstrating that a single preoperative physiotherapy session halves respiratory complications after major abdominal surgery. Previous trials have reported very large effects: a 70 to 80%

1836-9553/© 2018 Published by Elsevier B.V. on behalf of Australian Physiotherapy Association. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

reduction.[1] Is this too good to be true? Maybe if based on a single trial, but three positive trials across four countries with a combined sample size of close to 1000 provide very strong evidence.

In our trial, group imbalances were present at baseline. Mathematical modelling indicates that imbalances are statistically likely (>70% likelihood) to occur when >50 variables are reported. In accordance with recommendations,[2] it is important to specify a priori key variables known to influence postoperative pulmonary complications and to adjust results for these if required. Rather than speculation, this is a deliberate measure to ensure that results are a true reflection of independent treatment effects. Additionally, the imbalances are small in absolute numbers; at most, baseline covariate balance differed by eight people. Considering the large effect size, robust trial methods, and detailed statistical analysis, it is unlikely that these small imbalances affected the overall outcome.

LIPPSMAck-POP confirmed the findings of previous trials: preoperative education, in addition to early ambulation, prevents postoperative pulmonary complications.[1] Most importantly, timing is vital. Patients should commence breathing exercises immediately after surgery, not a day or two later as per usual physiotherapy service in Australia. Preadmission clinics are the opportune time to train patients on these breathing exercises. While physiotherapy in preoperative clinics is still common practice in Europe, Australian physiotherapists have disinvested from this highly effective therapy over the past 20 years. Considering the mounting evidence also supporting preoperative exercise training,[3] it is time for physiotherapists to turn back the clock and get back into preop!

**Provenance**: Invited. Not peer reviewed.

**Ianthe Boden**
on behalf of the LIPPSMAck POP investigators
*Physiotherapy Department, Allied Health Services, Tasmanian Health Services, North Launceston General Hospital, Australia*

## References

1. Reeve J, et al. *N Z J Physiother.* 2016;44:33–39.
2. Pocock S, et al. *Stat Med.* 2002;21:2917–2930.
3. Barberan-Garcia A, et al. *Ann Surg.* 2018;267:50–56.

https://doi.org/10.1016/j.jphys.2018.04.005

# CHAPTER 8

# LIPPSMAck-POP: Secondary analyses

## 8.1 Author contributions

IB conceived and designed the study, coordinated the trial, prepared the first draft of the manuscript, and was responsible for the final manuscript. IB, JR, LA, and CH were principal site investigators. IB and IKR planned and did the statistical analysis. IB, EHS, LB, JR, IKR, DS, and LD analysed and interpreted the data. All authors revised all manuscript drafts and approved the final manuscript.

This study was supported by competitive research grants from the Clifford Craig Foundation, Launceston, Australia; the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia; and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand.

## 8.2 Submitted manuscript

Boden I, Reeve J, Robertson IK, Story D, Browning L, Skinner EH, Anderson L, Hill C, and Denehy L. Effect of preoperative physiotherapy on clinical signs and symptoms of pulmonary collapse and infection after major abdominal surgery: secondary analysis of the LIPPSMAck-POP randomised controlled trial. 2020.

This chapter has been peer-reviewed by *Anaesthesiology* in February 2020. The following chapter is the revised manuscript submitted for publication with *Anaesthesia* on 22nd June 2020.

This chapter is in the format and reference structure as submitted.

## 8.3 Abstract

The LIPPSMAck-POP trial was a multicentre randomised controlled trial involving 432 patients having elective upper abdominal surgery. It found that a single preoperative education and breathing exercise training session delivered in preadmission clinics by a physiotherapist halved the incidence of postoperative pulmonary complications compared to an information booklet alone. Specific effects on other important clinical outcomes such as antibiotic prescriptions, and oxygen requirements are unknown. This *post hoc* analysis of prospectively collected data from the LIPPSMAck-POP trial explored treatment effects to postoperative antibiotic prescriptions, hypoxemia, sputum cultures, chest imaging, auscultation, leukocytosis, pyrexia, oxygen therapy, and diagnostic coding. Outcomes were assessed daily for 14 postoperative days. Analyses were intention-to-treat by adjusted generalised multivariate linear regression.

Intervention participants required fewer antibiotic prescriptions specific for a respiratory infection (RR 0.52; 95% CI 0.31-0.85, p=0.009), had less purulent sputum on the third and fourth postoperative days (RR 0.50; 95% CI 0.34-0.73, p=0.01), fewer positive sputum cultures from the third to fifth postoperative day (RR 0.17; 95% CI 0.04 to 0.77, p=0.01), and required less oxygen therapy (RR 0.49; 95% CI 0.31 to 0.78, p=0.002). Differences detected in chest imaging, hypoxemia, pyrexia, leukocytosis, or auscultation were not statistically significant.

Preoperative physiotherapy that prepares a patient to perform self-directed breathing exercises immediately after major abdominal surgery is associated with the minimisation of signs and symptoms specific to pulmonary collapse/consolidation and airway infection resulting in reduced oxygen therapy and antibiotic prescriptions.

## 8.4 Introduction

Pathophysiological effects of anaesthesia and the abdominal incision during major abdominal surgery cause deleterious effects on lung volumes, mucociliary clearance, and cough strength [1]. Atelectasis is almost inevitable in the immediate postoperative period, with up to 90% of patients having under-aerated lung tissue occupying up to a quarter of lung fields in the first hour after surgery [2], despite advances in perioperative surgical and anaesthetic practices [3]. Approximately 50% of patients continue to have notable atelectasis 24 hours after surgery [4]. Unresolved atelectasis is considered a primary pathogenic precursor for microbial contamination [5] predicating pneumonia and acute respiratory distress syndrome [6]. Postoperative pulmonary complications (PPC) are common after upper abdominal surgery and have considerable impacts on morbidity, mortality, and hospital costs [1, 7-9].

The Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP) study was a phase-three, binational, multicentre, randomised placebo-controlled trial [9] that found preoperative physiotherapy independently halves PPC rates, including pneumonia, after major abdominal surgery. The primary focus of the intervention was to educate, enable, and motivate participants to perform hourly sets of deep breathing and coughing exercises immediately upon waking from surgery. The hypothesis was that repetitive independent performance of breathing exercises in the early postoperative period would reverse atelectasis and improve sputum clearance resulting in reduced risk of a PPC. In a deliberate effort to minimise Hawthorne effects the performance of breathing exercises was not directly measured [9-11]. Consequently, it cannot be stated with absolute certainty that the mechanism of effect for PPC reduction in the LIPPSMAck-POP trial were self-directed breathing exercises. Additionally, the primary outcome was a PPC identified using a diagnostic screening tool, the Melbourne Group Score [8-10]. There is some debate surrounding the validity of generic PPC diagnosis tools and their relationship with clinical outcomes [8]. Specific effects on chest imaging, sputum cultures, antibiotic prescriptions, oxygen requirements, and administrative coding from the LIPPSMAck-POP trial have not been reported. This information would be vital for perioperative health professionals and hospital administrators to consider the relative value that physiotherapy has on important postoperative clinical outcomes. Positive effects to physiological outcomes would also provide concurrent validity to the primary results and support the hypothesis that preoperative physiotherapy enables patients to perform breathing exercises after surgery.

The first aim of these exploratory secondary analyses were to investigate the distribution and occurrence of common postoperative clinical signs and symptoms related to respiratory pathology using *a priori* prospectively collected data and acquired administrative clinical coding. The

hypotheses to be tested were; preoperative physiotherapy that reduces PPCs as assessed using the Melbourne Group Score should also affect clinical outcomes specifically related to pulmonary collapse and infection, such as oxygen therapy usage and antibiotic prescriptions; yet should not affect complications physiologically unlikely to be prevented with breathing exercises such as pulmonary emboli [9] or non-respiratory related infections. The second aim was to test the hypothesis that if self-directed breathing exercises are the primary method of effect, benefits in patients sedated and mechanically ventilated after surgery should not be expected due to their inability to perform these exercises.

## 8.5 Methods

LIPPSMAck-POP was a multicentre, parallel-group, double-blinded (assessors and patients), randomised controlled trial conducted at three hospitals in Australia and New Zealand. It tested the effectiveness of a single preoperative respiratory education and coaching session delivered by a physiotherapist, compared to an information booklet alone, to reduce PPCs following major abdominal surgery [9]. LIPPSMAck-POP was prospectively registered (ANZCTR 12613000664741), approved by local ethics committees, with participants providing written informed consent. Design, methodology, primary results, qualitative findings, and health economic outcomes are published in detail elsewhere [9-12].

As reported previously, 432 adults attending an outpatient pre-admission clinic within six-weeks of elective major abdominal surgery were block randomised without stratification via concealed allocation to receive preoperative physiotherapy (intervention, n=218) or an information booklet (control, n=214). Intervention participants were provided with the booklet and a single 30-minute education session about the effect of anaesthesia and abdominal surgery on mucociliary clearance, lung volumes, and the consequences of bacterial stagnation in the lungs. Patients were educated that self-directed breathing exercises were vital in preventing pneumonia and were directed to commence these exercises immediately after surgery. Participants were coached in the breathing exercises and provided with memory cues to prompt hourly postoperative performance. Control participants received a placebo information booklet. Following surgery, all participants received standardised postoperative ambulation and no additional prophylactic chest physiotherapy or incentive spirometers were provided.

The median age of participants was 65 (range 52-75) and proportionally more were males (61%). Surgery was mainly of curative intent for cancer (69%), requiring major colorectal (49%), renal

(26%), or upper gastrointestinal/hepatobiliary procedures (24%). Operations were generally longer than two hours (64%) via open upper midline (49%) or subcostal (18%) incisions [9].

This *post-hoc* exploratory secondary analysis was not pre-specified within the original trial registration. It utilises prespecified *a priori* data collected prospectively by masked assessors. Patients, postoperative physiotherapists, nurses, surgeons, anaesthetists, and clinical coders were unaware of group allocation.

Participants were assessed daily for a PPC using a modified Melbourne Group Score [9, 10] over the first 14 hospital days. This was the LIPPSMAck-POP trial's primary outcome. The Melbourne Group Score consists of eight clinical criteria; abnormal chest auscultation, abnormal sputum colour, hypoxemia on room air, pyrexia, collapse/consolidation on chest x-ray (CXR) or computerised tomography (CT), leukocytosis, infected sputum culture, and a medical diagnosis of a pulmonary complication or antibiotic prescription specific for a pulmonary infection (see Appendix for detailed description and standardised collection rules). The concurrent presence of four or more of these criteria in a calendar day triggered a PPC diagnosis.

For the purposes of these secondary analyses each criterion within the Melbourne Group Score was considered separately for between-group differences. Prescription of antibiotics specific for a respiratory infection was determined by probing medication charts for antibiotics prescribed in direct response to respiratory deterioration documented in the medical record by a physician. The medical team was contacted for clarification if required. The first day of antibiotic initiation was recorded. Auscultation abnormalities, sputum colour abnormalities, peripheral oxyhaemoglobin ($SpO_2$) desaturation <90% on room air, and temperature over 38°C were assessed daily and purposively for this trial. White blood cell counts, sputum sampling, and chest imaging were not ordered purposively and daily for this trial rather the collection of these criteria was based on pragmatic clinical practice as required by masked surgical or anaesthesia teams. Collapse/consolidation on CXR and CT, and abnormal pathology tests were reported by independent blinded radiologists or pathologists and these results were extracted from hospital databases by the trial's assessors. A physician diagnosis of a PPC was documentation within the medical record of pneumonia, upper or lower respiratory tract infection, or atelectasis.

Mode of oxygen therapy and mechanical ventilation was collected daily until the 14$^{th}$ hospital day. At participating hospitals, supplemental oxygen therapy was mandatory during administration of opioid-based intravenous analgesia. For the purposes of this study, this was not counted as oxygen therapy required to manage a respiratory deterioration [8] if the oxygen therapy was delivered in the absence of signs or symptoms of respiratory dysfunction (hypoxemia, chest imaging abnormalities, or physician documentation) and only for the purposes of the administration of intravenous analgesia.

As per standard hospital administrative practices, masked clinical coders assessed the medical record and classified each participant's episode of care for postoperative complications according to the World Health Organisation (WHO) International Classification of Diseases (ICD-10) coding set [13]. Diagnostic coding is used to assist governmental administrative reporting and for case-mix calculated activity-based funding of hospital services. Clinical coding was extracted and collated by masked trial assessors from hospital databases. Codes were grouped into intraoperative complications, non-respiratory postoperative complications, and respiratory postoperative complications. Respiratory complication coding was further divided into those related to atelectasis and airway infection, such as pneumonia, and those not related, such as a pneumothorax [8]. See Appendix for full listing of relevant codes, diagnostic labels, and cohorting rules.

The time from end of anaesthesia to extubation from mechanical ventilation was collected *a priori* [10]. For this secondary analysis, participants were separated into two cohorts for sub-group analysis of the treatment effect to the primary PPC endpoint; those sedated and continuously mechanically ventilated immediately after surgery, and those participants extubated on cessation of anaesthesia.

An *a priori* power calculation was not performed for these exploratory secondary analyses. Categorical values are presented as counts and percentages. Event rates for oxygen usage and mechanical ventilation are a single positive occurrence anytime within the first 14 postoperative days. Clinical signs and symptoms are reported two ways. Firstly, the proportion of participants who had a single positive occurrence anytime within the first 14 postoperative days, and secondly, a daily event rate where the daily proportion of participants with a positive incidence on each of the first seven postoperative days is represented graphically with 95% confidence intervals. Clinical criteria event rates were compared using adjusted generalised linear Poisson modelling. Diagnostic coding total event rates for each coding category were compared using adjusted multivariate robust random effects binary logistic generalised linear regression. The mean difference in total number of respiratory specific codes was assessed using adjusted multivariate linear regression. PPC incidence according to postoperative ventilation status and differences in antibiotic prescriptions was analysed using survival-time regression analysis and graphically illustrated using Kaplan-Meier methods. All data are intention-to-treat, relative risk, or mean difference between-groups with 95% confidence intervals and two-tailed p-values, adjusted for known baseline imbalances between groups in age, respiratory comorbidity, and surgical category [9]. Detailed description of the statistical analysis plan, covariates, and adjustment modelling are available open access [9, 10]. Analyses were performed using SPSS (V23, IBM) and STATA (V14.1, Stata Corp).

## 8.6 Results

From 2013 to 2015, 441 participants (intervention, n=218; control, n=214; withdrawn, n=9) were recruited in this double-blinded, multicentre randomised controlled trial across two countries. Baseline, clinical characteristics, and flow through trial are previously published [9]. Over the whole sample (n=432) an auscultation abnormality was the most common positive finding on postoperative day one (58% of all participants; see Figure A in Appendix), followed by leukocytosis (52%), hypoxemia on room air (21%), abnormal sputum colour (14%), and chest imaging findings of collapse/consolidation (10%). Daily rates of fever and positive sputum cultures were < 5%. Auscultation abnormalities, leukocytosis, and hypoxemia became less prevalent over time. The rate of change in daily purulent sputum production was notably different, elevating from 14% of all participants to 22% over the first three days.

Between the two groups (Figure 1), intervention participants had approximately half the risk of purulent sputum being detected on the third day (RR 0.54, 95% CI 0.33 to 0.90; p = 0.017; Figure 1(b)), and had an estimated 80% less risk of a positive sputum culture result from the third to the fifth days (RR 0.12, 95% CI 0.02 to 0.72; p = 0.02; Figure 1(g)) when compared to control participants. Although a separation between groups favouring the intervention group is graphically evident in other daily criteria, statistical significance was not found. These criteria had low daily event rates (pyrexia and physician diagnosis; Figure 1(d) & (h)) and small effect sizes (auscultation changes and hypoxemia on room air; Figure 1(a) & (c)), limiting the statistical power for these secondary endpoints.

When considering the proportional occurrence of criteria at any time in the first 14 postoperative days (Table 1), intervention participants were an estimated 40% less risk of being prescribed antibiotics specific for a respiratory infection (RR 0.60, 95% CI 0.40 to 0.91, p = 0.016; Table 1) when compared to the control group. Differences in antibiotic prescriptions rates were evident from the second day (Figure 2). No statistically significant treatment effects between-groups were detected in the event rate of other criteria occurring at least once anytime over the first 14 days (Table 1).

Intervention participants were at less risk of requiring oxygen therapy during the first 14 postoperative days (RR 0.49, 95% CI 0.31 to 0.78, p = 0.002; Table 1) with half as many intervention participants requiring standard supplemental or high-flow oxygen therapy. No statistical difference was detected for non-invasive or invasive mechanical ventilation requirements with a low event rate of 5% per group.

Intervention participants had fewer counts overall of diagnostic coding for pneumonia, pulmonary collapse, acute respiratory failure, and other respiratory diagnostic codes related to atelectasis and

airway infection when compared to control participants (Table 2). A difference between groups was not detected in the administrative diagnostic coding of respiratory complications unrelated to atelectasis or airway infection (pleural effusion, pneumothorax, pulmonary emboli), nor in the incidence of intraoperative or non-respiratory postoperative complications (Table 2).

A large treatment effect in the primary outcome of PPC was found only in the sub-group of participants who were extubated immediately after surgery (RR 0.33, 95% CI 0.17 to 0.64; p = 0.001; Figure 3) with no difference detected in PPC incidence between-groups in participants who remained sedated and mechanically ventilated on completion of surgery.

**Table 1:** Treatment effects to postoperative clinical criteria and oxygen therapy requirements. Values are number (proportion).

| | Control (n=214) | Intervention (n=218) | Adjusted RR (95% CI) | p value |
|---|---|---|---|---|
| **Clinical criteria 14-day event rates** | | | | |
| Auscultation abnormal | 161 (75%) | 151 (69%) | 0.94 (0.84 to 1.06) | 0.35 |
| Sputum colour abnormal | 90 (42%) | 81 (37%) | 0.94 (0.74 to 1.18) | 0.57 |
| Hypoxemia | 74 (35%) | 64 (29%) | 0.93 (0.71 to 1.23) | 0.63 |
| Pyrexia | 27 (13%) | 28 (13%) | 1.04 (0.63 to 1.73) | 0.87 |
| Collapse/consolidation on CXR/CT | 57 (27%) | 39 (18%) | 0.74 (0.52 to 1.05) | 0.09 |
| Leukocytosis | 134 (63%) | 141 (65%) | 1.05 (0.92 to 1.22) | 0.43 |
| Sputum culture positive for infection | 15 (7.0%) | 9 (4.1%) | 0.67 (0.30 to 1.48) | 0.33 |
| Physician diagnosis of PPC in medical record | 37 (17%) | 28 (13%) | 0.86 (0.51 to 1.35) | 0.51 |
| Respiratory antibiotics prescribed | 53 (25%) | 29 (13%) | 0.60 (0.40 to 0.91) | 0.02 |
| **Oxygen therapy and mechanical ventilation** | | | | |
| No oxygen therapy | 129 (60%) | 172 (79%) | 0.49 (0.31 to 0.78) | 0.002 |
| Standard oxygen therapy | 48 (22%) | 24 (11%) | | |
| High flow oxygen therapy | 25 (12%) | 10 (4.6%) | | |
| Invasive or non-invasive mechanical ventilation | 12 (5.6%) | 12 (5.5%) | | |

Data are event rates within the first 14 postoperative hospital days compared using mixed effects general linear Poisson regression reported as relative risk with 95% CI, adjusted for age, respiratory comorbidity, and surgical category, with exposure time as the time to cessation of observations.
Oxygen therapy was classified as the most intensive therapy provided to a patient, a rank-order scale, with comparison estimated as odds ratio using ordered linear regression adjusted as above.
Abbreviations: RR=relative risk; CI=confidence interval; PPC=postoperative pulmonary complications; CXR=chest X-ray; CT=computerised tomography

**Table 2:** Clinical coding of postoperative complications. Values are number (proportion) or mean (SD).

| | Control n=214 | Intervention n=218 | Adjusted RR or mean difference (95% CI) | p value |
|---|---|---|---|---|
| **Clinical coding (ICD-10) event rates of intraoperative and non-respiratory postoperative complications** | | | | |
| Intraoperative complications | | | | |
| Laceration | 12 (5.6%) | 22 (10%) | 1.71 (0.84 to 3.50) | 0.14 |
| Haemorrhage | 13 (6.1%) | 16 (7.3%) | 1.26 (0.61 to 2.62) | 0.53 |
| Postoperative complications - surgical | | | | |
| Wound infection | 25 (12%) | 22 (10%) | 0.90 (0.52 to 1.55) | 0.70 |
| Wound dehiscence | 7 (3.3%) | 6 (2.8%) | 0.92 (0.29 to 2.89) | 0.89 |
| Anastomosis leak | 1 (0.5%) | 3 (1.4%) | 3.16 (0.26 to 37.5) | 0.36 |
| Postoperative complications - general | | | | |
| Paralytic ileus | 42 (20%) | 36 (17%) | 0.87 (0.58 to 1.31) | 0.50 |
| Hypovolemia | 26 (12%) | 26 (12%) | 1.04 (0.62 to 1.75) | 0.87 |
| Delirium/altered conscious state | 25 (12%) | 21 (9.6%) | 1.01 (0.60 to 1.71) | 0.97 |
| Other infections | 24 (11%) | 18 (8.5%) | 0.84 (0.47 to 1.51) | 0.56 |
| Urinary tract infection | 18 (8.4%) | 12 (5.5%) | 0.85 (0.44 to 1.64) | 0.63 |
| Sepsis | 13 (6.1%) | 7 (3.2%) | 0.63 (0.26 to 1.57) | 0.33 |
| Acute kidney injury | 10 (4.7%) | 8 (3.7%) | 0.85 (0.33 to 2.20) | 0.74 |
| Pressure ulcer | 12 (5.6%) | 3 (1.4%) | 0.31 (0.09 to 1.09) | 0.07 |
| Cardiac | 7 (3.3%) | 10 (4.6%) | 1.72 (0.65 to 4.58) | 0.28 |
| Hypervolemia | 4 (1.9%) | 7 (3.2%) | 1.96 (0.57 to 6.71) | 0.28 |
| Deep vein thrombosis | 2 (0.9%) | 3 (1.4%) | 1.69 (0.30 to 9.60) | 0.56 |
| **Clinical coding (ICD-10) event rates of respiratory postoperative complications** | | | | |
| Coding of respiratory complications hypothesised to be preventable with breathing exercises | | | | |
| Nonspecific pulmonary problem* | 26 (12%) | 11 (5.0%) | 0.48 (0.24 to 0.95) | 0.03 |
| Pulmonary collapse | 21 (9.8%) | 16 (7.3%) | 0.83 (0.45 to 1.54) | 0.56 |
| Pneumonia | 19 (8.9%) | 15 (6.9%) | 0.94 (0.49 to 1.79) | 0.84 |
| Acute respiratory failure | 11 (5.1%) | 5 (2.3%) | 0.54 (0.19 to 1.49) | 0.23 |
| Mean number of codes per participant | 0.36 (0.48) | 0.22 (0.41) | 0.71 (0.41 to 1.22) | 0.22 |
| Coding of respiratory complications unlikely to be preventable with breathing exercises | | | | |
| Pleural effusion | 12 (5.6%) | 8 (3.7%) | 0.75 (0.31 to 1.76) | 0.50 |
| Pneumothorax | 8 (3.7%) | 12 (5.5%) | 1.42 (0.59 to 3.43) | 0.43 |
| Nonspecific pulmonary problem† | 6 (2.8%) | 11 (5.0%) | 1.74 (0.64 to 4.70) | 0.28 |
| Pulmonary emboli | 2 (0.9%) | 4 (1.4%) | 2.57 (0.47 to 14.2) | 0.28 |
| Mean number of codes per participant | 0.13 (0.34) | 0.16 (0.37) | 1.30 (0.71 to 2.36) | 0.40 |

Data compared using relative risk or mean difference with 95% CI adjusted for age, respiratory comorbidity, and surgical category.

Abbreviations: RR=relative risk; CI=confidence interval; ICD-10=International Classification of Diseases Version 10

*non-specific coding of a pulmonary problem/symptom in conjunction with coding specific to pulmonary collapse or infection (see Appendix)

†non-specific coding of a pulmonary problem/symptom in absence of coding specific to pulmonary collapse or infection (see Appendix)

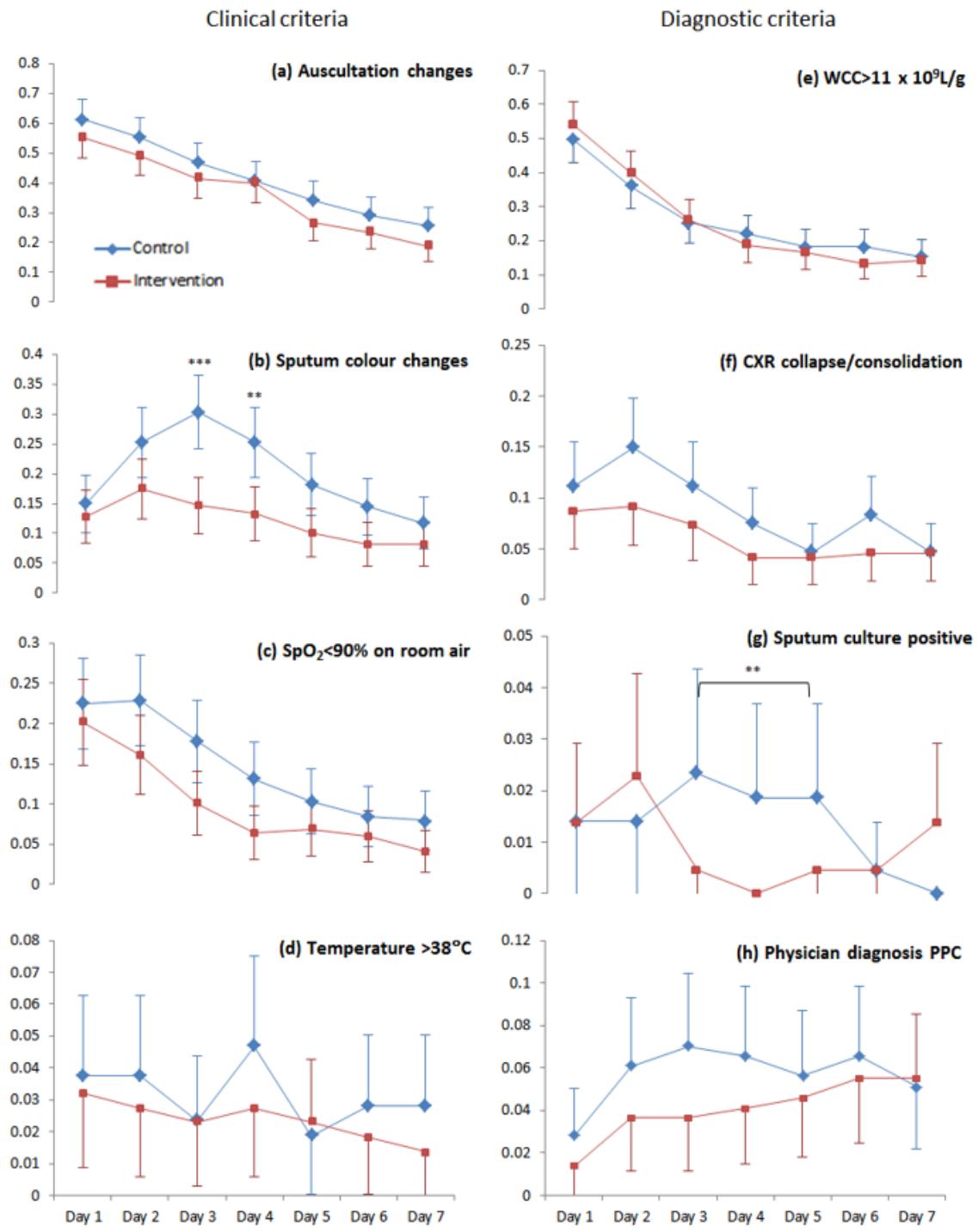



**Figure 1 (a)-(h):** Daily rates of clinical criteria. Data are proportions with error bars showing 95% confidence intervals. Intervention (red lines); control (blue lines). p values: *p = 0.02; **p = 0 .01; ***p < .001

**Figure 2** Cumulative rate of antibiotic prescriptions specific for a respiratory infection. Data are proportions. Intervention (dotted line); control (solid line).

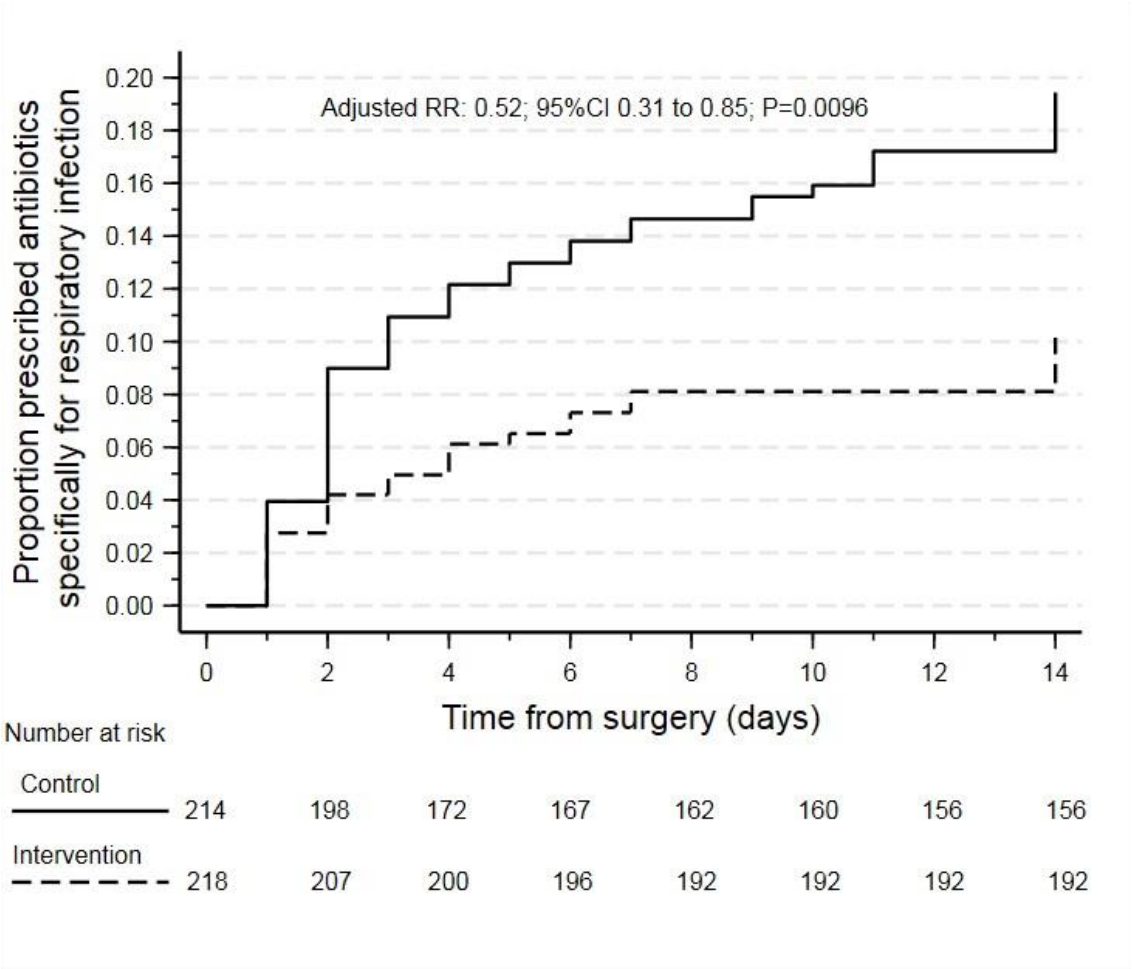
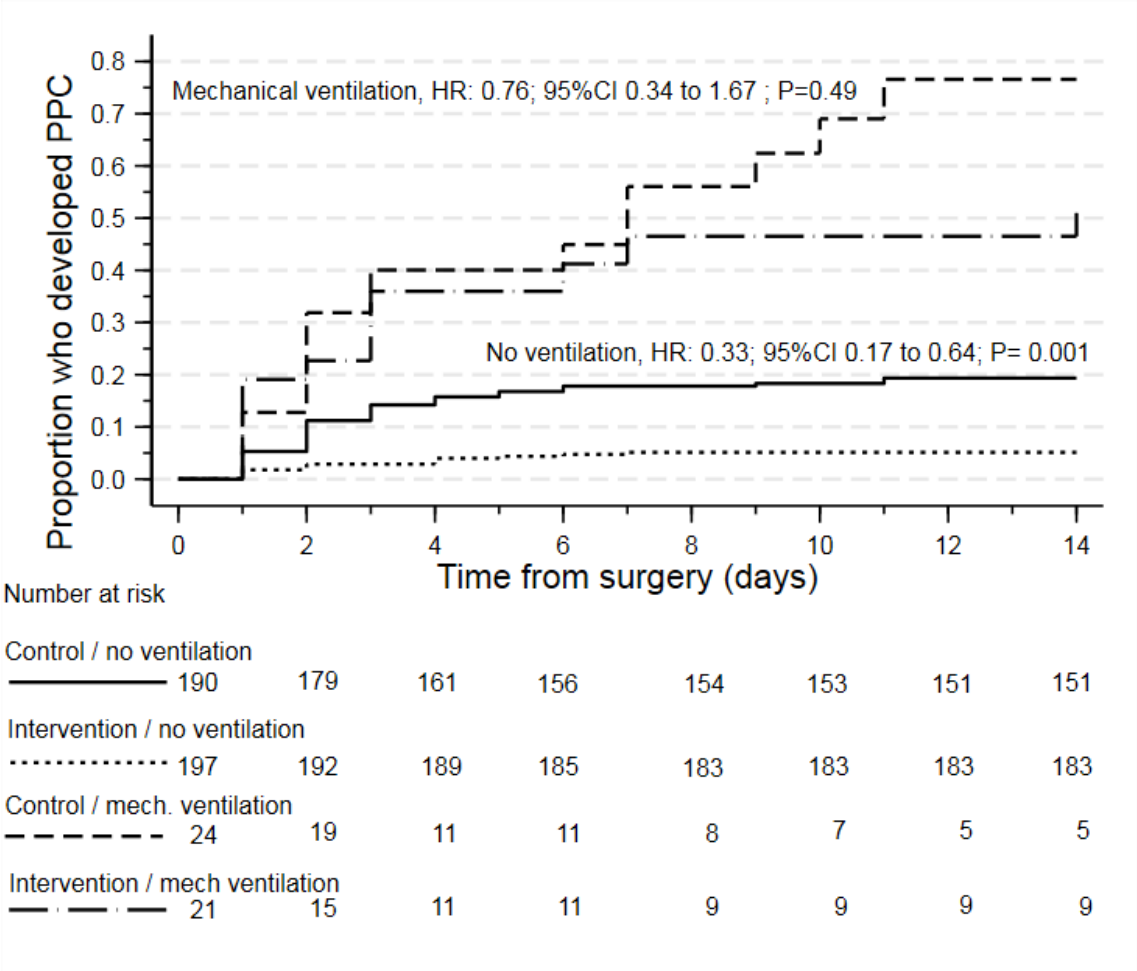


**Figure 3:** Time to PPC diagnosis sub-grouped to ventilation status immediately after surgery: (a) conscious and extubated; (b) sedated and mechanically ventilated. Data are proportions.



## 8.7 Discussion

This exploratory secondary analysis of prospectively collected *a priori* clinical data within an international, multicentre randomised controlled trial [9] finds that preoperative physiotherapy is associated with the minimisation of clinical signs and symptoms related to postoperative atelectasis and airway infection. Intervention participants were less likely to be prescribed antibiotics specific for a respiratory infection, require oxygen therapy, develop purulent sputum, have positive sputum cultures, or have their episode-of-care coded for a respiratory diagnosis specific to pulmonary collapse or airway infection. Furthermore, the preoperative physiotherapy intervention did not have any effect on complications that have no conceivable physiological basis for breathing exercises to prevent, such as wound infections or pulmonary emboli. Additionally, preoperative physiotherapy was only effective in participants who were extubated and conscious immediately after surgery and therefore more likely to be able to perform self-directed breathing exercises.

These new data provide concurrent validity to the original trial findings of a large significant reduction in PPC incidence following major abdominal surgery in those participants met by a physiotherapist in pre-admission clinics [9]. These patients were educated on their risk of a PPC and taught breathing exercises to start performing immediately on waking from surgery. In the absence of direct breathing exercise compliance data, the hypothesis that preoperative physiotherapy engenders the performance of efficacious breathing exercises in the early postoperative period is supported.

Atelectasis is present in almost all patients immediately after major abdominal surgery [4-6]. Extensive atelectasis predicates pulmonary shunt, hypoxemia, and microbial contamination [5, 6]. Expert opinion considers that atelectasis is best addressed in the early postoperative period [14]. At this time simple lung expansion techniques, such as breathing exercises, may more easily overcome collapsed small airways and the elastic resistance required to re-expand them. If atelectasis progresses to full lobar collapse, breathing exercises may not be effective as greater reductions in lung compliance require significantly more respiratory muscle work to generate the pleural pressure change needed to overcome greater elastic resistance across the lung. The first 24 hours may be a vital window where breathing exercises might be most effective [14]. There is some evidence supporting this theory. Breathing exercises performed immediately postoperatively are reported to reduce atelectasis [15] and pulmonary shunt [16], improving lung function [17], and oxygenation [18], whereas multiple coached breathing exercise sessions initiated on the first postoperative day may not be effective in reducing PPCs [19, 20]. Confirmation that early postoperative breathing exercises can effectively enhance alveolar recruitment is required to further investigate this hypothesis. This could be conducted using point-

of-care ultrasound. Ultrasound is more sensitive in detecting atelectasis than CXRs [21, 22], arguably less onerous and harmful to the patient, and could confirm in real-time the proposed physiological and timing of initiation effects of postoperative breathing exercises [23, 24].

The aim of preoperative physiotherapy is to enable a patient to starting performing breathing exercises immediately after surgery, rather than the day after surgery, which is normally when the first physiotherapy session provided [25, 26]. Bringing the time point of these exercises forward a day could also introduce a possible dose-dependent relationship benefit. An additional 200 repetitions (20 repetitions, hourly, for 10 hours) of deep breathing and coughing exercises are possible if initiated immediately on waking from surgery compared to starting the next day. Preliminary reports find that increased repetitions of breathing exercises augmented with either a positive expiratory pressure device [27], or an incentive spirometer with an electronic hourly reminder [28], significantly improve oxygenation [27] and reduce atelectasis [28] following open cardiac surgery.

Atelectasis traps bronchial secretions creating an environment conducive for microbial contamination [5, 6]. In this study, purulent sputum and positive sputum cultures occurred significantly more often in control participants, starting from the second postoperative day. Respiratory infection symptoms take between 24-48 hours to manifest [29]. This suggests that the pathogenesis of these increased rates of purulent infected sputum evident on the second postoperative day may have originated in the immediate postoperative period. Breathing exercises performed by intervention participants may have reversed atelectasis in this period thus reducing the risk of airway infection by the second day. It is not surprising that control participants were twice as likely to be prescribed antibiotics specific for a respiratory infection. Sputum colour is the most common reason to trigger an antibiotic prescription by doctors [30]. Prescribing antibiotics purely on suspicion of hospital-acquired pneumonia appears routine practice [31] and contrary to guidelines advising that antibiotics in ward-based patients should only be prescribed on empirical evidence, such as infection on sputum culture [32]. That preoperative physiotherapy independently reduced not only the onset of purulent sputum and positive sputum cultures, but also reduced antibiotic prescriptions has significant implications in assisting efforts to limit antibiotic over-prescription and combating the development of antibiotic resistant bacteria [33].

No difference between-groups was observed for hypoxemia, pyrexia, leukocytosis, auscultation changes, or CXR changes, however given the inherent reduction in statistical power for secondary outcomes, the lack of observed effects in criteria with low event rates should not be unexpected. Furthermore, these individual criteria are not strongly associated with clinically relevant PPCs. Although common after abdominal surgery, episodic hypoxemia does not appear to be associated with clinically relevant complications rates [34]; leukocytosis is a general sign of an immune

response and lacks specificity to pulmonary infection alone [35]; auscultation has poor sensitivity and reliability as a stand-alone measure of respiratory dysfunction [36]; and the association between fever and atelectasis is hotly contested [37]. As discussed earlier, preliminary research is finding that ultrasound, rather than CXR or CT, could be a more sensitive measure of respiratory dysfunction after surgery [21-24]

Hospitals routinely collect clinical coding for billing and epidemiology purposes. For this trial, clinical coding outcomes add concurrent validity to primary results. The increased documentation in the medical record of respiratory complications specific to pulmonary collapse and airway infection in control participants were clinically significant enough to be detected by masked coders analysing only the medical record. A differences between groups was only detected in respiratory complications considered responsive to breathing exercises, and not for pneumothorax, pulmonary emboli, and pleural effusions, and all other general intra-operative and non-respiratory postoperative complications with no conceivable physiological basis for breathing exercises to effect. These data should be considered with caution, however, as coding under-report true event rates and lack reliability [38].

Early self-directed breathing exercises most likely minimise signs and symptoms of atelectasis and pulmonary infection after surgery but only if patients remember the exercises and perform them as instructed. The memorability of this intervention has been previously demonstrated with 94% of intervention participants recalling the breathing exercises taught compared to 15% who received the instructions in written form only [11]. Furthermore, these secondary analyses demonstrate that no benefit was achieved from having received preoperative physiotherapy in patients who remained mechanically ventilated and sedated after surgery. This is likely due to their inability to perform the breathing exercises as taught.

In LIPPSMAck-POP, the only prophylactic respiratory physiotherapy participants received was a single session of preoperative education and breathing exercise training. This simple intervention reduced PPCs by half (RR 0.48, 95% CI 0.30 to 0.75) [9]. A superior result to multiple sessions of postoperative coached breathing exercises [19, 20] and incentive spirometer use [39]. It also delivered comparative PPC reduction benefits to modern perioperative surgical and anaesthetic practices such as lung protective ventilation, prophylactic non-invasive ventilation, goal directed fluid therapy, and epidural analgesia [40].

Although systematic reviews find that physiotherapy is an effective modality to reduce the risk of PPCs the most efficacious and cost-effective physiotherapy technique is unknown [40, 41]. Most physiotherapy trials were conducted more than 10 years ago, were of low quality, tested multimodal interventions, and did not adequately control or measure known confounders, such as early ambulation and other perioperative practices aimed at PPC minimisation. LIPPSMAck-POP

rigorously demonstrated that a single preoperative physiotherapy session conducted in the context of standardised early ambulation, enhanced recovery pathways, and modern perioperative anaesthetic and surgical practices independently minimises PPCs without the use of additional postoperative coached breathing exercises or devices and is cost-effective [12]. Trials are now required to determine if the addition of other interventions such as inspiratory muscle training, prehabilitation, or, postoperative coached breathing exercises and non-invasive ventilation confer any additional clinical benefit or are cost-effective compared to providing preoperative physiotherapy alone.

These secondary analyses contribute to original primary findings that a single preoperative session with a physiotherapist halves the risk of a PPC after major abdominal surgery. This paper reports associated clinical benefits to signs of airway infection, oxygen therapy use, and antibiotic prescription rates. In developed countries, preoperative physiotherapy is currently not standard practice [25, 26]. This new evidence, in conjunction with cost-effectiveness [12] and consumer-lead preference for this service [11], may now encourage hospitals to consider embedding a preoperative physiotherapy service within pre-admission clinics for all patients listed for elective upper abdominal surgery.

## 8.8 References


1. Miskovic A, Lumb AB. Postoperative pulmonary complications. *British Journal of Anaesthesia* 2017; **118**: 317-334.
2. Lundquist H, Hedenstierna G, Strandberg A, Tokics L, Brismar B. CT-assessment of dependent lung densities in man during general anaesthesia. *Acta Radiologica* 1995; **36**: 626-632.
3. Pereira SM, Tucci MR, Morais CCA, et al. Individual positive end-expiratory pressure settings optimize intraoperative mechanical ventilation and reduce postoperative atelectasis. *Anesthesiology* 2018; **129**: 1070-1081.
4. Touw HR, Schuitemaker AE, Daams F, et al. Routine lung ultrasound to detect postoperative pulmonary complications following major abdominal surgery: a prospective observational feasibility study. *The Ultrasound Journal* 2019; **11**:20. doi: 10.1186/s13089-019-0135-6
5. van Kaam AH, Lachmann RA, Herting E, et al. Reducing atelectasis attenuates bacterial growth and translocation in experimental pneumonia. *American Journal Respiratory Critical Care Medicine* 2004; **169**:1046-53.
6. Tusman G, Bohm SH, Warner DO, Sprung J. Atelectasis and perioperative pulmonary complications in high-risk patients. *Current Opinion in Anaesthesiology*. 2012; **25**:1-10.
7. Fleisher LA, Linde-Zwirble WT. Incidence, outcome, and attributable resource use associated with pulmonary and cardiac complications after major small and large bowel procedures. *Perioperative Medicine (London).* 2014; **3**:7.
8. Abbott TEF, Fowler AJ, Pelosi P, et al; StEP-COMPAC Group. A systematic review and consensus definitions for standardised end-points in perioperative medicine: pulmonary complications. *British Journal of Anaesthesia* 2018; **120**:1066-1079.
9. Boden I, Skinner EH, Browning L, et al. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ* 2018; **360**:j5916. doi: 10.1136/bmj.j5916.
10. Boden I, Browning L, Skinner EH, et al. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials* 2015; **16**: 573. doi: 10.1186/s13063-015-1090-6
11. Boden I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy* 2018; **104**: 194-202.
12. Boden I, Robertson IK, Neil A, et al Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis within a binational multicentre randomised controlled trial. *Journal of Physiotherapy.* 2020; accepted for publication in press.
13. International Classification of Diseases (ICD-10) [World Health Organisation web site]. 2018. www.who.int/classifications/icd/icdonlineversions/en/ (accessed 10/08/2018).
14. Ball L, Battaglini D, Pelosi P. Postoperative respiratory disorders. *Current Opinion in Critical Care* 2016; **22**: 379-385.
15. Westerdahl E, Lindmark B, Eriksson T, Friberg O, Hedenstierna G, Tenling A. Deep-breathing exercises reduce atelectasis and improve pulmonary function after coronary artery bypass surgery. *Chest* 2005; **128**: 3482-3488.

16. Ntoumenopoulos G, Greenwood K. Effects of cardiothoracic physiotherapy on intrapulmonary shunt in abdominal surgical patients. *Australian Journal of Physiotherapy* 1996; **42**: 297-303.

17. Zoremba M, Dette F, Gerlach L, Wolf U, Wulf H. Short-term respiratory physical therapy treatment in the PACU and influence on postoperative lung function in obese adults. *Obesity Surgery* 2009; **19**: 1346-1354.

18. Manzano RM, Carvalho CR, Saraiva-Romanholo BM, Vieira JE. Chest physiotherapy during immediate postoperative period among patients undergoing upper abdominal surgery: randomized clinical trial. *Sao Paulo Medical Journal* 2008; **126**: 269-273

19. Reeve J and Boden I. The physiotherapy management of patient undergoing abdominal surgery. *New Zealand Journal of Physiotherapy*. 2016**;** 44(1): 33-49.

20. Lunardi AC, Paisani DM, Silva CCBMD, Cano DP, Tanaka C, Carvalho CRF. Comparison of lung expansion techniques on thoracoabdominal mechanics and incidence of pulmonary complications after upper abdominal surgery: a randomized and controlled trial. *Chest*. 2015;**148** : 1003-1010

21. Ford JW, Heiberg J, Brennan AP, et al. A pilot assessment of 3 point-of-care strategies for diagnosis of perioperative lung pathology. *Anesthesia and Analgesia* 2017; **124**: 734-742.

22. Touw HR, Parlevliet KL, Beerepoot M, et al. Lung ultrasound compared with chest X-ray in diagnosing postoperative pulmonary complications following cardiothoracic surgery: a prospective observational study. *Anaesthesia* 2018; **73**: 946-954.

23. Song IK, Kim EH, Lee JH, Ro S, Kim HS, Kim JT. Effects of an alveolar recruitment manoeuvre guided by lung ultrasound on anaesthesia-induced atelectasis in infants: a randomised, controlled trial. *Anaesthesia* 2017; **72**: 214-222.

24. Monastesse A, Girard F, Massicotte N, Chartrand-Lefebvre C, Girard M. Lung ultrasonography for the assessment of perioperative atelectasis: a pilot feasibility Study. *Anesthesia and Analgesia* 2017; **124**: 494-504.

25. Reeve J, Anderson L, Raslan Y, Grieve C, Ford J, Wilson L. The physiotherapy management of patients undergoing abdominal surgery: A survey of current practice. *New Zealand Journal of Physiotherapy* 2019; **47**: 66-75.

26. van Beijsterveld CA, Heldens AF, Bongers BC, van Meeteren NL. Variation in preoperative and postoperative physical therapist management of patients opting for elective abdominal surgery. *Physical Therapy* 2019; **99**: 1291-1303.

27. Urell C, Emtner M, Hedenstrom H, Tenling A, Breidenskog M, Westerdahl E. Deep breathing exercises with positive expiratory pressure at a higher rate improve oxygenation in the early period after cardiac surgery--a randomised controlled trial. *European Journal of Cardiothoracic Surgery* 2011; **40**: 162-167.

28. Eltorai AEM, Baird GL, Eltorai AS, et al. Effect of an incentive spirometer patient reminder after coronary artery bypass grafting: a randomized clinical trial. *JAMA Surgery* 2019; **154**: 579-588.

29. Ottosen J, Evans H. Pneumonia: challenges in the definition, diagnosis, and management of disease. *Surgery Clinics North America* 2014; **94**: 1305-1317.

30. Butler CC, Kelly MJ, Hood K, et al. Antibiotic prescribing for discoloured sputum in acute cough/lower respiratory tract infection. *European Respiratory Journal* 2011; **38**: 119-125.

31. Torres A, Ferrer M, Badia JR. Treatment guidelines and outcomes of hospital-acquired and ventilator-associated pneumonia. *Clinical Infectious Diseases* 2010; **51** Suppl 1:S48-53.

32. American Thoracic Society: Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *American Journal Respiratory Critical Care Medicine* 2005; **171**: 388-416.

33. Guitor AK, Wright GD. Antimicrobial resistance and respiratory infections. *Chest* 2018; **154**: 1202-1212.

34. Bojesen RD, Fitzgerald P, Munk-Madsen P, Eriksen JR, Kehlet H, Gögenur I. Hypoxaemia during recovery after surgery for colorectal cancer: a prospective observational study. *Anaesthesia*. 2019; **74**:1009-1017

35. Alazawi W, Pirmadjid N, Lahiri R, Bhattacharya S. Inflammatory and immune responses to surgery and their clinical impact. *Annals of Surgery* 2016; **264**: 73-80.

36. Xavier G, Melo-Silva CA, Santos CE, Amado VM. Accuracy of chest auscultation in detecting abnormal respiratory mechanics in the immediate postoperative period after cardiac surgery. *Jornal brasileiro de pneumologia : publicacao oficial da Sociedade Brasileira de Pneumologia e Tisilogial* 2019; **45**: e20180032.

37. Crompton JG, Crompton PD, Matzinger P. Does atelectasis cause fever after surgery? Putting a damper on dogma. *JAMA Surgery* 2019; **154** :375-376.

38. Koch CG, Li L, Hixson E, Tang A, Phillips S, Henderson JM. What are the real rates of postoperative complications: elucidating inconsistencies between administrative and clinical data sources. *Journal of American College of Surgeons* 2012; **214**: 798-805.

39. do Nascimento Junior P, Módolo NS, Andrade S, Guimarães MM, Braz LG, El Dib R. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. *Cochrane Database Syst Rev*. 2014; **2014**:CD006058.

40. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. *BMJ*. 2020; **368**: m540.

41. Hanekom SD, Brooks D, Denehy L, et al. Reaching consensus on the physiotherapeutic management of patients following upper abdominal surgery: a pragmatic approach to interpret equivocal evidence. *BMC Medical Informatics and Decision Making*. 2012; **12**: 5.

## 8.9 Secondary analysis appendix

**Box 1S** Postoperative pulmonary complication diagnostic criteria.

**Table 1S** Methodological instructions for collection of clinical criteria within the Melbourne Group Score postoperative pulmonary complication diagnostic tool.

**Table 2S** List of International Classification of Diseases (ICD-10) clinical codes extracted

**Figure 1S** Proportion of participants with positive clinical criteria on each postoperative day.

**Box 1S:** Postoperative pulmonary complication diagnostic criteria.

Diagnosis confirmed when **4 or more** of the following were present in a calendar day:

CLINICAL CRITERIA

1. New abnormal breath sounds on auscultation different to pre-operative assessment
2. Production of yellow or green sputum different to pre-operative assessment
3. $SpO_2$ <90% on room air, two episodes over two consecutive postoperative day
4. Maximum temperature >38$^{o}$C, two episodes over two consecutive postoperative day

DIAGNOSTIC CRITERIA

5. CXR/CT report of collapse/consolidation
6. An unexplained WCC greater than 11 x $10^9$/l
7. Presence of infection on sputum culture report

CLINICIAN RESPONSE CRITERION; either of below

8. a) Physician's diagnosis documentation in the medical record of pneumonia, URTI, LRTI, or respiratory problem, **OR,**
   b) Prescription of an antibiotic specific for a respiratory infection

Abbreviations: $SpO_2$=pulse oximetry oxygen saturation, CXR=chest x-ray, CT=computerised tomography, WCC=white cell count, URTI=upper respiratory tract infection, LRTI=lower respiratory tract infection

**Table 1S:** Methodological instructions for collection of clinical criteria within the Melbourne Group Score postoperative pulmonary complication diagnostic tool.

| | |
|---|---|
| Auscultation | Sit patient in upright position if possible. Auscultate all zones of the lungs, apical, basal, anterior, and posterior.<br>Record any of the following findings:<br>- Reduced air entry<br>- Bronchial breath sounds or rales<br>- Crackles or creps<br>- Any added sounds that are abnormal<br>If any of these sounds are worse than the preoperative record, record as positive. |
| Sputum change | Review medical record for any record of coloured sputum being coughed or suctioned since time of last assessment.<br>Question participant about any production of coloured sputum since last assessment and, if possible, visualise a sample.<br>If the participant is mechanically ventilated interrogate the colour of the last suctioned secretions.<br>Compared colour to documentation of preoperative findings using the standardised colour chart provided.<br><br>Any new yellow-green-brown sputum or change of colour from preoperative reports in each postoperative 24hrs (midnight to midnight), documented in the medical record or measured directly, is recorded as positive. |
| $SpO_2$ on room air | Review medical record for any desaturation events since time of last assessment. If medical record of desaturation in the time from last assessment to midnight of that day, record as a positive for that postoperative day.<br>For each daily assessment, sit patient in upright position if possible. Remove supplemental oxygen, or in ventilated patients reduce fraction of inspired oxygen ($FiO_2$) to 0.21.<br>Measure pulse oximetry oxygen saturation ($SpO_2$) continuously for two minutes.<br>If $SpO_2$ became less than 90% immediately reapply oxygen and monitor patient for another two minutes or until back to baseline $SpO_2$. If $SpO_2$ remains below baseline, contact site investigator and record as an adverse measurement event. Continue monitoring for a further 2 minutes. If remains <92% after this time contact Senior Nurse.<br><br>Any desaturation event in the 24hrs (midnight to midnight) either documented in the medical record or measured directly is recorded as positive. |
| Temperature | Review observation chart and medical record for any febrile events >38C since time of last assessment. If medical record of pyrexia in the time from last assessment to midnight of that day, record as a positive for that postoperative day. |

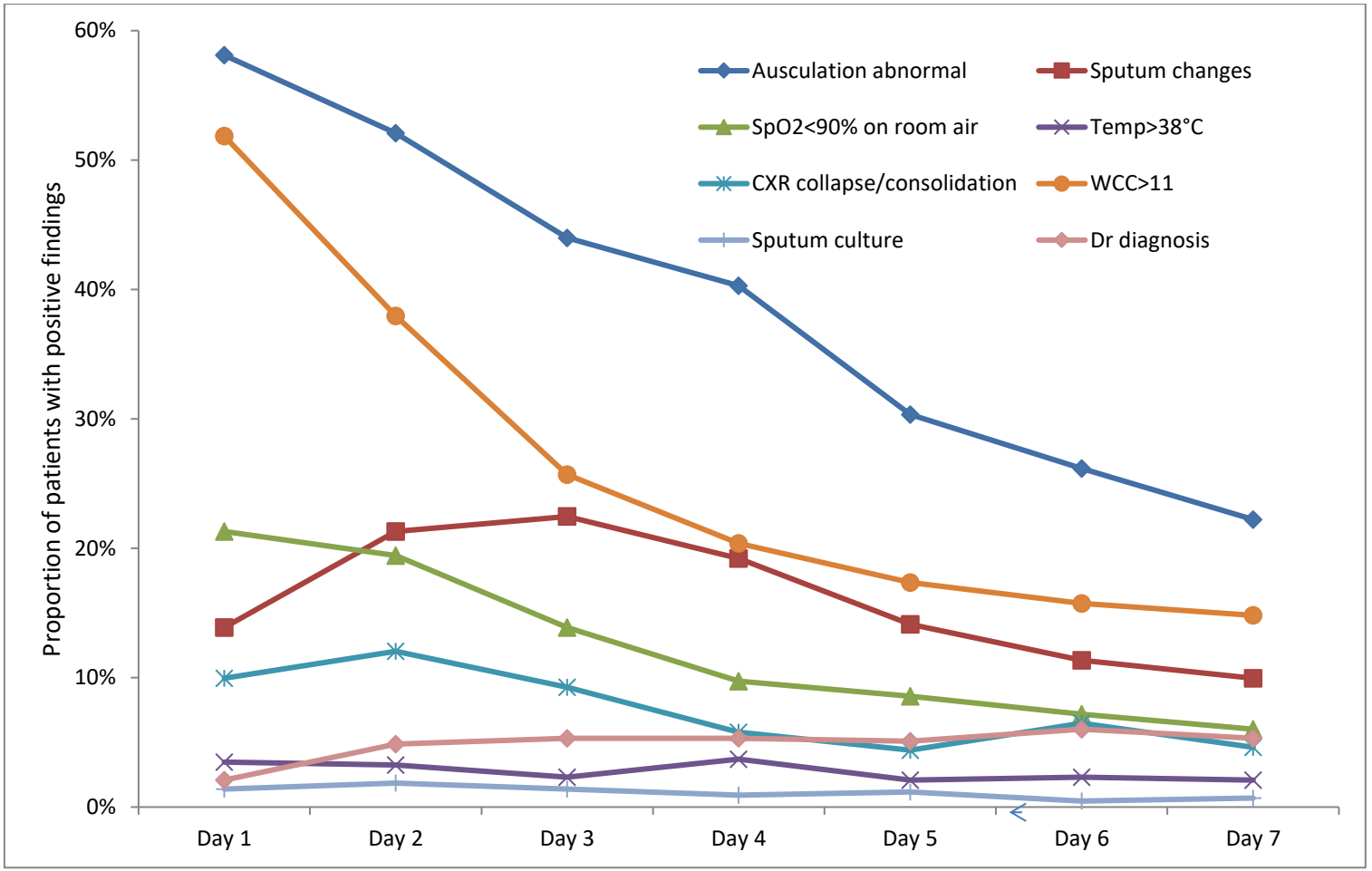
**Table 2S:** List of International Classification of Diseases (ICD-10) clinical codes extracted

| Code | | Description |
|---|---|---|
| A41.9 | | Sepsis, unspecified |
| | | |
| E86 | | Volume depletion |
| E87.7 | | Fluid overload |
| E87.0 | | Hyperosmolality and hypernatremia |
| E87.6 | | Hypokalemia |
| E87.7 | | Fluid overload |
| | | |
| F05.9 | | Delirium, unspecified |
| | | |
| I211.1 | | Acute transmural mycocardial infarction of inferior wall |
| I26.0 – I26.9 | + | Pulmonary embolism |
| I440 | | AV block |
| I46.0 | | Cardiac arrest with successful resusitation |
| I48.9 | | Atrial fibrillation and flutter, unspecified |
| I82.8 | | Embolism and thrombosis of other specified veins |
| | | |
| J00 – J06 | * | Acute upper respiratory infections, including pharyngitis, sinusitis, rhinitis, tonsillitis |
| J06 | * | Acute upper respiratory infections of multiple and unspecified sites |
| J06.9 | * | Acute upper respiratory infection, unspecified |
| J09 – J18 | * | Influenza and pneumonia |
| J20 – J22 | * | Other acute lower respiratory infections |
| J22 | * | Unspecified acute lower respiratory infection |
| J30 – J39 | * | Other diseases of upper respiratory tract including rhinitis, pharyngitis, nasal polyps, |
| J40 – J47 | | Chronic lower respiratory diseases |
| J44 | | Other chronic obstructive pulmonary disease |
| J44.0 | * | Chronic obstructive pulmonary disease with acute lower respiratory infection |
| J44.1 | * | Chronic obstructive pulmonary disease with acute exacerbation, unspecified |
| J60 – J70 | + | Lung diseases due to external agents |
| J69.0 | + | Pneumonitis due to food and vomit |
| J80 – J84 | + | Other respiratory diseases principally affecting the interstitium |
| J80 | + | Adult respiratory distress syndrome |
| J81 | + | Pulmonary oedema |
| J84.0 – J84.9 | + | Other interstitial pulmonary diseases |
| J90 – J94 | + | Other diseases of pleura |
| J90 | + | Pleural effusion, not elsewhere classified |
| J93 – J93.8 | + | Pneumothorax |
| J94 | + | Other pleural conditions |
| J95 | | Post procedural respiratory disorders, not elsewhere classified |
| J95.2 | + | Acute pulmonary insufficiency following nonthoracic surgery |
| J95.8 | + | Other post procedural respiratory disorders |
| J95.9 | + | Postprocedural respiratory disorder, unspecified |
| J96 | * | Respiratory failure, not elsewhere classified |
| J96.0 | * | Acute respiratory failure, type I |
| J96.1 | * | Acute respiratory failure, type II |
| J96.9 | * | Respiratory failure unspecified |
| J96.90 | * | Respiratory failure unspecified, type I |
| J96.09 | * | Acute respiratory failure, type unspecified |
| J96.99 | * | Respiratory failure unspecified, type unspecified |
| J98 | | Other respiratory disorders |
| J98.0 | * | Diseases of bronchus, not elsewhere classified |
| J98.1 | * | Pulmonary collapse |
| J98.8 | * | Other specified respiratory disorders |
| J99 | + | Respiratory disorders in diseases classified elsewhere |
| | | Includes rheumatoid lung disease and connective tissue disorders related lung disease |

| | | |
|---|---|---|
| K56.7 | | Ileus, unspecified |
| K59.0 | | Constipation |
| K91.3 | | Postprocedural intestinal obstruction |
| | | |
| L23.8 | | Decubitus ulcer and pressure area, unspecified |
| L89.1 | | Stage II decubitus ulcer and pressure area |
| | | |
| N17.9 | | Acute kidney failure |
| N39.0 | | Urinary tract infection, site not specified |
| | | |
| R00.0 – R00.8 | | Abnormalities of heart beat |
| R05 | + | Cough |
| R06 | + | Abnormalities of breathing |
| R06.0 | + | Dyspnoea |
| R06.8 | + | Other and unspecified abnormalities of breathing |
| R09.3 | * | Abnormal sputum |
| R09.89 | | Other specified symptoms and signs involving the respiratory system |
| R40-R46 | | Symptoms and signs involving cognition, perception, emotional state, and behaviour |
| R40.0 – R40.2 | | Somnolence, stupor, and coma |
| R41.0 | | Disorientation, unspecified |
| R44.0 – R44.8 | | Other symptoms and signs involving cognitive functions and awareness |
| R45.1 | | Restlessness and agitation |
| R44 | | Other symptoms and signs involving general sensations and perceptions including hallucinations |
| R53 | | Malaise and fatigue |
| R55 | | Syncope and collapse |
| R58 | | Haemorrhage, not elsewhere classified |
| R65.0 – R65.9 | | Systemic inflammatory response syndrome |
| | | |
| T81.0 | | Haemorrhage and haematoma complicating a procedure, not elsewhere classified |
| T81.2 | | Accidental puncture and laceration during a procedure, not elsewhere classified |
| T81.3 | | Disruption of operation wound, not elsewhere classified |
| T81.4 | | Infection following a procedure, not elsewhere classified |
| T81.41 | | Wound infection following a procedure |
| T857.8 | | Infection and inflammatory reaction due to other internal prosthetic devices, implants, and grafts |
| Other infection | | Cystitis N30.9, Candidiasis of skin and nail B37.2, cellulitis of upper limb L031.0 |
| Wound infection | | Candidal stomatitis B37.0 |

*codes classified as respiratory diagnoses related to pulmonary collapse or airway infection
+ codes classified as respiratory diagnoses not directly related to pulmonary collapse or airway infection

**Figure 1S:** Proportion of all trial participants with positive clinical criteria on each postoperative day.



# CHAPTER 9

# LIPPSMAck-POP: Health economic analysis

## 9.1 Author contributions

IB devised the idea for the paper. IB and IR contributed to the research design. IB and IR conducted the data analyses and interpretation. AN and AP reviewed the methodology, analyses and interpretations. IB wrote the first draft of the manuscript. All authors contributed to the revised manuscript and approved the final version of the manuscript prior to submission. IB managed the manuscript submission.

This study was supported by competitive research grants from the Clifford Craig Foundation, Launceston, Australia, the University of Tasmania (virtual Tasmanian Academic Health Science Precinct), Tasmania, Australia, and the Awhina Contestable Research Grant from the Waitemata District Health Board and Three Harbours Health Foundation, Auckland, New Zealand.

## 9.2 Accepted manuscript

This study has been submitted for publication to *Journal of Physiotherapy*, has been peer reviewed, and accepted for publication.

Boden I, Robertson IK, Neil A, Reeve J, Palmer A, Skinner EH, Browning L, Anderson L, Hill C, Story D, Denehy L. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis within a binational multicentre randomised controlled trial. *J Physiother*. 2020**:**

This chapter contains content which is substantially unchanged from the accepted manuscript.

## 9.3 Abstract

**Question:** Is preoperative physiotherapy cost-effective in reducing postoperative pulmonary complications (PPC) and improving quality adjusted life years (QALYs) after major abdominal surgery?

**Design:** Cost-effectiveness analysis from the hospitals' perspective within a binational, multicentre, blinded, randomised, placebo-controlled trial with concealed allocation and intention-to-treat analysis.

**Participants:** Four-hundred-and-forty-one adults awaiting elective upper abdominal surgery attending pre-anaesthetic clinics at three public hospitals in Australia and New Zealand.

**Interventions:** An information booklet (control) or an additional face-to-face 30-minute physiotherapy respiratory education and breathing exercise training session (intervention).

**Outcome measures:** The probability of cost-effectiveness and incremental net benefits were estimated using bootstrapped incremental PPC and QALY cost-effectiveness ratios plotted on cost-effectiveness planes and associated probability curves through a range of willingness-to-pay amounts. Cost-effectiveness modelling utilised 21-day postoperative hospital cost audit data and QALYs estimated from Short Form-Six Domain health utilities and mortality to 12 months.

**Results:** Preoperative physiotherapy had 95% probability of being cost-effective with an incremental net benefit to participating hospitals of $4,958 (95% CI $10 to $9,197) for each PPC prevented given the hospitals were willing-to-pay $45,000 to provide the service. Cost-utility for QALY gains were less certain. Sensitivity analyses strengthened cost-effectiveness findings. Improved cost-effectiveness and QALY gains were detected when experienced physiotherapists delivered the intervention.

**Conclusions:** Preoperative physiotherapy aimed at preventing PPCs was highly likely to be cost-effective from the hospitals' perspective. For each PPC prevented, preoperative physiotherapy is likely to cost the hospitals less than the costs estimated to treat a PPC after surgery. Potential QALY gains require confirmation.

**Trial registration:** ANZCTR-12613000664741.

## 9.4 Introduction

With 300-500 operations per 100,000 people annually, abdominal surgery is the most common major surgery type performed in developed countries with volumes increasing at 2-5% *per annum*[1-3]. Patients having surgery represent a quarter of hospital bed days, yet account for half of all hospital costs[4]. Existing large volumes, high costs, and increasing need for surgery suggest that methods to minimise hospital costs, whilst maintaining or enhancing service quality, are important to ensure long-term sustainability of hospital funding. Reducing postoperative complications could be one method. Complications after abdominal surgery are the principal driver for increased costs with higher expenditure on pharmaceutical needs, diagnostic testing, intensive care unit (ICU), and surgical ward length of stay (LOS)[5].

One of the most common complications after major abdominal surgery is a postoperative pulmonary complication (PPC)[5,6] with typologies ranging from mild atelectasis to severe hospital-acquired pneumonia and respiratory failure[6]. PPCs independently increase costs following major colorectal[7], upper gastrointestinal[8], and renal surgery[9]. Even mild PPCs are associated with increased hospital utilisation[6,10]. PPCs are strongly associated with poorer mortality[6-11] and health related quality of life (HRQoL)[12]. A recent multicentre randomised controlled trial[11], Lung Infection Prevention Post Surgery Major Abdominal with Pre-Operative Physiotherapy (LIPPSMAck-POP), replicated previous findings[13] confirming that a single preoperative physiotherapy education and training session halves PPC incidence with a number needed to treat of seven. Patients place a high priority on preventing pneumonia after surgery, value preoperative physiotherapy, and prefer individual face-to-face sessions[14]. Yet despite strong effectiveness[11,13], patient preference[14], and international consensus that preventing PPC should be a key feature of perioperative care[6], preoperative physiotherapy is seldom provided[15,16]. Uncertainty surrounding the economic cost/benefit of preoperative physiotherapy may be preventing the implementation of this highly efficacious patient-centred intervention.

This planned within-trial health economic analysis aimed to answer; compared to providing an information booklet; is preoperative physiotherapy cost-effective in reducing PPC and improving quality adjusted life years (QALYs) after major abdominal surgery?

## 9.5 Methods

### Design

This planned health economic evaluation was conducted within a multicentre parallel-group, double-blinded, pragmatic, randomised controlled trial involving three diverse (rural, regional and metropolitan) government-funded hospitals in Australia and New Zealand[11] and reported in accordance with Consolidated Health Economic Evaluation Reporting Standards[17] (see eAddenda Appendix 1).

Detailed design and methodology descriptions are available[11,18] and briefly outlined here. Participants were randomly assigned via sealed opaque envelopes. Independent audit confirmed appropriate randomisation[11]. Participants, outcome assessors, postoperative physiotherapists, doctors, nurses, hospital administrators, and statisticians were unaware of group assignment. Participant masking was successfully achieved[11].

### Participants

Eligible patients were English speaking adults (≥ 18years) attending a pre-anaesthetic assessment clinic within six-weeks of elective major abdominal surgery. Immobile patients and those having organ transplantation or hernia repair were excluded. Detailed participant characteristics have been published[11]. Median age was 66 (interquartile range 47–85), proportionally more were male (61%), having surgery for cancer (69%) requiring major colorectal (49%), urological (26%), or upper gastrointestinal/hepatobiliary procedures (24%). Operations were generally longer than two hours (64%) via upper midline (49%) or subcostal (18%) incisions.

### Interventions

At the pre-anaesthetic clinic all participants were seen by a physiotherapist for a 30 minute standardised assessment of social, functional, and respiratory status and provided with a booklet containing information about postoperative pneumonia risk and prevention with early ambulation and breathing exercises. Control participants received no further information or training from the physiotherapist.

Intervention participants received an additional one-on-one 30 minute physiotherapy education and training session about the effect of anaesthesia and surgery on mucociliary clearance, lung volumes, and the consequences of bacterial stagnation in the lungs. They were educated that self-directed postoperative deep breathing and coughing exercises were vital to reduce the risk of pneumonia after surgery and directed to commence these immediately upon regaining consciousness and to perform 30 repetitions hourly until fully ambulant.

Preoperative interventions were delivered by physiotherapists with experience ranging from new graduates through to over 10 years practicing in acute care and surgery ward settings. Postoperative early ambulation was standardised and no additional prophylactic respiratory physiotherapy was provided.

**Outcome measures**

The cost-effectiveness of preoperative physiotherapy to prevent PPC and improve QALYs after major abdominal surgery was assessed using an incremental cost/utility analysis conducted from the hospital perspective as payer of the service. Incremental cost-effectiveness ratios were determined by dividing the difference between the intervention and control groups in net mean hospital costs per participant by the differences in PPC rates 14 days after surgery and QALYs 12 months from surgery.

*Cost-effectiveness model inputs: Net 21-day hospital costs*

Hospital costs for each treatment comprised the costs of providing preoperative physiotherapy protocol and the costs of hospital resource use in the first 21 days after surgery.

Preoperative physiotherapy costs were estimated using salary rates in 2018 Australian dollars individualised to the experience level of each treating physiotherapist and costed to the maximum level within band (see eAddenda, Appendix 2). Overheads of 25% were added (e.g. superannuation, professional development, training, administration, backfill). New Zealand dollars were converted to Australian dollars using December 2018 exchange rates. Costings were based on control participants receiving a 30-minute physiotherapy session and intervention participants receiving 60 minutes. Booklet costs and clinic room hire was added (see eAddenda, Appendix 2). Administration costs to process referrals or coordinate bookings were not incorporated, as all participants attended an established clinic with existing infrastructure.

Postoperative downstream hospital costs were estimated using a detailed patient-level costings model. Units of hospital activity were counted prospectively and daily by blinded trial assessors using the written and electronic medical record until 21 days after surgery or hospital discharge, whichever occurred first. Hospital activity included bed days and location (ICU, surgical ward, or residential rehabilitation), mechanical and non-invasive ventilation hours, antibiotic prescriptions, modes and days of oxygen therapy, number and type of imaging and pathology tests, and medical consultations outside standard rounds. These items of hospital activity were chosen as their consumption is associated with PPC[5-11]. Duration of hospital stay was cross validated using hospital databases. Tariffs for items of hospital activity were derived from Australian healthcare authorities (see eAddenda, Appendix 2) and converted to 2018 Australian

dollars using consumer price indices 2013 to 2018 as listed by the Australian Bureau of Statistics. Discounting of costs was not necessary as follow up was within 12 months[17].

*Cost-effectiveness model inputs: Quality adjusted life years*

QALYs were estimated using health utilities converted from HRQoL measures assessed with the Short-Form 36-item questionnaire (SF-36), a valid and responsive patient-reported outcome after abdominal surgery[19]. HRQoL data acquisition started from the 79th participant following receipt of funding for research assistant activities. Baseline responses were measured at the preoperative clinic within six weeks of surgery then repeated by phone with a masked assessor at six to eight weeks post-surgery. Postoperatively, if patients were unable to be contacted, a standardised letter, the questionnaire, and self-addressed return paid envelope were posted. Forms not returned within two-weeks were considered lost to follow up. Acquired SF-36 scores were converted to SF-six domains (SF-6D) health utilities using commercially available software (licensing.sheffield.ac.uk/i/software) providing values from 0 (death) to 1 (full health)[20]. The SF-6D is valid and reliable for estimating health utilities after abdominal surgery[21].

The typical trajectory of HRQoL after major elective colorectal and upper gastrointestinal surgery is of an immediate postoperative deterioration with a return to baseline HRQoL at two to six months and remaining stable within presurgery HRQoL levels to at least one year after surgery[21-25]. Therefore, baseline preoperative HRQoL scores were used to estimate each participant's 12 month health utility values as an alternative to reassessing HRQoL at 12 months directly from participants[26]. QALYs were calculated by multiplying the reported health utility state by the number of weeks spent in this health state (see eAddenda, Appendix 3 for detailed descriptions of QALY calculations). For participants who died, QALY estimates were censored to this date[26]. Two time periods were calculated using the linear change area-under-the curve method[26]: baseline to six weeks (direct value) and six weeks to one year (estimated value). These values were summed to obtain 12-month QALYs. Maximum QALY for this study is 1, representing full health over the entire year.

*Cost-effectiveness*

A cost-effectiveness analysis considers the additional cost of a new intervention relative to the improvement in outcomes gained when compared to providing usual care or an alternative intervention. This incremental cost-effectiveness ratio is calculated by dividing the net cost difference between-groups by the differences in treatment effects (e.g. $\triangle$costs between groups / $\triangle$absolute risk reduction in PPC)[27, 28].

To manage fundamental heterogeneity in hospital costs, health utilities, and reduced statistical power regarding secondary outcomes, bootstrapping statistical techniques are considered essential in estimating cost-effectiveness within randomised controlled trials[27, 28]. All simulated bootstrapped cost-effectiveness ratios are then graphed on a cost-effectiveness plane (figure 1a). The cost-effectiveness plane has four quadrants. The quadrant in which the cost-effectiveness ratios predominantly fall in contributes to the decision by the purchaser of the intervention on whether or not it is cost-effective and provides value for money. Interventions where all cost-effectiveness ratios fall into the southeast quadrant (i.e. net cost savings and improved outcomes compared to an alternative treatment or control) are always considered cost-effective[28]. However, hospital resource cost accounting has high variance resulting in low statistical power and lack of precision in estimating the true cost differences between interventions. Consequently, cost-effectiveness ratios of an intervention may be scattered across a number of quadrants. This reflects the statistical possibility that in some circumstances the intervention could be more effective yet comes at a greater net cost than usual care/control (northeast quadrant).

Additional costs required by a hospital to fund a new treatment can be considered worthwhile if the improvement in clinical outcome is valued enough to pay more for[27]. This is known as the willingness-to-pay amount[29]. Willingness-to-pay is an arbitrary figure regarded by the payer (e.g. self-funded patient, hospital, or government) as the amount of money considered worthwhile to pay for each unit of improvement in a desired outcome. For example, 1,000 surveyed Australians were willing-to-pay $82,000 (95% CI $77,000 to $88,000; 2007 data adjusted to 2018 Australian dollars) from their own funds for a hypothetical treatment if it improved their QALYs[30]. From an Australian government perspective, although there is no explicit willingness-to-pay threshold currently stated, all new medications approved for public funding cost less than $75,000 per QALY gain (2003 data adjusted to 2018 Australian dollars)[31].

Whereas the literature discussing willingness-to-pay for QALY improvements is extensive, there is no published opinion available on what is considered a reasonable amount by a hospital to spend on PPC prevention. For the specific purposes of estimating the cost-effectiveness of preoperative physiotherapy in this trial it is hypothesised that a hospital would be willing-to-pay for a service to prevent PPC as long as it costs less than the treatment costs of a PPC. The additional cost burden independently attributed to PPCs in a 2008 study involving 46,000 major colorectal surgery patients across 600 US hospitals was $45,000 (2008 US dollars adjusted to 2018 Australian dollars)[7]. This is currently the most methodologically robust assessment of additional hospital costs directly attributable to PPCs.

Due to the statistical chance of a new intervention costing more than usual care and the lack of certainty surrounding a hospital's willingness-to-pay to prevent PPC or improve QALYs, cost-effectiveness is best determined using a cost-effectiveness acceptability curve[28]. This method provides the probability of an intervention being cost-effective over a range of willingness-to-pay amounts. The threshold on how much money is worthwhile spending on improving a clinical outcome will vary from hospital to hospital depending on the value placed on improving the target outcome and the extensive heterogeneity in the processes for funding new services. A cost-effectiveness acceptability curve provides information to the decision maker to guide this choice.

Due to the uncertainty surrounding an agreed willingness-to-pay for PPC, the return on investment for a hospital paying for a preoperative physiotherapy service was calculated as an alternative measure of cost-effectiveness (net Δ cost between groups / cost of intervention). In circumstances where the mean incremental cost-effectiveness ratio indicates improved outcomes with cost savings, the incremental net benefit[32] to the hospital was also calculated (incremental net benefit = (willingness-to-pay x Δ treatment effects) – Δ costs between groups). A higher value equals greater cost-effectiveness.

**Data analysis**

This study was primarily powered to detect a treatment effect on PPC[11, 18]. For this health economic analysis bootstrapping methods were employed to manage the inherently limited power to detect significant differences in secondary outcomes, including costs and QALYs. To manage missing HRQoL data, characteristics of participants with complete data were compared to those with missing data. Fully conditional specification and predictive mean matching were used to make multiple imputations with chain equations, assuming data were missed at random[33], and adjusted for baseline utility to account for regression to the mean[34].

Costs of hospital activity for individual items and the aggregate total were compared between-groups using adjusted mixed-effects linear regression analyses with logarithmic transformation of skewed data. Within- and between-group differences for HRQoL, health utility, and QALYs were analysed using adjusted repeated measures mixed-effects linear regression. All outcomes were assessed by intention-to-treat. Bootstrapping of 5,000 paired incremental cost-effectiveness ratio estimates were performed and graphed on a cost-effectiveness plane and mean differences and confidence intervals calculated.

Exploratory sub-group analyses were conducted by considering effects and costs separately in participants seen by experienced physiotherapists (≥10 years) or less-experienced physiotherapists. This was to analyse if the possible benefit of improved PPCs and mortality

reduction detected when preoperative education was delivered by an experienced physiotherapist[11] is outweighed by the increased costs of employing a more experienced clinician.

Two sensitivity analyses were conducted. Cost-effectiveness analyses involve several assumptions and value judgements in constructing models for determining hospital costs and QALYs. Sensitivity analyses consider the stability of health economic findings by assessing the variation in results when areas of uncertainty are changed. This provides confidence in the primary findings or suggest areas requiring further research[17,27]. Firstly, government hospital episode-of-care costs were used to compare groups. These costs were independently generated by hospital administrators and incorporate all direct (e.g. theatre time, personnel, equipment, medications) and ancillary costs (e.g. cleaning, catering, building overheads) for the whole hospital episode-of-care from admission to hospital discharge. This is the primary process of hospital cost accounting in Australia[35]. Secondly, only health utilities where a full set of preoperative and postoperative HRQoL data were collected directly from a patient, were considered to calculate QALYs.

All outcomes, including costs and HRQoL, were adjusted for imbalances in age, respiratory comorbidity, and surgical category detected at baseline[11]. Analyses[a] were conducted by the trial's statistician. Methodology, data, results, and interpretation was validated by two independent health economists.

## 9.6 Results

*Flow of participants*

From June 2013 to August 2015, 504 patients were eligible for inclusion with 441 (88%) randomly assigned; 219 received the information booklet and 222 received preoperative physiotherapy[11]. Nine (2%) participants were withdrawn. Data for PPC, mortality, and hospital costs was available for all 432 participants. Baseline characteristics of the cohort and treatment effects for PPC and mortality are published previously[11]. The flow diagram of HRQoL data acquisition is shown in Appendix 4 eAddenda. Preoperative HRQoL was obtained in 315 participants (73%). Missing preoperative HRQoL was proportionally higher in the experienced physiotherapist sub-group (Table 1, eAddenda) as HRQoL acquisition did not start until the 79$^{th}$ participant when only experienced physiotherapists were actively recruiting. There was a 69% (217/315) follow-up rate six weeks after surgery. Follow-up was similar between groups (114/160 (71%) intervention group; 103/155 (66%) control group) and between sub-groups. Participants who acquired a postoperative complication or had an extended hospital stay were more likely to have missing six-week postoperative HRQoL data (Table 1, eAddenda).

*Cost-effectiveness model inputs: 21-day hospital costs*

Across the whole cohort primary cost contributors for the first 21 postoperative hospital days were surgical ward (64%), ICU bed days (19%), and diagnostic testing and imaging (7%) as shown in Table 2. The cost of the intervention inclusive of salary, overheads, room hire, and consumables was an additional $52 (95% CI $51 to 53) per participant compared to control group participants, or $27 (95% CI $26 to $28) when using available clinic rooms. Following surgery, intervention participants consistently tended to consume fewer postoperative hospital resources across all assessed items compared to control participants (Table 2). Individual items with a 95% confidence interval estimate closest to statistically significant cost saving were usage of oxygen therapy, sputum cultures, blood cultures, and antibiotics prescribed for respiratory complications. The difference between-groups in adjusted total 21-day hospital costs was $458 saved (95% CI -$4,490 costs to $4,697 saved) favouring the intervention group. This mean estimate of net savings provides a return on investment of approximately 800% ($8 saved by the hospital for every $1 spent on physiotherapy to provide education and breathing exercise training to patients before surgery) although considering the wide confidence intervals the precision of this single-trial estimate is low.

*Cost-effectiveness model inputs: Quality adjusted life years*

Adjusted within- and between-group HRQoL are reported in Table 3 (eAddenda). Six weeks following surgery, physical domains had declined up to 30% in both groups, whilst emotional and mental health domains were unaffected. No differences were detected between-groups in HRQoL at six-weeks or QALYs at 12-months (mean difference, 0.020; 95% CI -0.008 to 0.045).

**Table 2:** Net 21-day hospital costs and effects of preoperative physiotherapy versus standard care

| | | Whole cohort n=432 | | Intervention n=218 | | Control n=214 | | Difference between-groups Intervention minus control | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Costs/unit of use | Mean (SD) units | Mean (SD) costs | Mean (SD) units | Mean (SD) costs | Mean (SD) units | Mean (SD) costs | Mean (95% CI) | p value |
| **Costs** | | | | | | | | | |
| Preoperative physiotherapy | | | | | | | | | |
| Physiotherapist salary | $45-55/hr | 0.75 (0.25) | $41 (17) | 1 (0) | $52 (10) | 0.5 (0) | $25 (1) | $27 ($26 to $28) | <.0001 |
| Room hire | $50/hr | 0.75 (0.25) | $38 (13) | 1 (0) | $50 (0) | 0.5 (0) | $25 (0) | $25 ($25 to $25) | <.0001 |
| Booklet | $5/booklet | 1 (0) | $5 (0) | 1 (0) | $5 (0) | 1 (0) | $5 (0) | $0 ($0 to $0) | 1.0 |
| Hospital ward use | | | | | | | | | |
| ICU/HDU stay | $3000/day | 1.4 (2.8) | $4,188 (8,438) | 1.3 (2.9) | $3,867 (8,633) | 1.5 (2.7) | $4,514 (8,242) | -$647 (-$2,244 to $950) | 0.43 |
| Surgical ward stay | $1500/day | 9.5 (8.5) | $14,153 (12,710) | 9.2 (8.5) | $13,728 (12,774) | 9.7 (8.4) | $14,586 (12,554) | -$858 (-$3,254 to $1,538) | 0.55 |
| Sub-acute stay | $800/day | 1.0 (5.4) | $779 (4,292) | 0.82 (4.5) | $659 (3,630) | 1.1 (6.1) | $902 (4,879) | -$243 (-$1,055 to $569) | 0.55 |
| Ventilation support | | | | | | | | | |
| Mechanical ventilation | $1500/day | 0.25 (1.4) | $377 (2,057) | 0.22 (1.2) | $330 (1,727) | 0.28 (1.6) | $425 (2,349) | -$95 (-$484 to $294) | 0.63 |
| Non-invasive ventilation | $500/day | 0.04 (0.3) | $21 (143) | 0.04 (0.3) | $18 (135) | 0.05 (0.3) | $23 (151) | -$5 (-$32 to $22) | 0.72 |
| High-flow oxygen | $100/day | 0.18 (0.9) | $36 (130) | 0.16 (0.9) | $33 (124) | 0.20 (1.0) | $40 (136) | -$7 (-$32 to $18) | 0.54 |
| Standard oxygen | $20/day | 3.0 (2.8) | $60 (57) | 2.8 (2.7) | $56 (53) | 3.2 (3.0) | $65 (60) | -$9 (-$20 to $2) | 0.11 |
| Imaging and pathology | | | | | | | | | |
| Sputum cultures | $50/test | 0.3 (0.8) | $14 (40) | 0.22 (0.6) | $11 (32) | 0.33 (0.9) | $17 (47) | -$6 (-$14 to $2) | 0.13 |
| Blood cultures | $50/test | 0.3 (1.1) | $17 (55) | 0.25 (0.9) | $12 (46) | 0.42 (1.3) | $21 (63) | -$9 (-$19 to $1) | 0.11 |
| All other pathology | $30/test | 40.4 (55.5) | $1,213 (1,666) | 38.0 (58.3) | $1,139 (1749) | 43.0 (52.6) | $1,289 (1578) | -$150 (-$465 to $165) | 0.35 |
| Chest X-rays | $70/test | 2.0 (3.2) | $142 (231) | 1.8 (2.8) | $129 (214) | 2.2 (3.5) | $155 (247) | -$26 (-$70 to $18) | 0.24 |
| Chest CT's | $450/test | 0.1 (0.4) | $42 (162) | 0.07 (0.3) | $31 (122) | 0.12 (0.4) | $53 (195) | -$22 (-$53 to $9) | 0.17 |
| All other imaging | $100/test | 1.1 (2.8) | $110 (278) | 1.0 (3.2) | $104 (326) | 1.2 (2.2) | $116 (219) | -$12 (-$65 to $41) | 0.63 |
| Antibiotics | | | | | | | | | |
| Respiratory indication | $100/day | 1.2 (3.0) | $121 (297) | 0.94 (2.8) | $94 (286) | 1.5 (3.1) | $149 (309) | -$55 (-$111 to $1) | 0.05 |
| All other indications | $100/day | 2.9 (4.4) | $169 (311) | 1.8 (3.4) | $181 (335) | 1.6 (2.8) | $156 (285) | $25 (-$40 to $84) | 0.42 |
| Medical visits | | | | | | | | | |
| Out of round visits | $300/visit | 1.9 (2.8) | $573 (854) | 1.8 (2.7) | $544 (817) | 2.0 (3.0) | $603 (891) | -$59 (-$221 to $103) | 0.43 |
| MET calls | $1000/call | 0.12 (0.5) | $116 (493) | 0.11 (0.5) | $106 (473) | 0.13 (0.5) | $127 (513) | -$21 (-$114 to $72) | 0.55 |
| **Total net 21-day costs**- unadjusted | | | $22,201 (24,142) | | $21,143 (24,290) | | $23,282 (23,998) | -$2,139 (-$6,706 to $2,428) | 0.19 |
| Targeted costs model – adjusted* | | | | | $21,867 (24,455) | | $22,325 (21,724) | -$458 (-$4,697 to $4,490) | 0.42 |
| Sensitivity analysis – whole episode-of-care costs* | | | $31,829 (26,845) | | $30,900 (25,165) | | $32,767 (28,469) | -$1,867 (-$6,946 to $3,212) | 0.47 |
| **Effects** | | | | | | | | | |
| Pulmonary complications* | | | | | 27 (12%) | | 58 (27%) | -10% (-14% to -5%) | 0.001 |
| 12-month mortality* | | | | | 16 (7%) | | 23 (11%) | -1.6% (-4.5% to 3.7%) | 0.46 |
| QALY, imputed data set - unadjusted | | | | | 0.671 (0.19) | | 0.642 (0.19) | 0.029 (0.002 to 0.055) | 0.015 |
| QALY, imputed data set - adjusted*+ | | | | | 0.667 (0.19) | | 0.647 (0.19) | 0.020 (-0.008 to 0.045) | 0.08 |
| Sensitivity analysis - QALY complete cases only*+ | | | | | 0.656 (0.22) | | 0.659 (0.20) | -0.003 (-0.05 to 0.04) | 0.89 |

All costs are in 2018 Australian dollars. Raw unadjusted cost data are mean (SD) and mean difference (95% confidence interval) with p-values estimated using mixed effects linear regression.
*Adjusted for age, respiratory comorbidity, surgical category using multiple regression and Poisson regression.
+Adjusted for baseline utility.
ICU=intensive care unit, HDU=high dependency unit, CT=computerised tomography, MET=medical emergency team, QALY=quality adjusted life year

**Figure 1 a) and b).** Cost-effectiveness plot and cost-effectiveness acceptability curve of preoperative physiotherapy versus information booklet to reduce postoperative pulmonary complications

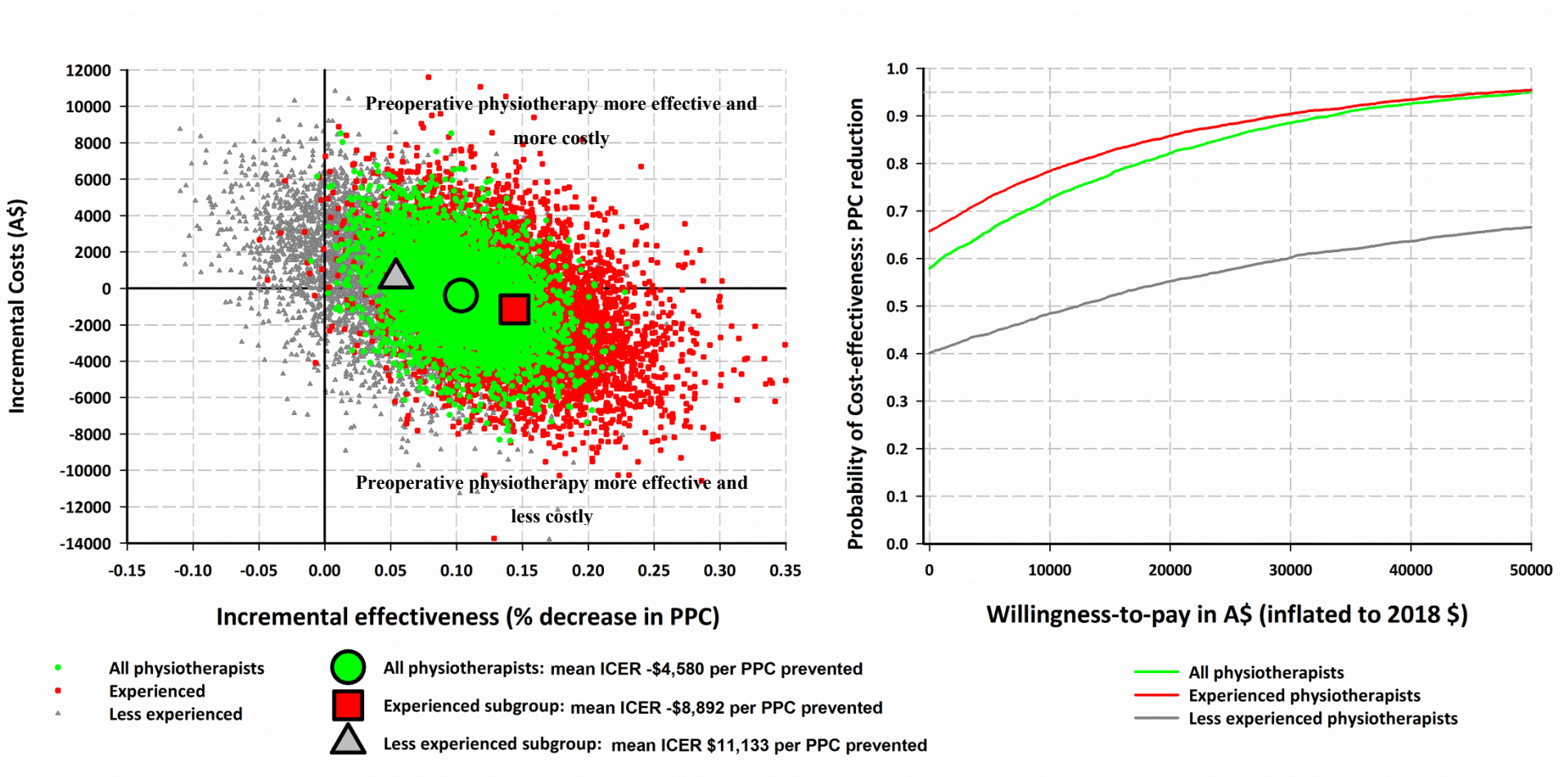
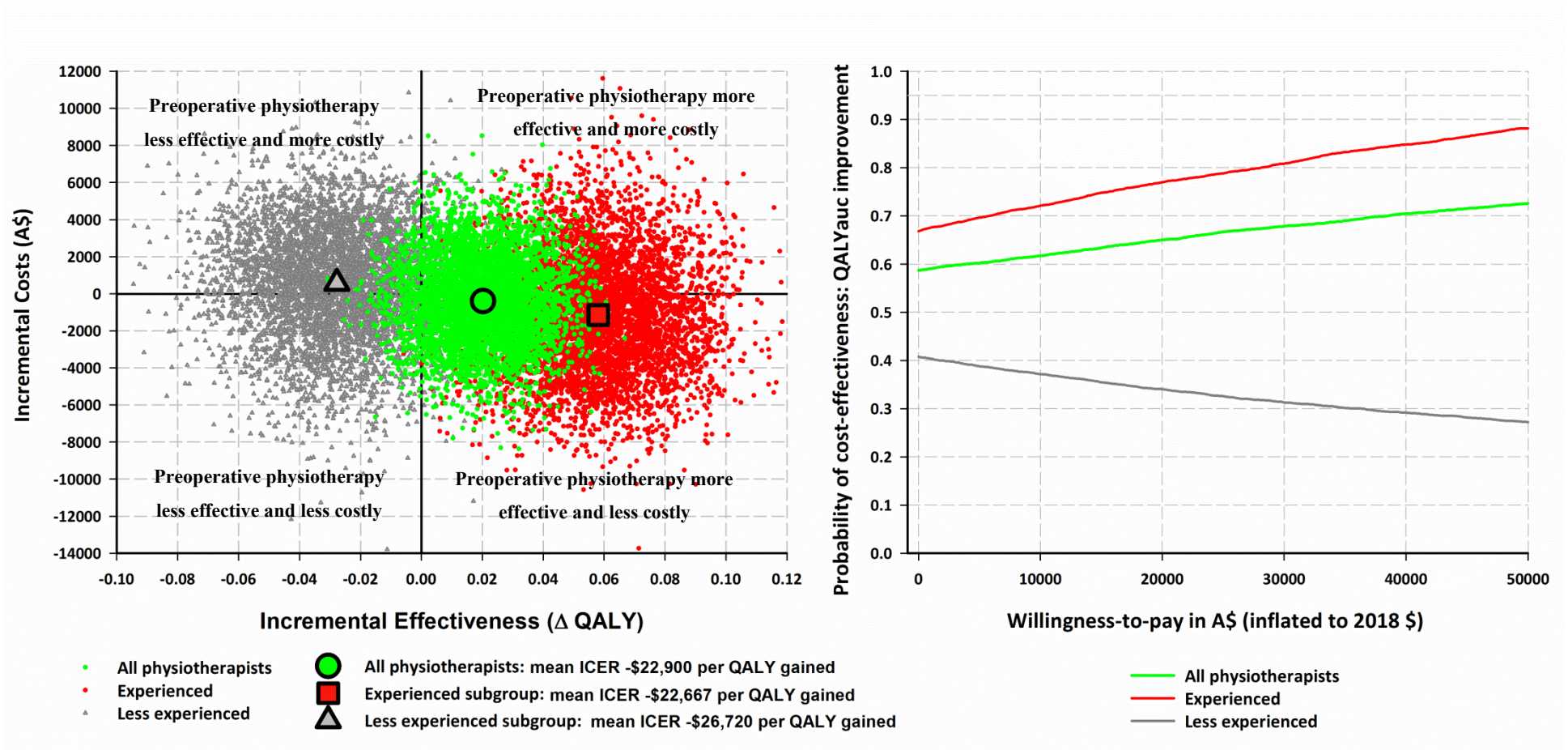


**Figure 2 a) and b)**. Cost-utility plot and cost-effectiveness acceptability curve of preoperative physiotherapy versus information booklet to improve quality adjusted life years



*Cost-effectiveness for PPC reduction*

As previously reported[11], preoperative physiotherapy halved PPC incidence (27% v 13%, adjusted hazard ratio 0.48, 95% 0.30 to 0.75). A large proportion of incremental cost effectiveness ratios fall in the south-east quadrant of the cost-effectiveness graph (Figure 1a) giving a 60% probability that the preoperative intervention was at least cost-neutral or cost-saving to the hospitals (Figure 1b). At a willingness-to-pay of $45,000 (the estimated additional cost to the hospital to treat patients with PPC[7]) preoperative physiotherapy had a 95% probability of being cost-effective to prevent PPC giving an incremental net benefit to the hospitals of $4,958 saved (95% CI $10 to $9,197, Figure 1b). At a lower willingness-to-pay of $18,000 there was an 80% probability of cost-effectiveness See Appendix 5 in eAddenda for graphed incremental net benefits for willingness-to-pay amounts from $0 to $60,000.

*Cost-utility for QALY improvement*

Bootstrapped estimates indicated that preoperative physiotherapy was likely to improve QALYs 12-months from surgery, however due to the spread of incremental cost-effectiveness ratios across both the south-east and north-east quadrants (Figure 2a), there is uncertainty if this comes at an additional cost, or is cost saving, to the hospital. Given a willingness-to-pay of $50,000 per one QALY gain, preoperative physiotherapy had 73% probability of being considered value for money (Figure 2b) with an incremental net benefit favouring the intervention group of $1,458 (95% CI -$3,490 to $5,697).

*Sub-group analyses*

Within the experienced physiotherapist sub-group (see Table 4 eAddenda) the mean adjusted hospital cost savings favouring the intervention were stronger ($1,156 saving per participant, 95% CI $5,300 costs to $6,937 savings) with an 80% probability of cost-effectiveness at a willingness-to-pay of $10,000 (Figure 2b). Large significant 12-month QALY gains were also detected in the intervention group treated by more experienced physiotherapists (adjusted mean difference 0.051, 95% CI 0.015 to 0.088, p=0.01) with a 90% probability of improving QALYs within a willingness-to-pay of $50,000 (figure 2a & b).

*Sensitivity analyses*

Government episode-of-care costings were $31,829 (SD $26,845) per participant with the adjusted between-group cost differences favouring the intervention group more strongly than the targeted costing model (Table 2). Preoperative physiotherapy was 95% certain of being cost-effective in preventing PPC at a willingness-to-pay $45,000 giving an incremental net benefit to hospitals of $6,367 (95% CI $1,288 to $11,446). When QALYs were calculated using health

utilities from complete cases only, cost-utility was reduced giving an incremental net benefit of $308 (95% CI -$4,640 to $4,547) per QALY gained.

## 9.7 Discussion

A PPC is a high-cost postoperative complication with severe negative consequences to patients and hospitals[4-10]. A PPC is more than 15 times more common than a cardiac complication, has similar effects on in-hospital mortality, and is responsible for more than doubling the baseline cost of abdominal surgery costing a hospital approximately $45,000 to treat[7]. Large randomised controlled trials find that a single preoperative physiotherapy education and training session reduces PPC incidence by between 25% to 75%[11,13]. This within-trial health economic analysis finds that when accounting for the cost of introducing the service there is a 60% likelihood that preoperative physiotherapy would lead to an overall cost-saving to the hospital through reductions in downstream hospital resource use. In circumstances where a net cost may be incurred to provide preoperative physiotherapy to prevent PPCs, it is reasonable to consider that hospitals would be willing-to-pay for this as long as it costs less than treating a PPC. This trial finds that if a hospital is willing-to-pay $18,000 to prevent one PPC, less than half the cost of a PPC, preoperative physiotherapy is 80% likely to be cost-effective.

Respiratory physiotherapy has been associated with reduced hospital LOS[36], antibiotic usage[36], and reintubation rates[37], through the reduction in PPC risk after major abdominal surgery. However, this is the first multicentre randomised controlled trial with a detailed audit of hospital resource use and a thorough health economic analysis. A consistent signal of reduced costs of downstream hospital resource use was found in intervention participants with an estimated return on investment of $8 saved postoperatively for every $1 spent on preoperative physiotherapy. Given the inevitable wide confidence intervals in a cost-benefit analysis based on a single trial, the level of precision around this estimate is low. A recent pre-habilitation trial that halved postoperative complication rates following high risk major abdominal surgery[38] reported wide variance in costing data and a non-significant difference in postoperative hospital costs favouring the intervention group ($536 net saving, 95% CI -$1,626 to $3,113; costs converted to Australian dollars at 2018 exchange rates)[39]. Randomised controlled trials rarely have large enough sample sizes to overcome the wide variance in patient-level resource use and costs and are generally unable to detect primary significance in cost measures. A cost-benefit analysis (simple comparison in net costs between a new intervention and usual care/control) not only requires exceptionally large clinical trials to definitely prove a fiscal benefit from a new intervention, but

also does not incorporate societal or consumer beliefs on the value of incurring additional costs for improved benefits[27].

A cost-effectiveness analysis considers the relative relationship between treatment costs and how effective the treatment is in improving the desired outcome. This value is then placed in the context of how much a consumer would be prepared to pay in order to gain an improvement in the desired outcome. For this trial most cost-effectiveness ratios fell in the south-east quadrant of the cost-effectiveness plane indicating an overall mean cost saving to hospitals and reduced risk of PPC for patients when compared to usual care. The probability that preoperative physiotherapy is cost-neutral or entirely cost-saving to the hospitals was 60% (Figure 1b). However, due to the very wide standard deviations in hospital costings, the statistical chance of preoperative physiotherapy costing the hospital more than is saved in downstream ward costs cannot be discounted. If the benefit gained in reducing PPC incidence and improving QALYs after major surgery are important to a hospital they may be willing-to-pay to instigate a preoperative physiotherapy service to achieve this. Within this trial there was only a 5% chance that the preoperative physiotherapy service cost the hospitals more to prevent one PPC than the estimated $45,000 it costs to treat a PPC. The chance of a preoperative physiotherapy service being cost-effective to prevent PPC at a reasonable cost is 95% certain. The consistent signal of individual hospital activity savings favouring the intervention group and independent hospital episode-of-care costings demonstrating a stronger reduction in costs strengthens the likelihood that preoperative physiotherapy truly reduces downstream hospital costs and constitutes a dominant strategy in preventing PPC.

Improved value for money appears to be gained by hospitals if experienced physiotherapists provide the intervention with greater PPC reductions[11], reduced postoperative mortality[11], large significant QALY gains, and a stronger signal towards reducing downstream hospital costs. Even when accounting for the additional costs of employing a more experienced physiotherapist, the probability of cost-effectiveness was 80% certain at willingness-to-pay less than a quarter of the estimated cost of treating a PPC[7] with a possible return on investment is in the order of 1800% ($18 saved for every $1 spent on an experienced physiotherapist). Further research is required to confirm these experiential effects, to determine what qualities and attributes regarding treatment from an experienced practitioner may make it more effective, and if these factors are trainable in others.

Although the probability of cost-effectiveness for preoperative physiotherapy to prevent PPC is strong, there is less certainty surrounding its ability to improve HRQoL and QALYs at a

reasonable cost. Sensitivity analysis of complete QALY data indicated fragility around the result. There are some limitations to the trial that could explain this. HRQoL data acquisition started after a fifth of all patients had been recruited. This incomplete baseline data set and a 31% missing six week follow-up rate led to imputed measures comprising 50% of all health utility results. As a consequence the trial's HRQoL estimates have inherent uncertainty and may not truly represent the whole population. Countering this concern, the large declines detected in HRQoL physical domains but not mental health domains within two months of surgery are congruent with other studies[12, 39].

Patients who develop postoperative complications tend to have poorer HRQoL compared to patients without complications[12]. An intervention that halves PPC after major abdominal surgery could benefit HRQoL trajectory at six weeks. This was not detected in this trial with findings possibly limited by inherently reduced power within this secondary outcome and/or a response bias. Participants who suffered a postoperative complication were more likely to be missed to follow-up, minimising power to detect a treatment response of preventing PPC on short-term HRQoL. Whilst the imputed data set demonstrates an improved signal towards improvements these findings are uncertain and need to be confirmed in a trial with adequate follow-up and power.

The time point of data collection could also impact the sensitivity of detecting an impact to HRQoL. After major abdominal surgery HRQoL tends to normalise around two months[21-25]. Assessment of HRQoL at an earlier time point (e.g. four weeks) may have more sensitivity at detecting possible differences associated with prevention of postoperative complications. Improvements in four week postoperative SF-36 physical domains have been reported following an intensive preoperative exercise and behavioural therapy intervention that halved postoperative complications[39]. A multimodal intervention targeting physical fitness might impact postoperative HRQoL physical domains more than a unimodal intervention targeting a single postoperative complication, as studied in this trial.

This study was conducted in Australia and New Zealand. Currently the best estimate of costs to hospitals attributable to a PPC after abdominal surgery is derived from a large US-based study[7]. To the authors' knowledge this is the most methodologically robust data in this field, however, US costs might not be directly comparable to hospitals operating within a universal public healthcare system. Cost-effectiveness interpretations could be improved if comparative PPC costs from similar healthcare funding structures in the LIPPSMAck-POP trial were available. Additionally, this health economic analysis also does not include the costs of the additional

physiotherapy required if participants contracted a PPC, hospital costs beyond 21 days, or medical and societal costs following hospital discharge, including primary healthcare use, hospital readmissions, and productivity. It is possible that the intervention could have better cost-effectiveness if these outcomes were included. Providing some support for this assumption is that the sensitivity analysis whole episode-of-care cost data demonstrated a mean cost difference favouring the intervention group four times the magnitude of the trial's restricted cost accounting modelling.

The decision on whether or not something is cost-effective comes down to the purchaser or consumer (i.e. the hospital) deciding if the benefit (i.e. a reduction in PPC or an improvement in QALY) is worth paying a certain amount to achieve. The determination of cost-effectiveness will be a valuation made by each hospital based on local ideals to prevent PPC and improve patient QALYs after surgery, available budgets, whilst considering the strength of evidence, consistency of results, generalisability to a local context, and the reported probabilities of cost-effectiveness. The LIPPSMAck-POP trial finds a 60% probability that preoperative physiotherapy was cost-neutral or entirely cost-saving in preventing PPCs. In Europe, Australia, and the US, at least 50 million patients undergo abdominal surgery every year[1-3]. At this estimate, millions of dollars of health care funding could be saved if preoperative physiotherapy is instigated as standard care to all patients awaiting major abdominal surgery. Alternatively, there is a 40% probability that reducing the PPC rate and improve QALYs after surgery with preoperative physiotherapy would require additional funding over and above standard care. In this case preoperative physiotherapy is 95% certain of being cost-effective if a hospital is willing-to-pay anywhere up to $45,000 for the service to prevent one PPC with an incremental net benefit of $4,958 (95% CI $10 to $9,197) in the hospital's favour for each PPC prevented.

This is the first multicentre randomised controlled trial investigating PPC prophylaxis with a comprehensive analysis of postoperative hospital use and a robust integrated health economic analysis. Preoperative physiotherapy is a highly efficacious treatment that halves the incidence of a serious postoperative complication[11,13], is valued by patients[14], is non-harmful[11], and is highly likely to be cost-effective from a hospital's perspective in preventing PPC after major abdominal surgery.

## 9.8 References


1. European Commission. Eurostat. Surgical operations and procedures performed in hospitals by ICD-9-CM. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hlth_co_proc2&lang=en. Accessed on December 18, 2018.
2. Steiner CA, Karaca Z, Moore BJ, Imshaug MC, Pickens G. Surgeries in hospital-based ambulatory surgery and hospital inpatient settings, 2014. HCUP Statistical Brief #223. May 2017. Agency for Healthcare Research and Quality, Rockville, MD. www.hcupus.ahrq.gov/reports/statbriefs/sb223-Ambulatory-Inpatient-Surgeries-2014.pdf. Accessed on December 18, 2018.
3. Procedures and healthcare interventions (ACHI 9th edition), Australia, 2015−16 to 2016−17. Australian Institute of Health and Welfare. https://www.aihw.gov.au/reports/hospitals/procedures-data-cubes/contents/data-cubes. Accessed on December 18, 2018.
4. McDermott KW, Freeman WJ, Elixhauser A. Overview of operating room procedures during inpatient stays in U.S. hospitals, 2014. HCUP Statistical Brief #233. December 2017. Agency for Healthcare Research and Quality, Rockville, MD. www.hcupus.ahrq.gov/reports/statbriefs/sb233-Operating-Room-Procedures-United-States-2014.pdf. Accessed on December 18, 2018.
5. Vonlanthen R, Slankamenac K, Breitenstein S, et al. The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Ann Surg* 2011; **254**:907-913.
6. Shander A, Fleisher LA, Barie PS, Bigatello LM, Sladen RN, Watson CB. Clinical and economic burden of postoperative pulmonary complications: patient safety summit on definition, risk-reducing interventions, and preventive strategies. *Crit Care Med* 2011; **39**: 2163-2172.
7. Fleisher LA, Linde-Zwirble WT. Incidence, outcome, and attributable resource use associated with pulmonary and cardiac complications after major small and large bowel procedures. *Perioper Med (Lond)* 2014; **3**:7.
8. Dimick JB, Pronovost PJ, Cowan JA, Lipsett PA. Complications and costs after high-risk surgery: where should we focus quality improvement initiatives? *J Am Coll Surg* 2003; **196**:671-8.
9. Kim SP, Leibovich BC, Shah ND, et al. The relationship of postoperative complications with in-hospital outcomes and costs after renal surgery for kidney cancer. *BJU Int* 2013; 111:580-8.
10. Fernandez-Bustamante A, Frendl G, Sprung J, et al. Postoperative pulmonary complications, early mortality, and hospital stay following noncardiothoracic surgery: A multicentre study by the perioperative research network investigators. *JAMA Surg* 2017; **152**: 157-66.
11. Boden I, Skinner EH, Browning L, et al. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ* 2018; **360**: j5916.
12. Brown SR, Mathew R, Keding A, Marshall HC, Brown JM, Jayne DG. The impact of postoperative complications on long-term quality of life after curative colorectal cancer surgery. *Ann Surg* 2014; **259**; 916-923
13. Fagevik-Olsén M, Hahn I, Nordgren S, Lonroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. *Br J Surg* 1997; **84**: 1535-8.
14. Boden I, El-Ansary D, Zalucki N, et al. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy* 2018; **104**: 194-202
15. Patman S, Bartley A, Ferraz A, Bunting C. Physiotherapy in upper abdominal surgery–what is current practice in Australia? *Arch Physiother* 2017; **7**:11.

16. Reeve J, Anderson L, Raslan Y, Grieve C, Ford J, Wilson L. The physiotherapy management of patients undergoing abdominal surgery: A survey of current practice. *N Z J Physio* 2019; **47**:66-75. doi.org/10.15619/NZJP/47.2.02

17. Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS) statement. *BMJ* 2013: **346**:f1049

18. Boden I, Browning L, Skinner EH, et al. The LIPPSMAck POP (Lung Infection Prevention Post Surgery-Major Abdominal-with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials* 2015; **16**: 1-15.

19. Fiore Jr JF, Figueiredo S, Balvardi S, et al. How do we value postoperative recovery?: a systematic review of the measurement properties of patient-reported outcomes after abdominal surgery. *Ann Surg* 2018; **267**: 656-669.

20. Kharroubi S, Brazier JE, Roberts JR, O'Hagan. Modelling SF-6D health state preference data using a nonparametric Bayesian method. *J Health Econ* 2007; **26**:597-612

21. Djalalov S, Rabeneck L, Tomlinson G, Bremner KE, Hilsden R, Hoch JS. A review and meta-analysis of colorectal cancer utilities. *Med Decis Making* 2014; **34:** 809-818.

22. Guillou PJ, Quirke P, Thorpe H, et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet* 2005; **365**:1718-26.

23. Martin RC, Eid S, Scoggins CR, McMasters KM. Health-related quality of life: return to baseline after major and minor liver resection. *Surgery* 2007; **142**:676-84.

24. Heerkens HD, Tseng DS, Lips IM, et al. Health-related quality of life after pancreatic resection for malignancy. *Br J Surg* 2016; **103**:257-66. doi: 10.1002/bjs.10032.

25. Foster C, Haviland J, Winter J, et al. Pre-surgery depression and confidence to manage problems predict recovery trajectories of health and wellbeing in the first two years following colorectal cancer: results from the CREW cohort study. *PLoS One* 2016; **11**:e0155434.

26. Richardson G, Manca A. Calculation of quality adjusted life years in the published literature: a review of methodology and transparency. *Health Econ* 2004; **13**:1203-10.

27. Angevine PD, Berven S. Health economic studies: an introduction to cost-benefit, cost-effectiveness, and cost-utility analyses. *Spine* 2014; **39**:S9-15. doi: 10.1097/BRS.0000000000000576

28. Fenwick E, Marshall DA, Levy AR, Nichol G. Using and interpreting cost-effectiveness acceptability curves: an example using data from a trial of management strategies for atrial fibrillation. *BMC Health Serv Res* 2006; **6**:52.

29. Olsen JA, Smith RD. Theory versus practice: a review of 'willingness-to-pay' in health and health care. *Health Econ* 2001; **10**:39-52.

30. Shiroiwa T, Sung YK, Fukuda T, Lang HC, Bae SC, Tsutani K. International survey on willingness-to-pay (WTP) for one additional QALY gained: what is the threshold of cost effectiveness? *Health Econ*. 2010; **19**:422-37. doi:10.1002/hec.1481.

31. Henry DA, Hill SR, Harris A. Drug prices and value for money: the Australian pharmaceutical benefits scheme. *JAMA* 2005; **294**:2630–2.

32. Willan AR, Bingshu Chen E, Cook RJ, Lin DY. Incremental net benefit in randomized clinical trials with quality-adjusted survival. *Stats Med* 2003; **22**:353-62.

33. Manca A, Palmer S. Handling missing data in patient-level cost-effectiveness analysis alongside randomised clinical trials. *Appl Health Econ Health Policy* 2005; 4:65-75.

34. Manca A, Hawkins N, Sculpher MJ. Estimating mean QALYs in trial-based cost-effectiveness analysis: the importance of controlling for baseline utility. *Health Econ* 2005;**14**:487-96

35. Australian Hospital Costing Standards Version 4.0. Independent Hospital Pricing Authority. February 2018. https://www.ihpa.gov.au/publications/australian-hospital-patient-costing-standards-version-40

36. Zhang XY, Wang Q, Zhang S, Tan W, Wang Z, Li J. The use of a modified, oscillating positive expiratory pressure device reduced fever and length of hospital stay in patients after thoracic and upper abdominal surgery: a randomised trial. *J Physiother* 2015; **61**:16-20.

37. Fagevik-Olsén M, Wennberg E, Johnsson E, Josefson K, Lonroth H, Lundell L. Randomised clinical study of the prevention of pulmonary complications after thoracoabdominal resection by 2 different breathing techniques. *Br J Surg* 2002; **89**:1228 – 1234.

38. Barberan-Garcia A, Ubré M, Roca J, et al. Personalised prehabilitation in high-risk patients undergoing elective major abdominal surgery: a randomized blinded controlled trial. *Ann Surg* 2018; **267**:50-56.

39. Barberan-Garcia A, Ubre M, Pascual-Argente N, et al. Post-discharge impact and cost-consequence analysis of prehabilitation in high-risk patients undergoing major abdominal surgery: secondary results from a randomised controlled trial. *Br J Anaesth* 2019; **123**:450-456.

## 9.9 Health economic analysis appendix

Published online as supplementary information to accompany published manuscripts

### Appendix 1: Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist

| Section/item | Item No | Recommendation | Reported on page No/ line No |
|---|---|---|---|
| **Title and abstract** | | | |
| Title | 1 | Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared. | Title |
| Abstract | 2 | Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions. | Abstract |
| **Introduction** | | | |
| Background and objectives | 3 | Provide an explicit statement of the broader context for the study. | p.4, para 1. |
| | | Present the study question and its relevance for health policy or practice decisions. | p.4, para 2-3 |
| **Methods** | | | |
| Target population and subgroups | 4 | Describe characteristics of the base case population and subgroups analysed, including why they were chosen. | p.5, para 2; p.8 para 4 |
| Setting and location | 5 | State relevant aspects of the system(s) in which the decision(s) need(s) to be made. | p.5 para 1 |
| Study perspective | 6 | Describe the perspective of the study and relate this to the costs being evaluated. | p.5 para 1 |
| Comparators | 7 | Describe the interventions or strategies being compared and state why they were chosen. | p.5 "Procedures" |
| Time horizon | 8 | State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate. | PPC, HRQoL, mortality – p.6 "Assessments and outcomes"<br>Costs – p.6 "Assessments and outcomes"<br>QALY – p.7 "Assessments and outcomes" |
| Discount rate | 9 | Report the choice of discount rate(s) used for costs and outcomes and say why appropriate. | p.7 "Assessments and outcomes" |
| Choice of health outcomes | 10 | Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed. | PPC, HRQoL, costs – p.4 "Introduction"<br>p.6 "Assessments and outcomes" |

| | | | |
|---|---|---|---|
| Measurement of effectiveness | 11a | *Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data. | p.4 "Methods"<br>p.11 "Discussion" |
| Measurement and valuation of preference based outcomes | 12 | If applicable, describe the population and methods used to elicit preferences for outcomes. | p.7 "Quality Adjusted Life Years" |
| Estimating resources and costs | 13a | *Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs. | p.6 "Intervention costs"<br>p.6 "Postoperative hospital costs"<br>EAddenda, table 2S |
| Currency, price date, and conversion | 14 | Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate. | p.6 "Intervention costs"<br>p.6 "Postoperative hospital costs"<br>EAddenda, table 2S |
| Choice of model | 15 | Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended. | No decision making model used |
| Assumptions | 16 | Describe all structural or other assumptions underpinning the decision-analytical model. | Cost-effectiveness – p.8 "Analysis of outcomes"<br>QALY – p.7 "Quality Adjusted Life Years" |
| Analytical methods | 17 | Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty. | p. 7 "Statistical analysis"<br>Adjustments – p.7 "baseline comparability and adjustment factors"<br>QALY calculation methods – p.7 "Quality Adjusted Life Years" EAddenda Figures 1S a-d.<br>Uncertainty – p.8 "Analysis of outcomes", "sensitivity analyses"<br>Willingness to pay – p.8 "Analysis of outcomes", EAddenda 3S a-b |
| **Results** | | | |
| Study parameters | 18 | Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty | p.9 "flow through study and baseline characteristics. Table 1 |

| | | | |
|---|---|---|---|
| | | where appropriate. Providing a table to show the input values is strongly recommended. | |
| Incremental costs and outcomes | 19 | For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios. | p.9 “costs and return on investment”; p.10 “treatment effects: PPC, mortality, HRQoL, health utility and QALYs”; “cost-effectiveness for PPC reduction; “Cost-utility for QALY improvement Table 1, Figures 1 & 2 |
| Characterising uncertainty | 20a | *Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective). | p.10-11 “sensitivity analysis” p. 12 “Limitations of the study and future direction of research” |
| Characterising heterogeneity | 21 | If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information. | p.10 “sub-group analyses” |
| **Discussion** | | | |
| Study findings, limitations, generalisability, and current knowledge | 22 | Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge. | p.11-13 |
| **Other** | | | |
| Source of funding | 23 | Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support. | Acknowledgements |
| Conflicts of interest | 24 | Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations. | Declaration of interests |

## Appendix 2: Individual item costs for each parameter within the targeted costing model.

| Parameter | Cost |
|---|---|
| Intervention | |
| Physiotherapist[1] | |
| Grade 4 Clinical supervisor with postgraduate qualifications | $55/hour |
| Grade 2, Physiotherapist, Year 6 | $45/hour |
| Room hire at pre-anaesthetic clinic | $50/hour |
| Printed colour booklet | $5 |
| Hospital bed day[2] | |
| ICU/HDU, non-ventilated bed | $3000/day |
| Surgical ward | $1500/day |
| Rehabilitation/sub-acute hospital | $800/day |
| Ventilation support[3] | |
| Mechanical ventilation | $1500/day |
| Non-invasive ventilation | $500/day |
| Oxygen therapy | |
| Standard oxygen | $20/day |
| High-flow oxygen | $100/day |
| Pathology tests[4] | |
| Sputum culture | $50/test |
| Blood culture | $50/test |
| All other tests, average | $30/test |
| Radiology tests[4] | |
| Chest X-rays | $70/test |
| Computerised tomography scan, non-contrast | $450/test |
| All other tests, average | $100/test |
| Antibiotics[5] | |
| Respiratory antibiotic | $100/day |
| All other antibiotics, average | $100/day |
| Medical visits[3] | |
| Out of round surgical team doctor visit | $300/visit |
| Medical emergency team call out | $1000/visit |

[1]Salary costs are taken from Tasmanian Department of Health and Human Services Allied Health Professional salary rates for 2018 Australian dollars using consumer price indices.

[2]Bed day costs are estimate averages taken from the Australian Independent Hospital Pricing Authority National Weighted Activity Unit calculators for 2017-2018. The Diagnosis Related Group (DRG) identifier for each type of upper abdominal surgery included in this trial was individually extracted. All corresponding length of stays were pooled and the mean taken. (www.ihpa.gov.au)

[3]Hospital administrative costings were derived according to the Australian Hospital Costing Standards Version 4.0. Independent Hospital Pricing Authority. February 2018

[4]Diagnostic imaging and pathology test costings were taken from 2018 Medical Benefits Scheme listed payments and increased by 140% to account for added infrastructure and overheads for public hospitals (www.mbsonline.gov.au)

[5]Antibiotic therapy costs were taken from the 2018 Australian Government Pharmaceutical Benefits Scheme listed payments and increased by 140% to account for added infrastructure and overheads for public hospitals. (www.pbs.gov.au)

**EAddenda Table 1.** Baseline characteristics between participants that provided at least one HRQOL response and those where no HRQOL data were available.

| | Complete HRQOL (n=205) | Incomplete HRQOL (n=227) | p value |
|---|---|---|---|
| Age, years | 63.6 (14.1) | 62.6 (15.4) | 0.45 |
| Male gender | 131 (64%) | 135 (60%) | 0.37 |
| BMI, (wt (kg)/ht (cm)2) | 28.4 (5.8) | 28.5 (6.2) | 0.89 |
| Preoperative co-morbidities | | | |
| Respiratory | 33 (16%) | 52 (23%) | 0.09 |
| Diabetes | 30 (15%) | 44 (19%) | 0.20 |
| Cancer | 148 (72%) | 148 (65%) | 0.12 |
| Cardiac disease | 28 (14%) | 32 (14%) | 1.00 |
| Current smoker[#] | 44 (22%) | 62 (27%) | 0.18 |
| Experienced physiotherapist at preop | 98 (48%) | 163 (72%) | <0.0001 |
| Surgical category | | | |
| Colorectal | 107 (52%) | 106 (47%) | 0.29 |
| Hepatobiliary/upper gastrointestinal | 46 (22%) | 60 (26%) | 0.37 |
| Renal/urology/other | 52 (25%) | 61 (27%) | 0.74 |
| Operation >3hrs | 55 (27%) | 62 (27%) | 0.91 |
| ASA 3-5 | 67 (33%) | 89 (39%) | 0.16 |
| Postoperative Complications | | | |
| PPC | 33 (16%) | 52 (22%) | 0.09 |
| Wound infection | 45 (22%) | 31 (14%) | 0.03 |
| Delirium | 10 (5%) | 29 (13%) | 0.004 |
| Sepsis | 6 (2.9%) | 16 (7.0%) | 0.08 |
| Cardiac | 4 (2.0%) | 9 (4.0%) | 0.27 |
| Pulmonary embolism | 2 (1.0%) | 5 (2.2%) | 0.45 |
| Hospital utilisation | | | |
| ICU admission | 91 (44%) | 103 (45%) | 0.85 |
| Hospital LOS | 10.3 (7.6) | 12.6 (13.4) | 0.026 |
| Hospital costs | $20,293 (21,974) | $23,918 (25,871) | 0.12 |
| 12-month mortality | 13 (6.3%) | 27 (12%) | 0.07 |

Data are mean (SD) or n (%)
p-values are two-tailed
BMI=Body Mass Index, ASA=American Society Anaesthesiologists, ICU=intensive care unit, PPC=postoperative pulmonary complications
[#]current smoker defined as having smoked tobacco regularly within 8 weeks of assessment
Cases were considered complete when HRQOL questionnaires were collected for both pre- and post-surgery periods. Note that no questionnaires were collected in 2013, 62 of 131 (47.3%) were collected in 2014, and 137 of 185 (74.1%) were collected in 2015: Questionnaires were only collected for cases with upper abdominal incisions (199 of 374 (53.2%), and from none of cases with lower abdominal incisions and laparoscopic surgery (n=58)

**Table 3.** Between-group health-related quality of life (SF-36) and health utilities at baseline and at six-weeks.

| | Baseline | | Post (six-weeks) | | Difference within groups | | | | | | | | Difference between groups | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Intervention | Control | Intervention | Control | | | | Intervention | | | | Intervention - Control | | |
| **Imputed cases** | (n=214) | (n=218) | (n=214) | (n=218) | Δ | 95% CI | %diff | P-value | Δ | 95% CI | %diff | P-value | Δ | 95% CI | P-value |
| SF-36 total | 66.2 (19.9) | 65.7 (19.6) | 62.9 (21.2) | 62.4 (20.6) | -3.3 | (-6.2 to -0.4) | -5.0% | 0.078 | -3.3 | (-6.2 to -0.4) | -5.0% | 0.072 | 0.0 | (-4.1 to 4.1) | 0.77 |
| SF-36 Physical domain | 60.8 (21.2) | 61.2 (20.8) | 56.0 (22.6) | 55.3 (22.1) | -4.8 | (-7.8 to -1.9) | -7.9% | 0.0042 | -5.9 | (-8.8 to -3.0) | -9.6% | 0.0002 | -1.1 | (-5.2 to 3.1) | 0.73 |
| SF-36 Mental domain | 68.1 (19.2) | 67.9 (18.8) | 66.6 (21.0) | 66.7 (20.6) | -1.4 | (-4.3 to 1.4) | -2.1% | 0.99 | -1.2 | (-4.0 to 1.6) | -1.8% | 1.00 | 0.2 | (-3.8 to 4.2) | 0.98 |
| Physical Function | 72.0 (25.1) | 71.7 (24.7) | 65.9 (28.9) | 65.2 (28.4) | -6.1 | (-9.9 to -2.4) | -8.5% | 0.0043 | -6.5 | (-10.2 to -2.7) | -9.1% | 0.0021 | -0.3 | (-5.6 to 5.0) | 0.80 |
| Role Physical | 52.8 (41.2) | 51.5 (39.2) | 36.8 (34.4) | 34.8 (34.9) | -16.0 | (-21.7 to -10.3) | -30% | <0.0001 | -16.7 | (-22.4 to -11.0) | -32% | <0.0001 | -0.7 | (-8.8 to 7.4) | 0.58 |
| Body Pain | 63.4 (27.7) | 64.2 (27.5) | 70.9 (23.9) | 66.3 (26.9) | 7.5 | (3.2 to 11.8) | 12% | 0.0017 | 2.1 | (-2.2 to 6.3) | 3.3% | 0.68 | -5.5 | (-11.5 to 0.6) | 0.06 |
| General Health | 62.0 (18.1) | 65.3 (18.8) | 60.2 (23.3) | 62.0 (21.5) | -1.8 | (-4.6 to 1.0) | -2.9% | 0.41 | -3.3 | (-6.0 to -0.5) | -5.1% | 0.044 | -1.4 | (-5.4 to 2.5) | 0.34 |
| Vitality | 53.2 (23.9) | 54.0 (23.2) | 49.8 (24.9) | 49.1 (24.8) | -3.4 | (-6.7 to 0.0) | -6.4% | 0.15 | -4.8 | (-8.2 to -1.5) | -8.9% | 0.013 | -1.5 | (-6.2 to 3.3) | 0.76 |
| Social Function | 78.2 (26.2) | 74.7 (26.9) | 71.5 (29.5) | 71.6 (29.9) | -6.7 | (-11.0 to -2.4) | -8.6% | 0.0064 | -3.1 | (-7.3 to 1.2) | -4.1% | 0.47 | 3.6 | (-2.4 to 9.7) | 0.96 |
| Role Emotion | 73.5 (35.4) | 71.0 (36.7) | 78.3 (29.4) | 74.0 (33.2) | 4.8 | (-0.8 to 10.4) | 6.5% | 0.28 | 2.9 | (-2.6 to 8.5) | 4.1% | 0.60 | -1.8 | (-9.7 to 6.0) | 0.18 |
| Mental Health | 72.8 (18.5) | 74.0 (17.0) | 72.7 (19.2) | 74.0 (18.0) | -0.2 | (-2.7 to 2.4) | -0.3% | 0.90 | 0.0 | (-2.5 to 2.5) | 0.0% | 1.00 | 0.2 | (-3.4 to 3.8) | 1.00 |
| Health Utility, SF-6D | 0.72 (0.14) | 0.71 (0.13) | 0.69 (0.13) | 0.69 (0.14) | -0.03 | (-0.05 to -0.01) | -4.2% | 0.029 | -0.02 | (-0.04 to 0.00) | -2.8% | 0.14 | 0.01 | (-0.02 to 0.03) | 0.77 |
| **Complete cases** | (n=98) | (n=107) | (n=98) | (n=107) | Δ | 95% CI | %diff | P-value | Δ | 95% CI | %diff | P-value | Δ | 95% CI | P-value |
| SF-36 total | 66.9 (21.9) | 66.5 (21.7) | 63.4 (20.1) | 61.5 (22.4) | -3.5 | (-7.4 to 0.4) | -5.2% | 0.16 | -4.9 | (-8.7 to -1.2) | -7.4% | 0.030 | -1.4 | (-6.9 to 4.0) | 0.51 |
| SF-36 Physical domain | 61.4 (23.4) | 62.3 (22.8) | 55.9 (21.9) | 54.4 (23.5) | -5.4 | (-9.5 to -1.3) | -8.8% | 0.028 | -7.9 | (-11.8 to -3.9) | -13% | 0.0003 | -2.4 | (-8.1 to 3.2) | 0.60 |
| SF-36 Mental domain | 68.8 (20.9) | 68.3 (21.1) | 68.4 (20.0) | 66.5 (22.5) | -0.4 | (-4.2 to 3.5) | -0.6% | 0.85 | -1.8 | (-5.4 to 1.9) | -2.6% | 1.00 | -1.4 | (-6.7 to 3.9) | 1.00 |
| Physical Function | 72.5 (26.6) | 72.8 (27.3) | 65.6 (28.3) | 63.8 (28.7) | -6.9 | (-12.2 to -1.7) | -9.5% | 0.020 | -8.9 | (-14.0 to -3.9) | -12% | 0.0016 | -2.0 | (-9.3 to 5.3) | 0.63 |
| Role Physical | 55.6 (45.6) | 52.1 (44.1) | 35.2 (41.4) | 30.7 (41.1) | -20.4 | (-29.2 to -11.6) | -37% | <0.0001 | -21.4 | (-29.8 to -12.9) | -41% | <0.0001 | -1.0 | (-13.2 to 11.2) | 0.44 |
| Body Pain | 63.2 (31.1) | 65.2 (30.6) | 66.5 (27.1) | 66.3 (29.9) | 3.3 | (-2.9 to 9.4) | 5.2% | 0.90 | 1.1 | (-4.8 to 7.1) | 1.7% | 1.00 | -2.1 | (-10.7 to 6.4) | 0.97 |
| General Health | 61.6 (19.9) | 65.8 (20.6) | 63.4 (23.4) | 63.0 (23.0) | 1.8 | (-2.0 to 5.7) | 2.9% | 0.69 | -2.8 | (-6.5 to 0.9) | -4.3% | 0.27 | -4.6 | (-9.9 to 0.7) | 0.88 |
| Vitality | 54.1 (25.7) | 55.1 (25.9) | 51.1 (24.4) | 49.2 (26.9) | -3.0 | (-7.5 to 1.6) | -5.5% | 0.41 | -5.9 | (-10.3 to -1.5) | -11% | 0.026 | -2.9 | (-9.3 to 3.4) | 0.56 |
| Social Function | 79.2 (28.4) | 75.4 (30.2) | 72.5 (31.2) | 71.9 (33.1) | -6.7 | (-12.7 to -0.7) | -8.5% | 0.084 | -3.5 | (-9.2 to 2.3) | -4.6% | 0.71 | 3.3 | (-5.0 to 11.6) | 0.89 |
| Role Emotion | 76.2 (38.8) | 70.7 (41.7) | 81.2 (33.3) | 74.2 (39.0) | 5.0 | (-3.4 to 13.3) | 6.6% | 0.49 | 3.5 | (-4.5 to 11.6) | 5.0% | 0.39 | -1.4 | (-13.0 to 10.2) | 0.36 |
| Mental Health | 73.1 (20.8) | 74.5 (19.1) | 74.8 (18.8) | 75.1 (19.8) | 1.7 | (-1.6 to 5.1) | 2.3% | 0.95 | 0.6 | (-2.6 to 3.8) | 0.8% | 1.00 | -1.1 | (-5.7 to 3.5) | 0.91 |
| Health Utility, SF-6D | 0.71 (0.15) | 0.71 (0.14) | 0.69 (0.12) | 0.69 (0.15) | -0.02 | (-0.05 to 0.01) | -2.8% | 0.25 | -0.02 | (-0.05 to 0.00) | -2.8% | 0.29 | 0.00 | (-0.04 to 0.04) | 0.70 |

Data are mean (SD), mean with group differences (95% CI), mean between group differences (95% CI), estimated using adjusted repeated measures mixed effects linear regression.
SF-36=Short form 36, SF-6D= Short form six domains, METS=Metabolic equivalents, [+]derived from the Specific Activity Questionnaire

**Table 4.** Sub-group analysis: Net hospital costs and effects of preoperative physiotherapy versus standard care according to experience level of physiotherapist.

| | Experienced physiotherapist (≥10 years) | | | Physiotherapists (<10 yrs experience) | | |
|---|---|---|---|---|---|---|
| Parameter | Intervention n=135 | Control n=125 | Mean diff (95% CI) | Intervention n=83 | Control n=89 | Mean diff (95% CI) |
| **Costs** | | | | | | |
| Intervention | $116 (4) | $60 (1) | $56 ($55 to $57) | $106 (1) | $56 (0) | $50 ($50 to $50) |
| Hospital stay | | | | | | |
| ICU/HDU stay | $3728 (9420) | $4488 (7702) | -$760 (-$2871 to $1351) | $4098 (7188) | $4551 (8990) | -$453 (-$2914 to $2008) |
| Surgical ward stay | $13579 (14478) | $14256 (10000) | -$677 (-$3739 to $2385) | $13976 (9366) | $15051 (15702) | -$1075 (-$5002 to $2852) |
| Sub-acute stay | $356 (1917) | $1086 (5814) | -$730 (-$1771 to $311) | $1170 (5388) | $647 (3177) | $532 (-$798 to $1844) |
| Ventilation support | | | | | | |
| Mechanical ventilation | $303 (1736) | $367 (1842) | -$64 (-$501 to $373) | $376 (1722) | $507 (2927) | -$131 (-$860 to $598) |
| NIV | $18 (112) | $36 (192) | -$18 (-$56 to $20) | $18 (166) | $6 (53) | $12 (-$25 to $49) |
| High-flow oxygen | $26 (108) | $49 (155) | -$23 (-$55 to $9) | $43 (147) | $28 (102) | $15 (-$23 to $53) |
| Standard oxygen | $51 (52) | $64 (63) | -$13 (-$27 to $1) | $65 (55) | $65 (55) | $0 (-$17 to $17) |
| Pathology tests | | | | | | |
| Sputum cultures | $11 (33) | $14 (37) | -$3 (-$12 to $6) | $10 (30) | $21 (58) | -$11 (-$25 to $3) |
| Blood cultures | $11 (36) | $18 (48) | -$7 (-$17 to $3) | $15 (60) | $24 (79) | -$19 (-$61 to $23) |
| All remaining tests | $1171 (2036) | $1380 (1620) | -$209 (-$661 to $243) | $1085 (1130) | $1161 (1516) | -$76 (-$481 to $329) |
| Radiology tests | | | | | | |
| Chest X-rays | $127 (216) | $174 (236) | -$47 (-$102 to $8) | $133 (211) | $129 (262) | $4 (-$68 to $76) |
| Chest CT's | $30 (125) | $50 (173) | -$20 (-$57 to $17) | $33 (118) | $56 (223) | -$23 (-$77 to $31) |
| All remaining tests | $120 (401) | $126 (248) | -$6 (-$88 to $76) | $77 (126) | $103 (172) | -$26 (-$72 to $20) |
| Antibiotics | | | | | | |
| Respiratory indication | $79 (269) | $162 (330) | -$47 (-$120 to $26) | $117 (307) | $130 (277) | -$13 (-$102 to $75) |
| All other indications | $162 (306) | $125 (228) | $37 (-$29 to $103) | $212 (378) | $199 (342) | $13 (-$95 to $121) |
| Medical visits | | | | | | |
| Out of round visits | $463 (676) | $715 (1030) | -$252 (-$463 to -$41)† | $669 (996) | $448 (627) | $221 (-$28 to $470) |
| MET calls | $103 (390) | $179 (628) | -$76 (-$203 to $51) | $108 (585) | $56 (276) | $52 (-$84 to $188) |
| **Total net costs** | | | | | | |
| Targeted costs model - unadjusted | $20451 (27268) | $23313 (20733) | -$2862 (-$8812 to $3089) | $22291 (18418) | $23237 (28074) | -$946 (-$8147 to $6255) |
| Targeted costs model – adjusted* | $20391 (27960) | $21547 (16729) | -$1156 (-$6937 to $5300) | $23513 (20269) | $22844 (25823) | $668 (-$6428 to $6247) |
| Sensitivity analysis | | | | | | |
| Government episode of care costs* | $31316 (27904) | $33522 (30927) | -$2206 (-$9391 to $4979) | $30195 (19804) | $31705 (24739) | -$1510 (-$8286 to $5260) |
| **Effects** | | | | | | |
| Pulmonary complications* | 16 (12%) | 38 (30%) | -13% (-17% to -6%)†† | 11 (13%) | 20 (22%) | -5.7% (-12% to 5.6%) |
| 12-month mortality* | 6 (4.4%) | 17 (14%) | -6.4% (-8.7% to -0.7%)† | 10 (12%) | 6 (6.7%) | 5.6% (-0.9% to 22%) |
| QALY, imputed data sets* | 0.670 (0.124) | 0.619 (0.171) | 0.051 (0.015 to 0.088)‡ | 0.659 (0.154) | 0.684 (0.116) | -0.025 (-0.066 to 0.015) |
| Sensitivity analysis | n= 90 | n=74 | | n=70 | n=81 | |
| QALY, complete cases only* | 0.674 (0.167) | 0.643 (0.223) | 0.031 (-0.016 to 0.078) | 0.643 (0.173) | 0.679 (0.121) | -0.036 (-0.080 to 0.008) |

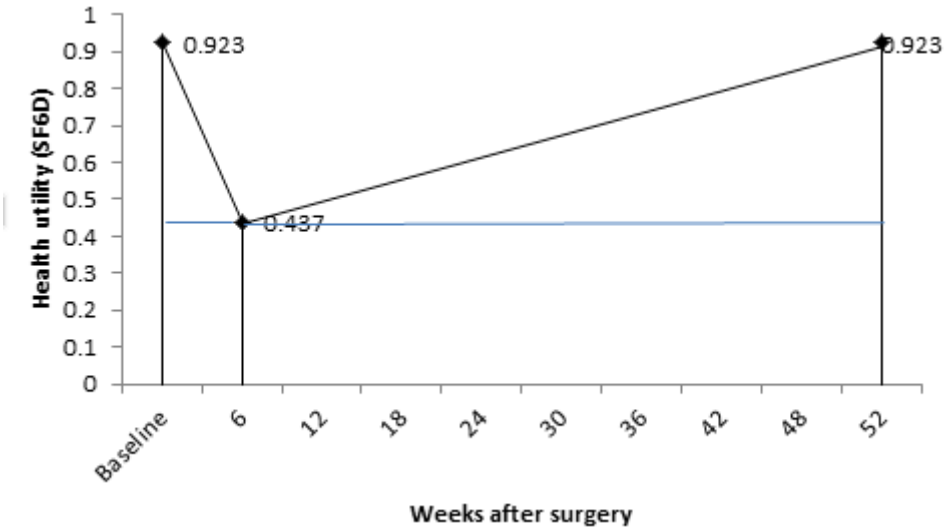
All costs are in 2018 Australian dollars. Raw cost data are mean (SD) and mean difference (95% confidence interval)

*Total costs, PPC, mortality and QALY comparisons are adjusted for age, respiratory comorbidity, surgical category using multiple regression and Poisson regression. QALY also adjusted for baseline utility. † p=0.04, ††p=0.03, ‡ p=0.01. All p-values two-tailed.

ICU=intensive care unit, HDU=high dependency unit, NIV=noninvasive mechanical ventilation, CT=computerised tomography, MET=medical emergency team, QALY=quality adjusted life year

## Appendix 3: Quality of life years calculation methods with examples

**Figure 1S (a)**
Patient deteriorates over first 6 weeks. Alive at 12 months.
Baseline utility = 0.923 6 week utility = 0.437

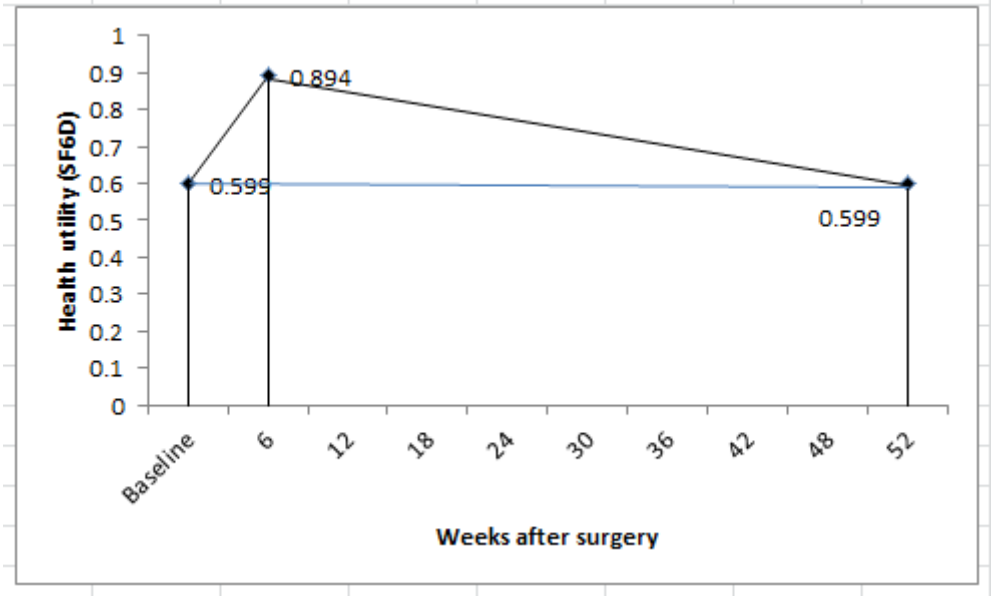



QALY - baseline to 6 weeks
= area of the square of lowest health utility value during 6 weeks + area of triangle of highest to lowest health utility value during 6 weeks
= (0.437 x 6/52) + (((0.923-0.437) x 6/52)/2) = 0.078

QALY - 6 weeks to 12 months
= area of square from lowest health utility value at 6 weeks by the remaining 46 weeks + area of triangle of lowest to highest health utility.
= (0.437 x 46/52) + (((0.923-0.437) x 46/52)/2) = 0.387 + 0.215
= 0.602

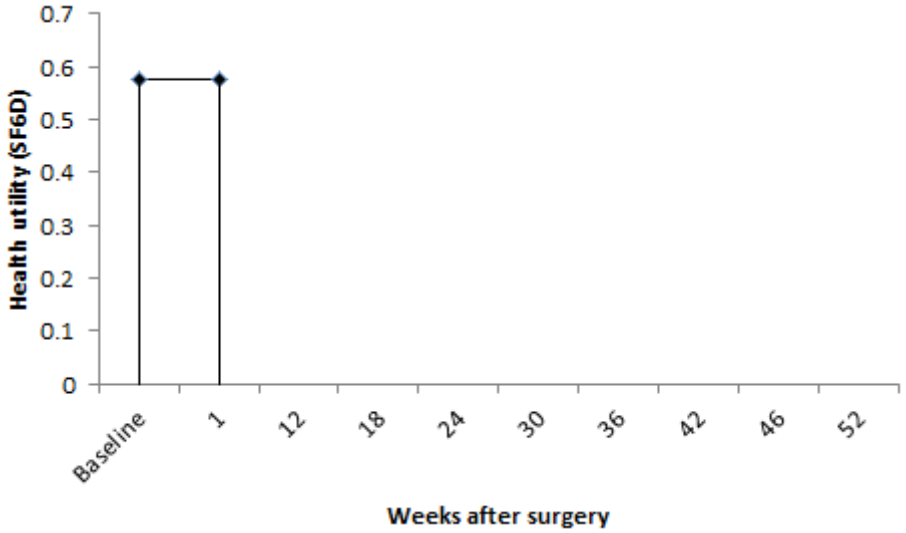
Total QALY for the 12 months from baseline = 0.078 + 0.602 = 0.680

**Figure 1S (b)**
Patient improves over first 6 weeks. Alive at 12 months. Baseline utility = 0.599 6 week utility = 0.894



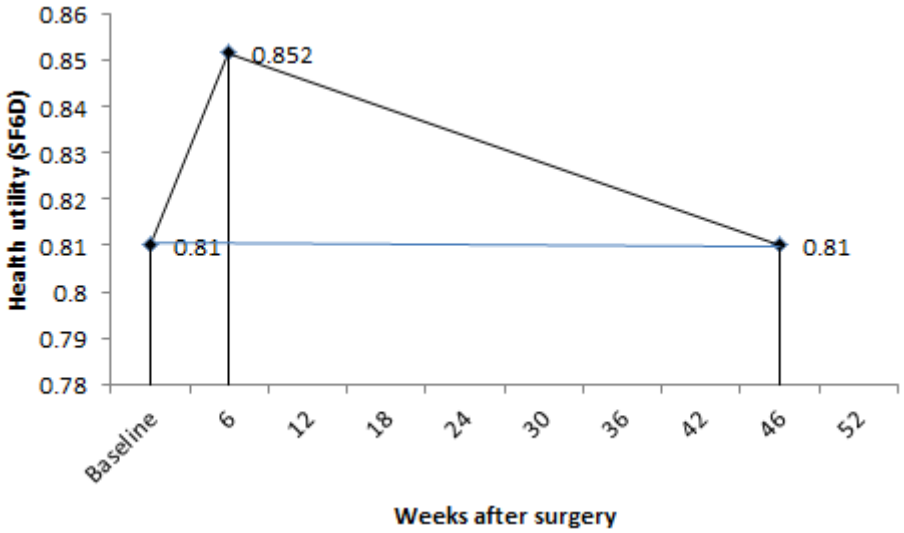

QALY 6 weeks = (0.599 x 6/52) + (((0.894-0.599) x 6/52)/2) = 0.086
QALY 6 weeks to 12 months = (0.599 x 46/52) +(((0.894-0.599) x 46/52)/2) = 0.791
Total 12 month QALY = 0.877

**Figure 1S (c)**
Patient dies 16 days after surgery
Baseline utility = 0.577




QALY = Last taken utility x weeks from this utility to death
= 0.577 x 16/7/52
= 0.025

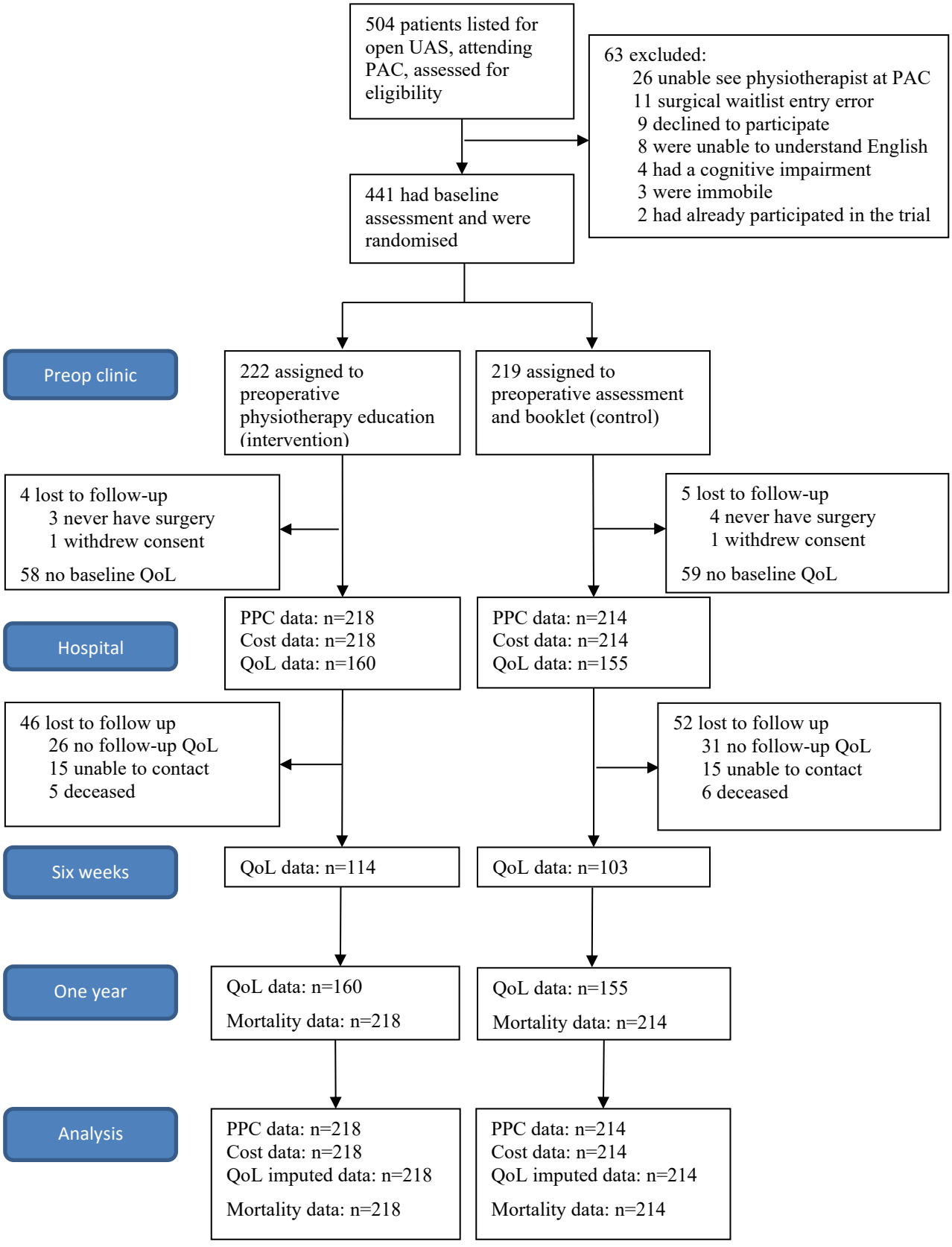
**Figure 1S (d)**
Patient dies 167 days after surgery
Baseline utility = 0.810 6 week utility = 0.852




QALY 6 weeks = (0.810 x 6/52) + (((0.852-0.810) x 6/52)/2) = 0.096
QALY 6 weeks to death at 167 days = (0.810 x 167/7/52) +(((0.852-0.810) x 167/7/52)/2) = 0.292
Total 12 month QALY = 0.381

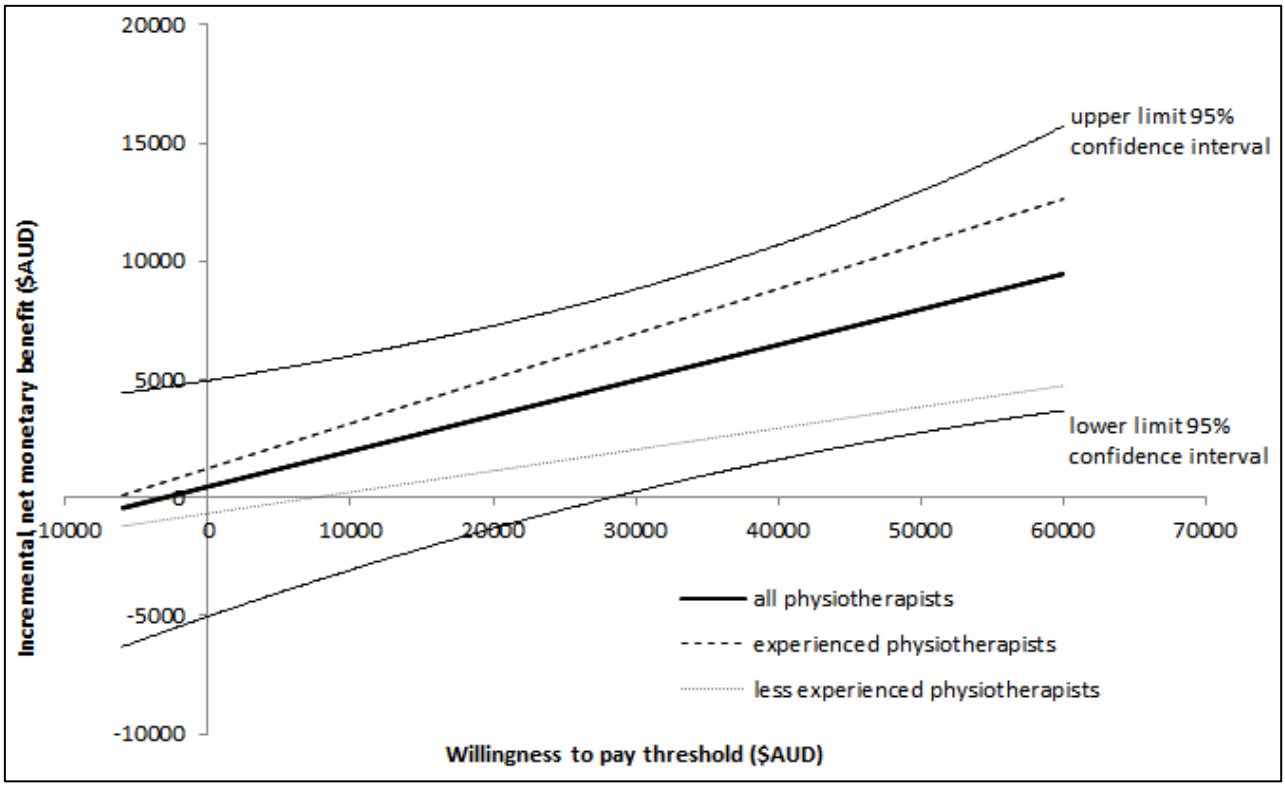
## Appendix 4. CONSORT flow diagram for health-related quality of life acquisition

UAS=upper abdominal surgery, PAC=pre-anaesthetic clinic, QoL=Quality of Life, PPC=postoperative pulmonary complication, CONSORT=Consolidated Standards of Reporting Trials

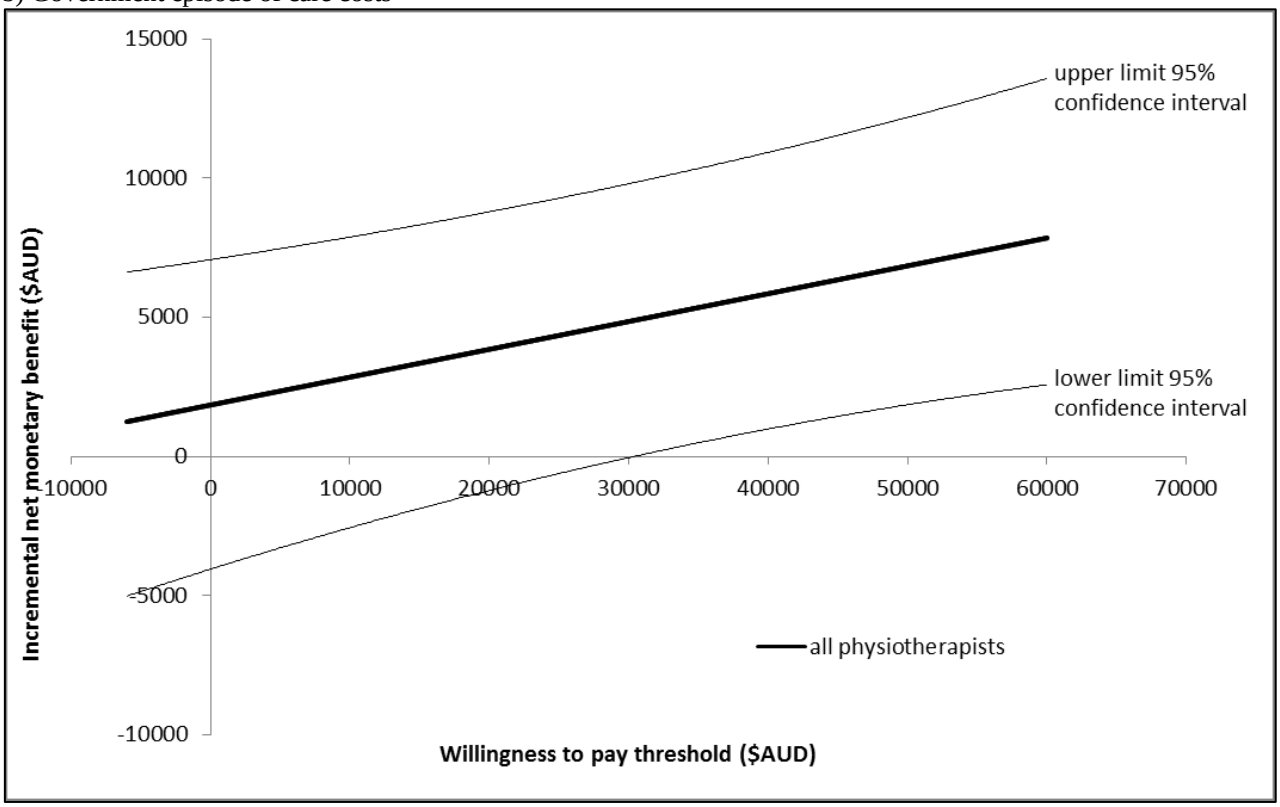


**Appendix 5.** Incremental net benefit of preoperative physiotherapy to prevent postoperative pulmonary complications for a range of willingness-to-pay thresholds

a) Targeted hospital cost model




b) Government episode of care costs



# CHAPTER 10

# Update of thesis content to 2020

## 10.1 Introduction

This part-time PhD was initiated seven years ago, June 2013, and it has been five years since enrolment in the LIPPSMAck-POP trial closed. From this time (2015 – 2020) advances have been made to perioperative medicine practices. The purpose of this chapter is to consider the findings presented in the previous chapters as studied from 2013-2016 in the context of new and emerging evidence within the field of perioperative medicine. This will include recalculating the volumes of open elective upper abdominal surgery currently conducted in Australia; repeating the systematic review to include papers published 2016 to 2020; and critically reviewing this thesis's findings within the key rapidly emerging field of 'prehabilitation'.

## 10.2 Updated volume of open elective upper abdominal surgery

In 2013 data were extracted from the Australian Institute of Health and Welfare (AIHW) to provide information on numbers of major abdominal surgical procedures for inclusion in the published manuscript comprising Chapter 2 (Reeve & Boden 2016). This found that approximately 130,000 elective open upper abdominal procedures were conducted in Australia in 2012 (AIHW 2013). An update to collate the number of procedures performed 2017-2018 was conducted to better understand how this thesis' research sits within contemporary surgical volumes and the increasing implementation of minimally invasive surgery and laparoscopic upper abdominal surgery within ERAS pathways.

Procedures commonly conducted via an abdominal incision longer than 5cm above, or extending above, the umbilicus were extracted from AIHW metadata reporting all surgical procedures and associated volumes performed in Australia in the year 2017-2018 (AIHW 2018). The specific procedures, annual units, and total combined volume of major open elective upper abdominal surgical procedures are presented in Table 10.1. Procedures excluded from those listed were those conducted exclusively via a lower abdominal incision, thoracic incision, or laparoscopically, or were day surgery cases, organ transplants, or emergency/trauma procedures.

**Table 10.1 Major elective upper abdominal surgery procedures in Australia 2017-2018**

| Procedure codes | Procedure | Number |
|---|---|---|
| **0119** | Partial adrenalectomy | 105 |
| | Total adrenalectomy | 663 |
| | **Adrenalectomy** | **768** |
| **0815** | Splenectomy, partial or full | 577 |
| **0816** | Splenorrhaphy | 116 |
| | **Splenectomy** | **693** |
| **0858** | Oesophagectomy by abdominal and thoracic mobilisation | 96 |
| **0859** | Oesophagectomy by abdominal and cervical mobilisation | 71 |
| **0860** | Oesophagectomy by abdominal and transthoracic mobilisation | 436 |
| **0867** | Repair of oesophageal perforation | 133 |
| | **Oesophagectomy** | **736** |
| **0875** | Partial gastrectomy | 602 |
| **0876** | Selective vagotomy with partial gastrectomy | 18 |
| **0877** | Total, subtotal, radical, Gastrectomy | 784 |
| **0879** | Pyloroplasty | 145 |
| **0883** | Open fundoplasty | 164 |
| **0886** | Open gastroplasty | 18 |
| **0889** | Open sleeve gastrectomy | 168 |
| | Open gastric bypass | 227 |
| | Duodenal-jejunal bypass or biliopancreatic diversion | 44 |
| | **Gastrectomy** | **2,170** |
| **0895** | Resection of small intestine | 5716 |
| **0898** | Reduction procedures on small intestine | 81 |
| **0900** | Repair of small intestine | 53 |
| | **Small bowel resection** | **5,850** |
| **0913** | Colectomy | 14043 |
| **0916** | Reduction procedures on large intestine | 147 |
| **0918** | Revision procedures on large intestine | 400 |
| | **Large bowel resection** | **14,590** |
| **0934** | Rectosigmoidectomy or protectomy | 1597 |
| **0935** | Anterior resection of rectum | 7569 |
| **0936** | Total proctocolectomy | 320 |
| **0940** | Abdominal rectopexy | 985 |
| | **Rectal resection** | **10,471** |
| **0953** | Segmental resection of liver | 1023 |
| **0955** | Lobectomy of liver | 653 |
| | Trigsegmental resection of liver | 212 |
| | Total hepatectomy | 37 |
| | Partial liver resection | 630 |
| | **Liver resection** | **2,555** |
| **0965** | Open cholecystectomy | 3267 |
| **0966** | Resection of hepatic duct or porta hepatis | 148 |
| **0967** | Resection of choledochal cyst | 13 |
| **0970** | Roux-en-Y bypass | 115 |
| | **Gall bladder and biliary tract** | **3,543** |
| **0978** | Pancreatectomy | 1625 |
| **0979** | Other excision procedures on pancreas | 40 |
| **0980** | Anastamosis of pancreas | 34 |

| | | | |
|---|---|---|---|
| | | **Pancreatectomy** | **1,699** |
| **0985** | Laparotomy | | 1593 |
| **0986** | Division of adhesions | | 25422 |
| **0989** | Pelvic exenteration | | 133 |
| | Open excision procedures of abdomen | | 9546 |
| | | **General laparotomies** | **90,697** |
| **0992** | Repair umbilical, epigastric hernia | | 15046 |
| **0993** | Repair incisional hernia | | 9644 |
| **0994** | Repair parastomal hernia | | 1393 |
| **0996** | Repair abdominal wall hernia | | 9569 |
| **0998** | Repair diaphragmatic hernia | | 1261 |
| | | **Hernia repairs** | **36,913** |
| **1048** | Partial nephrectomy | | 852 |
| **1049** | Complete nephrectomy | | 220 |
| **1050** | Complete nephrectomy for transplantation | | 265 |
| **1051** | Radical nephrectomy | | 533 |
| **1053** | Nephroureterectomy | | 172 |
| **1057** | Pyeloplasty | | 122 |
| **1076** | Ureterectomy | | 195 |
| **1081** | Ileal conduit procedures | | 911 |
| | | **Kidney and ureter procedures** | **3,270** |
| **1102** | Cystectomy | | 1073 |
| **1104** | Repair of ruptured bladder | | 122 |
| | | **Bladder resections/repairs** | **1,195** |
| TOTAL MAJOR ELECTIVE ABDOMINAL SURGERY PROCEDURES | | | **175,150** |

For the year 2017-2018 approximately 175,000 elective open upper abdominal surgical procedures were performed in Australia. This represents a case increase rate of 7% *per annum* on the previous accounting of 130,000 procedures collated from surgical procedure data published five years previously in 2012-2013.

These data demonstrate the current and ongoing high numbers of major open elective abdominal surgery, irrespective of increasing efforts to operative via minimally invasive procedures within ERAS pathways. On 2018 volumes, an estimated PPC incidence rate of between 10 and 20% equates to at least 19,000 to 38,000 PPCs per year in Australia. The severe negative consequences associated with this type of postoperative complication justify the ongoing importance of studying methods to minimise PPC after major abdominal surgery.

## 10.3 Updated systematic review and meta-analysis

### 10.3.1 Background

The systematic review and meta-analysis contained within Chapter 4 was conducted in 2016 and included trials published up to 2015. To ensure that the conclusions drawn by this thesis sit within contemporary evidence and surgical practices, this analysis was repeated with the range of eligible trials extended to June 2020.

This updated analysis will be developed further with the intention to publish.

### 10.3.2 Methods

The methods specified in Chapter 4 were replicated exactly except for:

1. extending the literature search time range to June 2020.
2. Adding a third analysis; The addition of preoperative chest physiotherapy to postoperative chest physiotherapy alone (active control). This was added due to the first publication of a trial investigating this question.

### 10.3.3 Results

#### 10.3.3.1 Flow of studies through the review

The updated search strategy yielded an additional 232 articles, from which 24 were considered possibly eligible for inclusion and full text manuscripts were retrieved for consideration. Of these, 20 were excluded according to the specified eligibility criteria as outlined in Table 4.1, Chapter 4. Table 10.2 outlines the newly excluded trials (2016 – 2020) and reasons for exclusions. Figure 10.1 shows the updated flow of trial selection (1950 – 2020).

## Table 10.2 Excluded trials 2016 to 2020

| Reason for exclusion | Study | Details |
|---|---|---|
| Not randomised or pseudorandomised allocation | AbuBakr AS, Ibrahim HD, Abdallah T. Effect of pulmonary care measures on reducing respiratory tract infection and dispend grades among postoperative elderly patients with abdominal surgeries. *IOSR J Nur Health Sci*. 2018;7(4):87-97. | Non random allocation. |
| | Dakshinamurthy A, Ilavazhagan JJ. Influence of Preoperative Physiotherapy on Respiratory Muscle Function and Quality of Life in Laparotomy Patients. *Int J Pub H Health Sys*. 2019 Apr 9;4(3):58. | Convenient sample. Used emergency laparotomy patients as a control. |
| | Hussein EE, Taha NM. Effect of Breathing Exercises on Quality of Recovery Among Postoperative Patients. *Int J Stud in Nur*. 2018 Jul 30;3(3):151. | Convenient sample |
| | Raj AR, Kathyayani BV. Pre-operative breathing exercise using instructional demonstration in preventing post-operative pulmonary complications for patients undergoing elective abdominal surgery. *Manipal Journal of Nursing and Health Sciences.* 2016;2(1):16-20. | Not randomised comparative trial. |
| | Sanya AO, Akinremi AO. Effects of breathing exercise training on selected pulmonary indices in post-abdominal surgery patients. *Nigerian J of Clin Prac*. 2001;4(2):91-5. | Non randomised allocation. No control group |
| Ineligible participants | Allam NM, Khalaf MM, Thabet WN, Ibrahim ZM. Effect of combination of Acapella device and breathing exercises on treatment of pulmonary complications after upper abdominal surgeries. *J of Surg*. 2016 Jan 1;4(2-1):10-4. | Participants entered into trial if they already had a PPC |
| Ineligible control group | Othman EM, Abaas SA, Hassan HH. Resisted breathing exercise versus incentive spirometer training on vital capacity in postoperative radical cystectomy cases: a pilot randomized controlled trial. *Bul of Fac Phys Ther*. 2016 Jul 1;21(2):61. | Incentive spirometry v breathing exercises. Outcome: Lung function |
| | Shingavi SS, Kazi A, Gunjal S, Lamuvel M. Effects of active cycle of breathing technique and autogenic drainage in patient with abdominal surgery. *Int J App Research*. 2017;3(2):373-6. | Autogenic drainage v deep breathing exercises Outcomes: Lung function |
| | Thakre P, Sagar JH. Effect of incentive spirometry and lateral costal expansion in patients with upper abdominal surgery. *Int J Phy, Nutr Phys Ed* 2018; 3(1): 1222-1226. | Incentive spirometer v DB exercises |
| | Wange P, Jiandani M, Mehta A. Incentive spirometry versus active cycle of breathing technique: Effect on chest expansion and flow rates in post abdominal surgery patients. *Int J Research Med Sci*. 2016 Nov;4(11):4762. | Incentive spirometer v DB exercises Outcomes: Lung function |
| Ineligible intervention group | Alaparthi GK, Augustine AJ, Anand R, Mahale A. Comparison of diaphragmatic breathing exercise, volume and flow incentive spirometry, on diaphragm excursion and pulmonary function in patients undergoing laparoscopic surgery: a randomized controlled trial. *Minimally invasive surgery*. 2016; doi: 10.1155/2016/1967532. | Preop training on flow IS OR volume IS OR DB exercises v no preop training. Outcomes: Lung function |

| | | |
|---|---|---|
| | Fernandes SC, Santos RS, Giovanetti EA, Taniguchi C, Silva CS, Eid RA, Timenetsky KT, Carnieli-Cazati D. Impact of respiratory therapy in vital capacity and functionality of patients undergoing abdominal surgery. *Einstein (Sao Paulo)*. 2016 Jun;14(2):202-7. | Incentive spirometer v Bi level positive pressure ventilation<br>Outcomes: Lung function |
| | Klaiber U, Stephan-Paulsen LM, Bruckner T, Müller G, Auer S, Farrenkopf I, Fink C, Dörr-Harim C, Diener MK, Büchler MW, Knebel P. Impact of preoperative patient education on the prevention of postoperative complications after major visceral surgery: the cluster randomized controlled PEDUCAT trial. *Trials.* 2018 May 24;19(1):288. | Preop education many topics including DB&C training using Flutter or Incentive spirometer v information booklet alone. |
| | Pantel H, Hwang J, Brams D, Schnelldorfer T, Nepomnayshy D. Effect of Incentive Spirometry on Postoperative Hypoxemia and Pulmonary Complications After Bariatric Surgery: A Randomized Clinical Trial. *JAMA Surg*. 2017;152(5):422-428. | Incentive spirometer v no treatment control. |
| | Rodrigues MA, Ferreira LM, de Carvalho Calvi EN, Nahas FX. Preoperative respiratory physiotherapy in abdominoplasty patients. *Aesthetic surgery journal*. 2018 Feb 15;38(3):291-9. | Preoperative DB&C exercises + incentive spirometer compared to no treatment control<br>Outcomes: Lung function |
| | Rowley DD, Malinowski TP, Di Peppe JL, Sharkey RM, Gochenour DU, Enfield KB. A randomized controlled trial comparing two lung expansion therapies after upper abdominal surgery. *Resp Care* Oct 2019, 64 (10):1181-1192. | Incentive spirometry v EzPAP lung expansion |
| | Tripathi S, Sharma R. Deep Breathing Exercise and Its Outcome among Patient with Abdominal Surgery: A Pilot Study. *Int J Nursing*. 2017;7(5):103-6. | IS + DB exercises v control group |
| Ineligible outcome measure | Duymaz T, Karabay O, Ural IH. The effect of chest physiotherapy after bariatric surgery on pulmonary functions, functional capacity, and quality of life. *Obesity surgery*. 2020 Jan;30(1):189-94. | Postop coached DB&C exercises v early mobilisation alone.<br>Outcome: Oxygenation, lung function, dysponea, QOL |
| | Gastaldi AC, Magalhães CM, Baraúna MA, Silva EM, Souza HC. Respiratory kinesiotherapy following laparoscopic cholecystectomy. *Rev Bras Fisioter*. 2008;12(2):100-6. | Preop instruction on DB exercises to perform independently postoperatively v no treatment control.<br>Outcome: Lung function |
| | Kale PM, Mohite VR, Chendake MB, Gholap MC. The effectiveness of preoperative deep breathing exercise on postoperative patients of abdominal surgery. *Asian J Pharm Clin Res*. 2017;10(2):157-60. | Preop education and DB exercise training v control<br>Outcomes: Lung function |

**Table 10.3** Characteristics of new studies (2016 – 2020) included in review

| **Author; year** | Country; centres, n | n | PEDro score | Pop | Control | Intervention | Outcome | Result: Control v Intervention/s | Relative risk | Comparator | Interpretation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Abdelaal 2017** | Egypt Single | 50 | 4 | LAS | No preop chest PT Postop twice daily chest PT 15min for 4 days<br><br>PT sessions: 8 | Prehab + preop chest PT 15mins twice a week for 2 weeks. Self-directed DB&C ex twice daily 4 d/week + postop chest PT as per control<br><br>PT sessions: 12 | Atelectasis<br>Pneumonia<br>ARF<br>PPC | 7/24 (29%) v 3/26 (12%)<br>8/24 (33%) v 2/26 (8%)<br>3/24 (13%) v 0/26 (0%)<br>15/24 (63%) v 7/26 (27%) | 0.40 (0.12 to 1.36)<br>**0.23 (0.05 to 0.98)**<br>n/a<br>**0.43 (0.21 to 0.87)** | Postop PT v additional preop PT | The addition of preop supervised prehab and DB&C exercises may minimise PPC after laparoscopic bariatric surgery compared to postop DB&C exercises alone. |
| **Wang 2018** | China Single | 92 | 5 | OAS | No preop chest PT No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br><br>PT sessions: 1 | PPC | 12/46 (26%) v 4/46 (9%) | **0.33 (0.12 to 0.96)** | No PT v preop chest PT | Preop chest PT may minimise PPC after abdominal surgery. |
| **Lohiya 2018** | India Single | 35 | 2 | OAS | No preop chest PT No postop chest PT<br><br>PT sessions: 0 | Preop chest PT<br><br>PT sessions: 1 | Atelectasis<br>Pneumonia<br>PPC | 3/25 (12%) v 1/10 (10%)<br>7/25 (28%) v 1/10 (10%)<br>18/25 (72%) v 4/10 (40%) | 0.83 (0.10 to 7.1)<br>0.36 (0.05 to 2.5)<br>0.56 (0.25 to 1.2) | No PT v preop chest PT | Preop chest PT may not reduce PPC rates |
| **Boden 2018b** | Australia New Zealand Multi N=3 | 432 | 8 | OAS | No preop chest PT Standardised postop ambulation<br><br>PT sessions: 3-4 | Preop chest PT Standardised postop ambulation<br><br>PT sessions: 4-5 | Atelectasis<br>Pneumonia<br>PPC | 57/214 (27%) v 39/218 (18%)<br>42/214 (20%) v 18/218 (8%)<br>58/214 (27%) v 27/218 (12%) | **0.67 (0.47 to 0.96)**<br>**0.42 (0.25 to 0.71)**<br>**0.46 (0.30 to 0.69)** | No PT v preop chest PT | Preop chest PT reduces postoperative PPC and pneumonia |

Legend: ARF = acute respiratory failure, d = days, DB&C = deep breathing and coughing, LAS = lower abdominal surgery, multi = multicentre trial, n = number, OAS = open abdominal surgery, PEDro = physiotherapy evidence database, pop = population, PPC = postoperative pulmonary complication, postop = postoperative, preop = preoperative, PT = physiotherapy, single = single centre trial, v = versus.
Statistically significant results are in **bold font**

**Table 10.4** Methodological quality of new included trials in updated systematic review

| Study | Random allocation | Concealed allocation | Baseline comparability | Participant blinding | Therapist blinding | Assessor blinding | <15% dropouts | Intention-to-treat analysis | Between-group difference | Point estimate | Total score (0 to 10) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Abdelaal 2017** | Y | N | Y | N | N | N | N | N | Y | Y | 4 |
| **Wang 2018** | Y | Y | N | N | N | N | Y | N | Y | Y | 5 |
| **Lohiya 2018** | Y | N | N | N | N | N | N | N | Y | N | 2 |
| **Boden 2018b** | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | 9 |

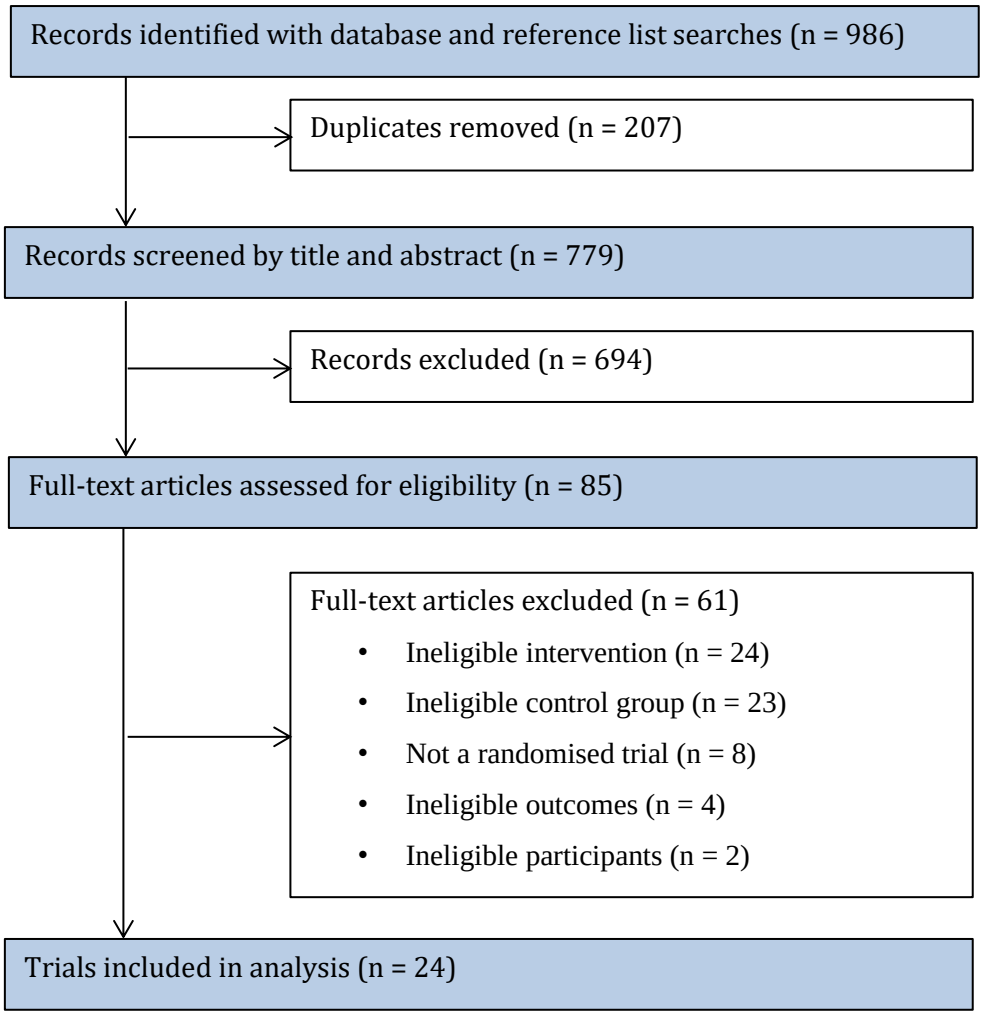



**Figure 10.1** Flow of studies for selection in updated review

#### 10.3.3.2 Characteristics of new included studies

The four new included studies (Abdelaal et al 2017, Wang, Yuan & Ding 2018, Lohiya et al 2018, Boden et al 2018b) involved an additional 609 participants having major abdominal surgery. The total number of participants in this updated meta-analysis is 2524. Tables 10.2 and 10.3 summarise the characteristics and methodological quality of the newly included studies. Three of the new studies (Wang, Yuan & Ding 2018, Lohiya et al 2018, Boden et al 2018b) investigate the effectiveness of preoperative chest physiotherapy alone compared to a no treatment control group. The remaining study investigates the effect of the addition of preoperative chest physiotherapy to postoperative chest physiotherapy (Abdelaal et al 2017).

*Quality*

Three of the new studies had low methodological quality with an average PEDro score of 3.6 (SD 1.5). The risk of bias is high in these studies with unblinded outcome assessors. The study

included in this thesis (Boden et al 2018b), and now included in this updated meta-analysis, has the highest methodological quality of all included 24 trials with a PEDro score of 9.

*Participants*

Of the four new studies, three involved open abdominal surgery (Wang, Yuan & Ding 2018, Lohiya et al 2018, Boden et al 2018b) and the other enrolled only patients undergoing laparoscopic bariatric surgery (Abdelaal et al 2017). The three single centre studies were conducted in Egypt, India and China. The LIPPSMAck-POP trial was one of only two multicentre trials included in this meta-analysis (Boden et al 2018b, Condie, Hack & Ross 1993).

*Interventions*

Three of the newly added trials tested the effect of preoperative chest physiotherapy to reduce PPC after abdominal surgery compared to a no treatment control (Wang, Yuan & Ding 2018, Lohiya et al 2018, Boden et al 2018b). Abdelaal and colleagues (2017) assessed the benefit of adding preoperative chest physiotherapy to a postoperative chest physiotherapy program alone. Of all 24 studies included in the updated review, three specified that postoperative ambulation was standardised between groups (Boden et al 2018b, Silva, Li & Rickard 2013, Mackay, Ellis & Johnston 2005).

#### 10.3.3.3 Synthesis of results: meta-analysis

*Effect of chest physiotherapy versus no chest physiotherapy*

The updated effects of the 18 studies investigating the incidence of PPC after abdominal surgery, comparing the effect of providing chest physiotherapy to no chest physiotherapy, is shown in Figure 10.2. The addition of the four new trials did not impact the main findings as presented in Chapter 4.

The updated total pooled RR estimate finds that chest physiotherapy significantly reduced PPC by an estimated 16%, with the true value lying somewhere between 11% and 20% (RR 0.84, 95% CI 0.80 to 0.89). This is an equivalent NNT of 6 (95% CI 5 to 9). With new data, point estimates are more precise with tighter confidence intervals and the estimate of effect becomes marginally lower.

The pooled estimated PPC incidence of patients who did not receive any coached DB&C exercises by a physiotherapist was 265/906 (29%, 95% CI 26% to 32%). For patients provided with DB&C exercises by a physiotherapist either before or after surgery, or both, the overall estimate of PPC incidence was 135/889 (15%, 95% CI 13% to 18%). In this updated analysis the

PPC incidence in participants provided with preoperative physiotherapy was higher at 9% (40/423, 95% CI 7% to 13%). For those who received chest physiotherapy only in the postoperative phase the pooled PPC incidence remained at 27% (95% CI 21% to 33%).

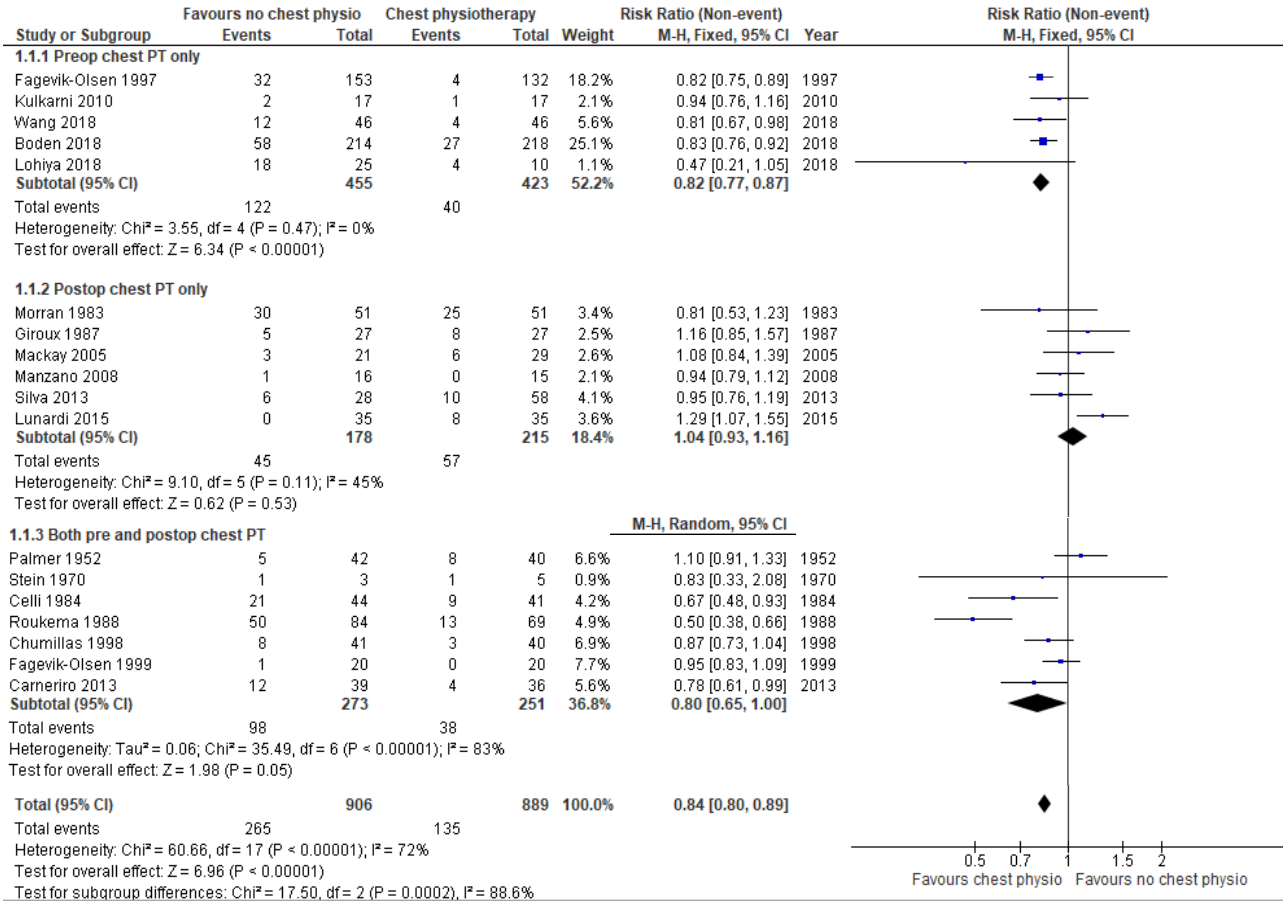



**Figure 10.2** Updated meta-analysis of the effect of chest physiotherapy compared to no-treatment control on PPC risk after abdominal surgery.

The additional studies improved the homogeneity of results from studies involving only preoperative chest physiotherapy. Funnel plot comparison finds all studies investigating preoperative chest physiotherapy to be within a reasonable standard error (Figure 10.3). Studies combining both pre- and postoperative chest physiotherapy had the greatest heterogenity at $I^2$ = 83%.

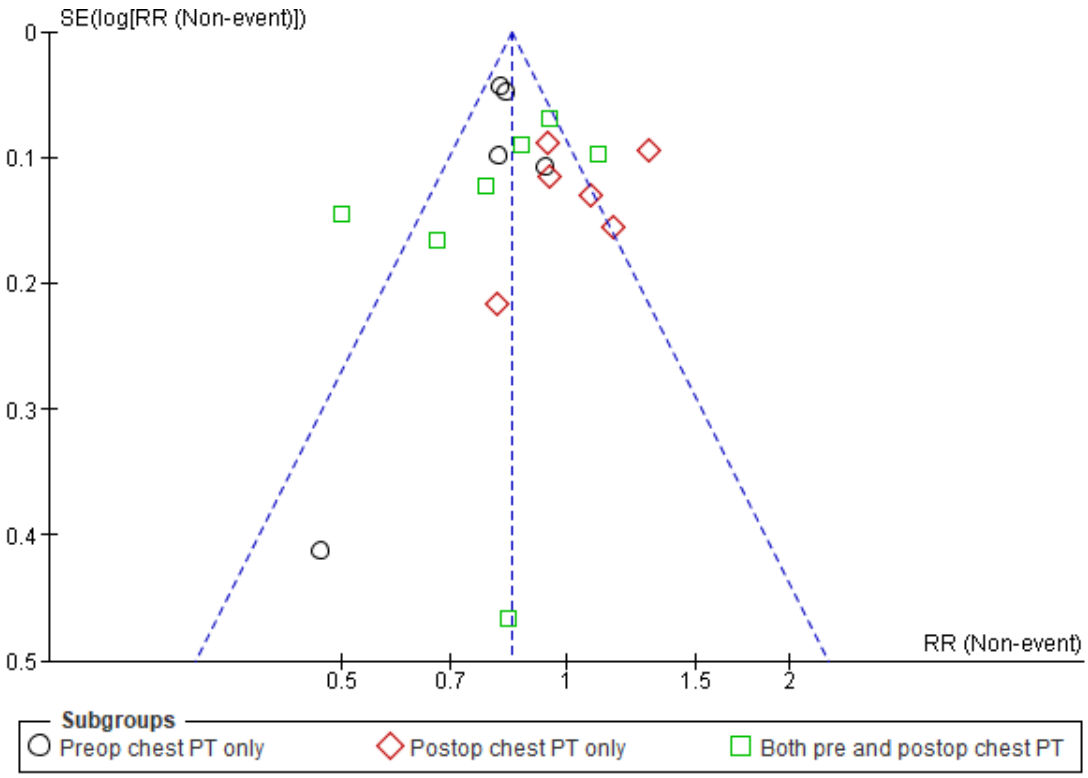



**Figure 10.3** Funnel plot of studies comparing chest physiotherapy to a no-treatment control

**No-treatment control comparator**

*Effect of preoperative physiotherapy alone versus no-treatment control*

The newly added studies strengthen previous findings that patients have significantly less estimated risk of a PPC after abdominal surgery if provided with preoperative education and training on DB&C exercises. As shown in Figure 10.2, the updated analysis finds that the risk of a PPC is reduced by an estimated 18%, with the true value lying between 13% and 23%. This provides a more precise estimate of effect, with preoperative chest physiotherapy preventing one PPC for *at least* every 8 patients treated.

*Effect of postoperative physiotherapy alone versus no-treatment control*

The updated analysis did not alter original findings (Figure 4.2 and Figure 10.2) as no new trials were added to this sub-group analysis. Providing chest physiotherapy in the postoperative phase only was found not to confer a benefit in the reduction of PPC with an RR of 1.04 (95% CI 0.93 to 1.16).

*Effect of combined pre- and postoperative chest physiotherapy versus no-treatment control*

The updated analysis did not alter original findings as no new trials were added to this sub-group analysis. The RR estimate is of 0.80 (95% CI 0.65 to 1.00), favouring patients who receive chest

physiotherapy both before and after surgery (Figure 4.2 and Figure 10.2). This estimate lacks precision and the possibility of no benefit exists with the upper 95% CI touching 1.00.

**Active control comparator**

*Effect of adding postoperative chest physiotherapy to preoperative physiotherapy alone*

The updated analysis did not alter original findings as no new trials were added to this analysis. (Figure 4.3). The addition of postoperative chest physiotherapy did not confer any benefit over and above preoperative chest physiotherapy alone (RR 1.07, 95% CI 0.71 to 1.60).

*Effect of adding preoperative chest physiotherapy to postoperative physiotherapy alone*

A newly added trial conducted in 2017 (Abdelaal et al 2017) assessed the benefit of adding preoperative chest physiotherapy and supervised physical activity to an existing postoperative chest physiotherapy protocol compared with postoperative physiotherapy alone. This trial found that adding a multimodal preoperative physiotherapy programs reduced PPC incidence by approximately a half (Figure 10.4; RR 0.51, 95% CI 0.29 to 0.90). Interpretations of this outcome should be cautious considering that this is a single trial only of small numbers and only fair methodological quality, including unblinded assessors.

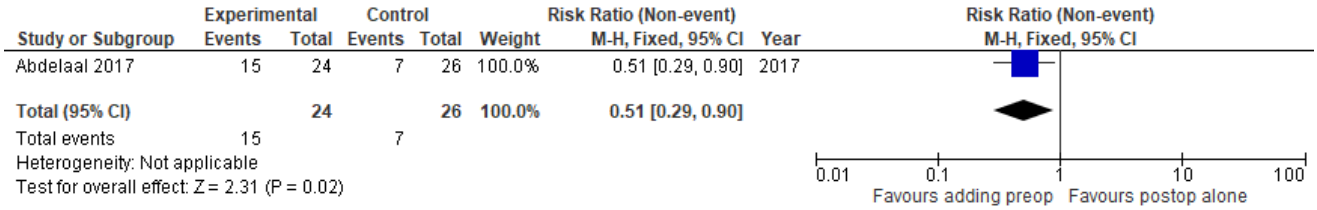



**Figure 10.4** Forest plot of a trial testing the addition of multimodal preoperative physiotherapy compared to postoperative chest physiotherapy alone.

## 10.3.4 Discussion

This updated meta-analysis of eligible trials from 1950 to 2020 that investigated the effect of chest physiotherapy to reduce the risk of PPC after abdominal surgery finds that there is 95% certainty that chest physiotherapy reduces PPC incidence by between 11% and 20%. The addition of four new trials conducted from 2016 to 2020, including the LIPPSMAck-POP trial contained within this thesis, confirms previous findings of a significant sub-group benefit to the timing of chest physiotherapy delivery. In trials where patients received preoperative physiotherapy the risk of PPC was reduced by between 16% to 24%, whereas if patients were seen by a physiotherapist after surgery only no PPC risk reduction is realised.

The reliability of these meta-analysis findings should be considered quite robust. Results are not affected by sensitivity analyses where lower quality trials are removed. Moreover, the

LIPPSMAck-POP trial has the highest methodology score of all included trials, including blinding of both assessors and patients and concealed allocation of group assignment. In addition, it was the only multicentre bi-national pragmatic clinical trial conducted within modern perioperative surgical practices of an outpatient preoperative assessment clinic and included a hospital with ERAS principles.

## 10.4 Prehabilitation updated to 2020

The concept of prehabilitation ('prehab') has been discussed in earnest since the early 2000s (Carli & Zavorsky 2005). Consistent strong associations between poor preoperative strength and fitness and increased risk of postoperative complications, mortality, and hospital LOS (Soares & Nucci 2019, Moran et al 2016b, Hightower et al 2010, Smith et al 2009) have led to the compelling concept that improving a patient's physical fitness prior to surgery could reduce the risk of adverse events and enhance recovery following surgery (Mayo et al 2011). 'Prehab' is a term encompassing targeted programs and interventions that aim to improve a patient's functional capacity prior to surgery, with the goal to ameliorate the inevitable declines in short and medium-term physical function and performance after surgery (Lawrence et al 2004).

The first randomised controlled trial in prehab for patients awaiting abdominal surgery was published in 2009 (Kim et al 2009). In the 10 years since approximately 15 additional trials have been published (Hughes et al 2019). Many new trials are currently active and recruiting (Berkel et al 2020, Sheill et al 2020, van Rooijen et al 2019, Karlsson et al 2019, Allen et al 2018, McIsaac et al 2018, Woodfield et al 2018, Abdullah et al 2017). This reflects the intense interest that the perioperative medicine community has in this field.

The prehabilitation literature up to 2016 was reviewed and discussed briefly in Chapter 2, p. 18. Since that time there is no shortage of systematic reviews that have attempted to synthesize the evidence of clinical trials in prehab specifically for patients undergoing abdominal surgery (Hughes et al 2019, Bolshinsky et al 2018, Hijazi, Gondal & Aziz 2017, Moran et al 2016b, Bruns et al 2016). Unfortunately, the findings of these reviews remain as unclear as the ones discussed in Chapter 2, p.18, and for the same reasons. The main limitations are heterogeneity of included trials, namely: studies with differing patient risk profiles, multimodal intervention packages, non-exercise based therapy (e.g. IMT only, or breathing exercises only), active control groups (e.g. high intensity exercise versus low intensity exercise; prehab versus walking program), and studies that involved a heterogeneous mix of exercise modalities, intensities, time frames, and number of supervised sessions. This heterogeneity precludes an overarching statement regarding the effectiveness of prehab in general.

The use of multimodal interventions in prehab trials can make interpretation difficult and clouded. Trials included in systematic reviews that have specifically reported on PPC have almost all involved a combination of exercise therapy and IMT (Valkenet et al 2011, Santa Mina et al 2014, Pouwels et al 2014). IMT is likely to be independently and strongly associated with reduced risk of PPC after surgery (Kendall et al 2018, Mans, Reeve & Elkins 2015). For multimodal studies that combine exercise therapy and IMT, it cannot be determined if positive outcomes to PPC are improved through the IMT, the exercise program, or the combination of both. A conclusion that 'prehab results in reductions to PPC' may be erroneous (Moran et al 2016b) rather the conclusion that 'IMT leads to reduction in PPCs' (Kendall et al 2018) would be more appropriate. The INSPIRE trial is a large (n=2500) multicentre randomised controlled trial that is currently active and aiming to definitively determine if IMT independently reduces PPC in patients undergoing cardiothoracic or abdominal surgery (UK POMCTN 2018).

The confusion surrounding what exactly is 'prehabilitation' highlights the importance of distinct definitions of the variety of preoperative interventions, and the term 'prehabilitation' itself. A lack of a clear understanding of the different prehab interventions could lead clinicians to misinterpret broad statements made by authors that e.g. 'prehab prevents PPCs' (Moran et al 2016b). Clinicians might interpret this statement that exercise-based prehab is effective and neglect to implement IMT in favour of exercise alone. Interpretation and implementation errors could also occur through misunderstanding the differences between multidisciplinary *multimodal* prehabilitation; that is, various combinations of exercise, diet, psychology, and respiratory interventions, and *unimodal* exercise-alone prehabilitation.

There is little doubt that a supervised preoperative moderate to high intensity cardiovascular exercise programs improves physical fitness (Moran et al 2016a, Cabilan, Hines & Munday 2015, O'Doherty et al 2013, Lemanu et al 2013). Whether the fitness improvements carry over to impact postoperative complications and length of stay is still unknown. **Table 10.5** summarises all prehabilitation randomised controlled trials published to 2020 in the abdominal surgery population, both multimodal and unimodal, that have reported on postoperative hospital stay and complications. As the evidence for IMT to reduce postoperative LOS and complications is strong (Kendall et al 2018, Mans, Reeve & Elkins 2015), trials which included IMT have been excluded. This is to prevent the possibility of results being confounded by the effects of this single intervention.

**Table 10.5 Randomised controlled trials involving exercise-only prehabilitation prior to abdominal surgery.**

| Author | Sample size | Patients | Control | Intervention | Outcomes, control v intervention: LOS, all-cause complications, PPC | General conclusion |
|---|---|---|---|---|---|---|
| **Home-based exercise program v no exercise control** | | | | | | |
| *Unimodal – exercise alone* | | | | | | |
| Santa Mina 2018 | 86 | Radical prostatectomy | Standard care | Individualised home-based moderate intensity strength and condition program. 60 mins, 3-4/week for 4-6 weeks | LOS: 2 (1) v 2 (1); NS<br>Complications, postop: 36% v 42%; NS | UNCERTAIN<br>An individualised home exercise program did not reduce LOS or reduce complications. |
| Jensen 2015 | 107 | Radical cystectomy | No preop exercise<br>Early postop mobilisation once daily | Home-based daily strength and conditioning for 2 weeks<br>+ Enhanced physio on ward postop (2 x 30 min daily) | LOS: 8 [4-55] v 8 [3-30]; NS<br>Complications, 90d: 60% v 60%; NS | UNCERTAIN<br>A home-based exercise program did not improve postoperative outcome or shorten LOS |
| *Multimodal* | | | | | | |
| Minnella 2018 | 68 | Esophagectomy | Standard care | Dietary advice and protein supplementation<br>Individualised home-based strength and conditioning program. 30 min 4/week for 4-5 weeks. Supervised once. Weekly phone support. | LOS: 7 [6-13] v 8 [6-12]; NS<br>Complications, 30d: 72% v 58%; NS | UNCERTAIN<br>Multidisciplinary assessment and prescription of a telephone supported home based exercise program did not reduce postoperative complications or LOS. Possible effects detected to morbidity warrant testing in a powered RCT. |
| Liang 2018 | 77 | Obese ventral hernia repairs | Standard preop counselling | Multidisciplinary preop optimisation focusing on diet and exercise.<br>General home exercise program with DVD | LOS: 0 (0.1) v (0.2); NS<br>Complications, 30d: 18% v 7%: NS | UNCERTAIN<br>A generic home exercise program with dietary advice did not reduce LOS or reduce complications. Possible effects detected to surgical site complications warrant testing in a powered RCT. |
| Gillis 2014 | 77 | Colorectal cancer resection | No preop exercise | 1h assessment and prescription with Physio, 1h with dietician, 1h with psychologist<br>Home exercise moderate intensity strength and conditioning program 1/h 3/week<br>Weekly phone calls | LOS: 4 [3-7] v 4 [3-5]; NS<br>Complications, 30d: 44% v 32%; NS | UNCERTAIN<br>Multidisciplinary assessment and prescription of a telephone supported home based exercise program did not reduce postoperative complications or LOS. Possible effects detected to morbidity warrant testing in a powered RCT. |

**Table 10.5 Randomised controlled trials involving exercise-only prehabilitation prior to abdominal surgery (cont).**

| Author | n | Patients | Control | Intervention | Outcomes: LOS, all-cause complications, PPC | General conclusion |
|---|---|---|---|---|---|---|
| **Home-based strength and conditioning v walking/breathing exercises** | | | | | | |
| Carli 2010 | 112 | Colorectal surgery | Exercise test<br>Single home visit<br>Weekly phone calls<br>30-min daily walking<br>Breathing exercises 5min/day | Exercise test<br>Single home visit<br>Weekly phone calls<br>Home based bike training and weight training, 30-45min for 6-8 weeks preop | LOS: 7 (4) v 12 (35), or,<br>7 (4) v 7 (7) removing outlier; NS<br>Complications, postop: 32% v 39%; NS | NEGATIVE<br>A supported home-based strength and conditioning program did not reduce LOS or postoperative complications compared to a breathing exercise and walking program. |
| **Supervised multimodal prehabilitation v home exercise program** | | | | | | |
| Bausquet Dion 2018 | 80 | Colorectal cancer resection | Exercise test and exercise advice<br>Respiratory and nutritional education<br>Psychology session<br>Home-based moderate intensity strength and conditioning program 1/h 3/week | Control +<br>Prescribed home-based moderate intensity exercise program (strength and conditioning)<br>Supervised training 1h 1/week for 4 weeks<br>Diet advice and protein supplementation<br>Psychological counselling | LOS: 3 [2-4] v 3 [3-4]; NS<br>Complications, 30d: 31% v 38%; NS | UNCERTAIN<br>A supervised multimodal prehabilitation program did not reduce LOS or postoperative complications compared to a home-based unsupervised program. |

**Table 10.5 Randomised controlled trials involving exercise-only prehabilitation prior to abdominal surgery (cont).**

| Author | n | Patients | Control | Intervention | Outcomes: LOS, all-cause complications, PPC | General conclusion |
|---|---|---|---|---|---|---|
| **Supervised prehabilitation v no exercise control** | | | | | | |
| *Unimodal – exercise alone* | | | | | | |
| Banerjee 2018 | 60 | Radical cystectomy | No preop exercise | Supervised high intensity interval training cycle-based.<br>30mins, 2/week, 3 – 6 weeks; 10 total sessions | LOS: 7 [5-107] v 7 [4-78]; NS<br>Complications, postop: 36% v 15%; NS | UNCERTAIN<br>Supervised high intensity cycle training did not reduce LOS or postop complications. Possible effects detected to morbidity warrant testing in a powered RCT. |
| Tew 2017 | 53 | AAA | No preop exercise | Supervised hospital-based high intensity cycle training. 30min, 3/week for 4 weeks | LOS: 6 [4-8] v 7 [5-9]; NS<br>Complications, postop: NS (data not in proportions, reported as a composite score) | UNCERTAIN<br>Supervised hospital high intensity exercise program did not reduce LOS or postop morbidity. |
| Dunne 2016 | 38 | Liver resection | No preop exercise | Supervised intense interval training cycle-based.<br>30 mins for 12 sessions over 4 weeks<br>30min 3/week 4 weeks; 12 total sessions | LOS: 5 [5-7] v 5 [4-6]; NS<br>Complications, postop: 47% v 42%; NS | UNCERTAIN<br>Supervised intense cycle training did not reduce LOS. Possible effects detected to morbidity warrant testing in a powered RCT. |
| Barakat 2016 | 124 | Open (63%) or endovascular (37%) AAA | No preop exercise | Supervised group-based strength and conditioning program<br>1h 3/week 6 weeks; 18 total sessions | LOS: 8 [6-12] v 7 [5-9]; p=0.03<br>Complications, postop: 42% v 23%; p=0.02<br>PPC: 21% v 11%; NS | POSITIVE<br>A supervised group strength and condition program reduced LOS and complications. Possible effects detected to PPC require verification in a powered RCT. |
| *Multimodal* | | | | | | |
| Carli 2020 | 418<br>Multicentre | Frail colorectal cancer resection | No preop interventions<br>Standard care | Hospital-based supervised moderate intensity strength and conditioning. 1/wk for 4 weeks.<br>Personalised home-based moderate intensity walking program 30 min daily, strength training 3/week.<br>Dietary counselling and protein supplementation | LOS: 4 [3-8] v 4 [3-8]; NS<br>Complications: 46% v 46% | NEGATIVE<br>A multimodal prehabilitation program did not reduce LOS or postoperative complications compared to standard care. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Psychology counselling and exercises 3/week | | |
| Barberan-Garcia 2018 | 144 | High-risk major abdominal surgery | Exercise advice | Motivational interviewing<br>Prescribed home exercise program<br>Supervised high-intensity cycle training, 40 mins, 1-3/week for 4 weeks preop | LOS: 13 (20) v 8 (8); NS<br>Complications, postop: 62% v 31%; p=0.001<br>PPC: 16% v 7%; NS | POSITIVE<br>A high intensity cycle program with intensive motivational interviewing reduces postop complications. Possible effects detected to LOS and PPC warrant testing in a powered RCT. |
| Kaibori 2013 | 51 | Hepatectomy | Diet advice | Diet advice + supervised moderate to high-intensity walking and stretching 1h 3/week for 4 weeks preop | 17.5 v 13.7 days LOS (NS)<br>13% v 8.7 % morbidity (NS) | UNCERTAIN<br>Supervised moderate to high intensity exercise program with diet advice may reduce LOS and morbidity in an appropriately powered study |
| **Abbreviations:** AAA=abdominal aorta aneurysm; h=hour; ISQ=no difference; LOS=length of stay; min=minute; NS=not significant; preop=preoperative; postop=postoperative; PPC=postoperative pulmonary complication; RCT=randomised controlled trial; v=versus;<br>Legend: ( )=standard deviation; [ ]=interquartile range | | | | | | |

On the evidence presented there is uncertain benefit for prehab to influence postoperative outcomes in patients provided with a *home-based* prehabilitation program, either through exercise alone (Santa Mina et al 2018, Jensen et al 2015), or combined with dietary advice, protein supplementation, or psychological support (Minnella et al 2018, Liang et al 2018, Gillis et al 2014). None of these trials were adequately powered to detect small, yet arguably clinically important, differences in postoperative complications. The non-significant differences detected in postoperative complications favouring patients provided with multimodal prehab (Minnella et al 2018, Liang et al 2018, Gillis et al 2014) require confirmation with an adequately powered multicentre randomised controlled trials.

The failure of home-based exercise programs to benefit postoperative outcomes has been posited as due to uncertainty over patient compliance and maintenance of adequate exercise intensity during unsupervised exercise (Carli et al 2010). There is a possibility that supervising a patient directly in a formal gym environment will improve the treatment fidelity and increase the likelihood of a positive effect. This has been explored in seven *supervised gym-based* trials: four unimodal exercise-alone prehab trials (Banerjee et al 2018, Tew et al 2017, Dunne et al 2016, Barakat et al 2016), and three multimodal multidisciplinary trials (Carli et al 2020, Barbaran-Garcia et al 2018, Kaibori et al 2013). All trials compared prehabilitation to standard care. Across these seven trials, there is again a lack of a clear improvement in postoperative LOS and complications in patients who attended gym-based supervised prehab programs, with or without additional components, such as dietary and psychological support (Table 10.5).

Only two trials (from the entire 15 reviewed here) have reported a significant reduction in postoperative complications; a multimodal prehab trial (Barbaran-Garcia et al 2018), and an exercise-only trial (Barakat et al 2016), with only this last trial reporting a significant reduction in LOS (Barakat et al 2016). Both trials were in high-risk populations. It may be that prehab is only effective in a targeted high-risk population, rather than for all-comers listed for elective abdominal surgery. Some patients may be more responsive to prehab than others. Previous prehab trials specifically targeting frail patients have been of low quality and with uncertain benefit to postoperative mortality and morbidity (Milder et al 2018).

A recently published high quality trial with a sample size almost four times larger than the next largest and, to date, the only multicentre trial in the prehabilitation field (Carli et al 2020) set out to determine if a multimodal prehab program could reduce postoperative complications in frail patients awaiting colorectal resection. This trial found that prehabilitation provided no benefit to complication rates, LOS, or patient-reported outcomes. This negative outcome was suggested by the authors to be due to the independent treatment benefit of ERAS pathways which were embedded in the two participating hospitals. However, the baseline overall complication rate was

45%. A treatment effect would be reasonable to expect on such a high baseline, irrespective of existing ERAS pathways.

Another possible limitation is that the selected patient cohort was not responsive to prehab. It is possible that the stratification tool used to identify frailty did not accurately detect high-risk patients. Recent high-quality evidence has added to the debate surrounding how to accurately identify high risk patients. Wijeysundera and colleagues (2018) reported a large multicentre international study investigating the accuracy of preoperative fitness in predicting postoperative morbidity and mortality after non-cardiac surgery. These data showed that a preoperative formal cardiopulmonary exercise test is not superior to a simple paper-based patient-reported fitness and activity questionnaire. These findings would indicate that it may be possible to stratify high-risk patients into a prehab program without the use of high-cost, moderate-risk formal exercise testing. Determining the most accurate means to measure and predict postoperative risk of morbidity and mortality is important and warrants further research (Moran et al 2016a). This will ensure that patients are selected appropriately and provided targeted efficacious preoperative interventions that improve postoperative outcome.

Based on the existing evidence of prehabilitation trials it is unclear if prehab can improve postoperative recovery in the abdominal surgery population. Further research is required to determine the ideal timing, method, and dosage of preoperative exercise training required to, not only improve a patient's fitness prior to surgery, but also lead to a reduction in postoperative morbidity. It is possible that prehabilitation improves postoperative recovery, yet this has not been measured with a sensitive tool that detects factors important to patients (Fiore et al 2018). It is currently not proven that prehab can prevent early postoperative mortality. Long-term effects of prehabilitation may need to be considered in future trials. An association between disease-free survival and prehabilitation interventions has been found in pooled data from three prehab trials in patients having colorectal surgery (Trépanier et al 2019). It may be that a prehabilitation intervention engenders a behaviour change to increase overall physical activity even after surgery, and beyond the postoperative period, that may affect mortality.

The ideal type of multimodal package of care that is required to optimize a patient's postoperative outcome is unknown. There is little evidence to indicate whether each component (dietary advice, exercise training, psychological support) is independently beneficial, or cost-effective if provided as a whole, or indeed, if only one component is needed. Data on cost-effectiveness remains to be verified with positive data currently from only one single centre trial (Barbaran-Garcia et al 2019). Despite this, the lack of clear evidence supporting prehab has not stopped health care services from implementing targeted formal prehabilitation programs (Moore et al 2020).

In light of the above synthesis of the current evidence for prehab and in context of the findings of this thesis, it is apparent that the evidence for preoperative physiotherapy alone to reduce a postoperative complication is stronger than that for prehabilitation. The specificity of targeted treatments to effect specific outcomes may also be important to consider. Respiratory targeted interventions such as preoperative physiotherapy (Boden et al 2018b) and IMT (Kendall et al 2018) to prevent PPC after abdominal surgery; the delivery of exercise-based prehabilitation to a targeted high-risk population to improve physical fitness. Preoperative physiotherapy at preadmission clinics is arguably more cost-effective for the hospital than a full prehabilitation program and more feasible for patients to comply with, being only a single session and delivered within existing clinics and infrastructure, without additional equipment, or additional travel for the patient. On the balance of the evidence presented in this thesis, it would be a sensible recommendation for hospitals to first implement preoperative physiotherapy to all patients listed for elective abdominal surgery, secondly, implement additional IMT in those considered at risk of a PPC, and thirdly, investigate scope, costs, and local capacity to introduce a prehabilitation service for high-risk patients once evidence for this intervention firms.

## 10.5 Implications

Future trials investigating the prophylaxis of PPC will need to consider the influence of emerging interventions aiming to minimise this serious postoperative complication. If confounding treatments cannot be controlled for through protocol mandated therapy, then at a minimum they will need to be measured, recorded, and reported, and considered as a baseline covariate to determine baseline comparability.

The strong consistent evidence presented in this thesis regarding the independent effect that preoperative physiotherapy has on PPC minimisation has implications for other perioperative medicine researchers who may need to consider this in their future trial design, where preoperative physiotherapy will need to be standardised between groups.

Anaesthetists and physiotherapists are the two main professions driving research in the prevention of PPC, prehabilitation, IMT, and postoperative recovery. Natural synergies already exist between the two professions with common interests and fields of speciality in pain science, respiratory physiology, and exercise science. The consolidation of a dedicated multidisciplinary team involving anaesthetists, surgeons, and physiotherapists to conjointly manage perioperative pathways of risk assessment, fitness for surgery, preoperative optimisation, and postoperative recovery is an exciting future prospect.

# CHAPTER 11

# Conclusion and future directions

## 11.1 Summary of thesis findings

Despite modern advances in surgery and anaesthetic practices, a PPC remains a common cause of morbidity and mortality following elective upper abdominal surgery (Ferrando et al 2018, Fernandez-Bustamente et al 2017). A narrative review of the literature finds that preoperative education and training in breathing exercises to be performed in the early postoperative period has the potential to reduce the incidence of PPC. The efficacy of preoperative physiotherapy to reduce the risk of PPC after abdominal surgery has not previously been tested in a rigorous manner.

**Key findings from this thesis are:**

**1. Systematic review main findings:**

- Compared to participants who did not receive any chest physiotherapy, participants who received chest physiotherapy of coached DB&C exercises at any time in their perioperative journey had an estimated 16% less risk (RR 0.84, 95% CI 0.80 to 0.89) of a PPC after abdominal surgery, with a NNT of 6 (95%CI 5 to 9).
- Participants whose only intervention was preoperative physiotherapy education and training on DB&C exercises to perform on waking from surgery had a significant reduction in PPC incidence compared to those who received no physiotherapy (RR 0.82, 95% CI 0.77 to 0.87).
- Participants who received chest physiotherapy in the postoperative phase only may not have reduced risk of PPC compared to participants receiving no chest physiotherapy.
- The addition of postoperative chest physiotherapy to preoperative chest physiotherapy may not confer additional reduction in PPC risk compared to preoperative chest physiotherapy alone.
- Increasing the dosage of postoperative chest physiotherapy sessions may not confer additional benefit in the reduction in PPCs.
- Trials testing chest physiotherapy and reporting on PPCs after abdominal surgery are predominately of low methodological quality.

**2. RCT main findings:**

- Preoperative physiotherapy education and breathing exercise training has high impact with eight out of 10 intervention participants reporting the treatment session to be the most memorable part of the entire preadmission clinic day.
- A sample of participants reported that preventing pneumonia after surgery was very important to them. They found the preoperative physiotherapy intervention interesting, informative, and empowering.
- Preoperative physiotherapy has high treatment fidelity, with participants receiving a face-to-face preoperative physiotherapy session significantly more likely to remember DB&C exercises (94%) after the operation compared to those participants given the information in booklet form only (15%).
- The incidence of PPCs, including pneumonia, was halved in the intervention group (HR 0.48, 95% CI 0.30 to 0.75).
- Intervention participants required 40% fewer antibiotics for respiratory infections, had less purulent sputum, had fewer positive sputum cultures, and were less likely to require oxygen therapy.
- Administrative diagnostic coding specific to pulmonary collapse and infection were significantly lower in the intervention group.
- There were no statistically significant benefits measured for the secondary outcomes of hospital length of stay (1.12 days, 95% CI 0.94 to 1.34) or hospital mortality.
- Analysis by sub-group indicated that there may be a benefit in patients being treated by an experienced physiotherapist, with a statistically significant effect on all-cause mortality at 12 months (HR 0.29, 95% CI 0.09 to 0.90).
- The clinical benefit of the intervention to PPC reduction was evident only in participants who were conscious and extubated following surgery.
- The intervention group tended to consume fewer hospital resources following surgery.
- Preoperative physiotherapy is likely to be cost-effective, with a 60% probability that the service would be at least cost neutral.
- There is 95% probability that the cost of funding a preoperative physiotherapy service to reduce the incidence of one PPC would cost less than the costs to the hospital of treating a single PPC after surgery.
- Sub-group analysis according to experience level found that when experienced physiotherapists provide the intervention there is improved incremental net cost benefit to the hospital and benefits to the patient, with significantly better QALYs at 12 months.

## 11.2 Strengths and limitations of the thesis research

The major strengths of this thesis include:

- The systematic review provides a unique summary of the effect of breathing exercises alone on the incidence of PPC after abdominal surgery when compared to true no-treatment control groups. It provides a novel perspective on the influence of timing of the first physiotherapy session.
- The narrative review highlights the physiological plausibility of preoperative physiotherapy being an effective method to enable patients to start breathing exercises immediately after surgery.
- LIPPSMAck-POP provides strong evidence within a phase-3 binational, multicentre trial of high methodological quality and generalisability regarding the efficacy of preoperative physiotherapy to reduce the risk of PPC and affecting other important clinical outcomes such as antibiotic prescriptions and oxygen therapy requirements to all patients having major elective abdominal surgery.
- The qualitative outcomes provide evidence regarding the value and perceived benefits that patients place on receiving a physiotherapy session within preadmission clinics prior to major abdominal surgery. This has not been reported previously.
- The health economic analysis demonstrates that this intervention is also cost-effective.

Limitations within this thesis need to be considered. LIPPSMAck-POP was not powered for secondary outcomes such as hospital LOS or mortality. Additionally, this trial was conducted in developed Western countries and with English speakers only. The effectiveness of preoperative physiotherapy education and breathing exercise training could be different within other cultures and languages. Given a number of participants were unable to be interviewed at the six-week follow up point, it is possible that the HRQoL results within this thesis may not be representative of all patients having abdominal surgery.

Further in-depth details regarding research limitations are outlined in Chapters 4, 6, 7, 8, and 9. The possible benefit of preoperative physiotherapy should be investigated further in other patient populations and in different settings.

## 11.3 Future directions

**Implementation of preoperative physiotherapy**

Future research is required to explore how to effectively implement a new preoperative physiotherapy service. Qualitative and implementation science research is required to explore the

barriers and enablers surrounding the implementation of a new physiotherapy service within preadmission clinics.

**Mode of delivery of preoperative education and training**

The experiential effects detected within LIPPSMAck-POP, with improved outcomes when experienced practitioners applied the intervention, also need exploring. General preoperative education that included detailed information on preventing PPC, delivered by a nurse in a group setting did not alter postoperative pneumonia rates (Klaiber et al 2018). The strong effectiveness of the LIPPSMAck-POP intervention compared to the negative PEDUCAT trial (Klaiber et al 2018) could be explained by the differences between the trials. Firstly, a physiotherapist delivered the respiratory education and training in LIPPSMAck-POP, and secondly, the session was delivered individually and not in a group setting. The difference in outcomes dependent on profession and mode deserve further exploration, especially considering the possible difference this could have on a serious outcome such as postoperative pneumonia. There is mounting evidence that the quality and quantity of preoperative education is strongly related to postoperative outcomes (Koivisto et al 2020, Forsmo et al 2018, Wright et al 2018, Zhou et al 2018) and that nurses may not be ideally placed to deliver information specific to respiratory complications and breathing exercises (Ünver, Kivanc & Alptekin 2018, McTier, Botti & Duke 2016).

Methods need to be developed to efficiently measure treatment fidelity, e.g. digital technologies and provide clinicians with feedback on success of patient recall of the education and training provided. Options need to be explored on how to deliver preoperative physiotherapy to those patients who are unable to come to a face-to-face clinic. It is unknown if the effects reported in the LIPPSMAck-POP trial and others (Wang, Yuan & Ding 2018, Fagevik-Olsén et al 1997) could be replicated with different modes of service delivery such as on-line webinars, telehealth, and other innovative media. Although the provision of internet-based personalised and interactive perioperative information and guidance has been found to improve the rate of postoperative recovery following abdominal surgery (van der Meij et al 2018), the effectiveness of web-based preoperative education and respiratory training on postoperative morbidity is unknown.

**Effects on other surgical cohorts, cultures, and hospital settings**

The effectiveness of preoperative physiotherapy to reduce PPC needs to be tested in other surgical populations at risk of PPC, e.g. major cardiac and thoracic surgery, and in other cultural environments. In the past 10 years, four studies have investigated the effectiveness of preoperative education to reduce PPC after abdominal surgery in Pakistan (Samnani et al 2014), Egypt (Abdelaal et al 2017), China (Wang, Yuan & Ding 2018), and India (Lohiya et al 2018). All these

trials are favourable to supporting the findings of LIPPSMAck-POP, however, with lower methodological quality these findings may not be indicative of a valid result.

**Independent effect of early ambulation to reduce PPC**

Current physiotherapy practice in Australia and New Zealand predominantly provides assisted structured early ambulation to patients after abdominal surgery (Patman et al 2017, Reeve et al 2019). Only three physiotherapy trials have carefully standardised early ambulation in both control and treatment groups (Mackay, Ellis & Johnston 2005, Silva, Li & Rickard 2013, Boden et al 2018b). Unregulated postoperative ambulation may have confounded the results in other trials. However, despite a widespread perception that early ambulation after surgery reduces PPC risk, this assumption is supported by a single observational study (Haines et al 2013), with other evidence inconsistent and of lower methodological quality (Castelino et al 2016, Browning, Denehy & Scholes 2007b). The only randomised controlled trial that compared an early ambulation treatment group after abdominal surgery to a forced rest-in-bed control group found a non-significant increase in PPC rates in those participants provided with early ambulation (Silva, Li & Rickard 2013). Although the association between early ambulation and PPCs is currently uncertain, future trials would need to be carefully designed to standardise early ambulation, as it may impact secondary outcomes such as length of stay (Browning, Denehy & Scholes 2007b, Ahn et al 2013, Silva, Li & Rickard 2013).

There is limited evidence exploring the use of early ambulation as a stand-alone intervention to prevent PPC. A comparison of PPC incidence in a group of high-risk patients randomised to three days bedrest compared to early ambulation following abdominal surgery found no significant difference in PPC rates (Silva, Li & Rickard 2013). This is the only randomised controlled trial investigating the effects of early ambulation on PPC rates after abdominal surgery. Although there was no difference in PPC, there was a significant increase in LOS of 4.4 days (95%CI 0.3 to 8.8) in those who ambulated later. These patients also required increased physiotherapy resources to facilitate a functional recovery and discharge from hospital. The professional group that is best and most cost-effective (e.g. physiotherapist, allied health assistant, registered nurse, enrolled nurse, ward attendant) to provide the structured early ambulation program needs to be evaluated. There is evidence that patients who are assisted to ambulate by nursing staff and Allied Health Assistants do not achieve as far a distance nor at as high an intensity as sessions delivered by Physiotherapists (Browning 2007a). Whether or not this difference in ambulation service delivery affects recovery outcomes is yet to be determined.

**Diagnosis of postoperative pulmonary complications**

Numerous methods have been used in clinical trials by physiotherapists, anaesthetists, and surgeons to identify PPC onset in patients. The lack of a clear and universally accepted definition of a PPC creates significant limitations in directly comparing incidence rates between studies. The use of different criteria within the same population can lead to different incidence rates. When three PPC diagnostic tools were used within the same elective thoracic surgery population by the same two assessors, incidence rates ranged from 6% to 40% (Agostini et al 2011). With such variations in event rates, the question arises: which PPC diagnostic tool most accurately measures the "true" PPC event rate? In 2018, the Standardised End-points in Perioperative medicine (StEP) group drew experts in the field of perioperative medicine together to develop a consensus opinion on which currently used PPC diagnosis framework should be recommended for use in future trials (Abbott et al 2018). They were unable to do so. Instead, this group agreed on a new definition of PPCs. Even for the very specific diagnosis of pneumonia, there is no consensus on a gold-standard definition (Russell et al 2019, Abbott et al 2018, Ottosen & Evans 2014). Similar to generic PPC diagnosis, pneumonia diagnoses have significant heterogeneity of included items, uncertainty in being able to generalise definitions to different cohorts, and the balance between being practical to use in a clinical situation or dependent on invasive pathology and radiology testing which may not be readily available in every setting. Other considerations are whether lower diagnostic thresholds could increase rates of antibiotic prescriptions, which may be undesirable in the face of increasing bacterial resistance to antibiotics (Stuart et al 2019).

Given the uncertainty surrounding PPC recognition tools and reliability, research is required to assess the measurement properties of the MGS PPC diagnostic tool used within LIPPSMAck-POP and other clinical trials in this field. The validity, reliability, and relationship to short-term, medium, and long-term clinical and patient-reported outcomes needs to be confirmed.

**Establishing a minimally clinically important difference of PPC**

There is no consensus agreement on what the minimal clinically important difference for PPC reduction is. It is possible that the 20% reduction detected in PPC rates within LIPPSMAck-POP may not be clinically important to hospitals or patients. However, considering that PPC is strongly associated with morbidity, mortality, and hospital costs (Shander et al 2011) the opposite is more likely; that a small difference in PPC rates, i.e. 2%, could be considered significantly beneficial to the hospital and patient alike. To measure a statistically significant difference in PPC incidence of 2% would require very large randomised controlled trials or combined meta-analyses of more than 12,000 patients to provide enough statistical power to detect a true difference between groups in this small effect size. It is important to establish the minimally clinical important difference of PPC incidence. Doing so would improve the design of adequately powered studies establishing the efficacy of prophylactic treatments and grant funding bodies can have confidence of the

necessity to fund such large trials. Research establishing the ideal method to determine a minimal clinical important difference for PPC is needed, and this may involve representation from consumers/patients, hospital funders, and clinicians.

**Reducing PPCs in high risk elective abdominal surgery patients**

For elective abdominal surgery patients, despite preoperative physiotherapy demonstrating a halving of PPCs with a single intervention session, 8% of low risk and 20% of high-risk patients still contracted a PPC (Boden et al 2018b). Other interventions need to be investigated to see if this incidence rate can be reduced further. These should include investigations into the benefit of additional preoperative phase interventions such as supervised physical activity (prehab) and/or inspiratory muscle training (IMT), and postoperative phase interventions such as coached sessions of breathing exercises in the postoperative phase, the use of adjunctive devices such as incentive spirometers or positive expiratory pressure (PEP) devices, or the benefit of prophylactic non-invasive ventilation (NIV).

**Reducing PPCs and improving physical recovery after emergency abdominal surgery**

The most effective way to reduce PPCs in emergency abdominal surgery also needs to be investigated as preoperative physiotherapy may not be possible in this population. Despite ubiquitous provision of physiotherapy in Australia to enhance physical recovery and prevent respiratory complications after major abdominal surgery, there are no clinical trials that have investigated the effect of ambulation, early rehabilitation, and/or respiratory exercises on PPCs and overall physical recovery in patients specifically following emergency abdominal surgery. Considering that emergency abdominal surgery patients have a higher risk of PPC, longer physical recovery, tend to be more acutely unwell on presentation to hospital, more likely to require an ICU admission, and have a higher degree of surgical trauma and systemic inflammation when compared to elective surgery, a clinical trial investigating physiotherapy to prevent complications and improve postoperative recovery in this cohort is urgently needed (Sullivan et al 2016). The candidate has designed and is currently Chief Investigator of a multicentre randomised controlled trial aiming to address this gap in clinical science (Boden et al 2018d).

**How to manage a PPC once it occurs**

The focus of this thesis and all randomised controlled trials previously have all been on preventing the occurrence of PPC. There are no clinical trials on the effectiveness of physiotherapy to accelerate recovery and improve outcomes following the diagnosis of a PPC or pneumonia after surgery.

To conclude, an invited opinion written by a UK academic published by the National Institute of Health Research highlights the need for implementation into clinical practice.

> "When patients and carers prepare for upper abdominal surgery, the possibility of post-operative complications is a major concern. Respiratory complications in particular, such as hospital-acquired pneumonia, are more likely to increase the length of stay in the hospital, reduce general function and well-being and can often increase mortality.
>
> Breathing exercises are vital to reducing respiratory complications post-surgery and teaching them is a core skill of all physiotherapists.
>
> When a well-designed, multi-centre study shows that even a single pre-operative education session leads to better outcomes if appropriately timed and organised, what are we waiting for to implement this recommendation in clinical practice?"
>
> Dr Dimitra Nikoletou, Associate Professor, Director of Postgraduate Research,
> Kingston University and St George's University of London Joint Faculty.

# References

Abbott TEF, Fowler AJ, Pelosi P, Gama de Abreu M, Møller AM, Canet J, Creagh-Brown B, Mythen M, Gin T, Lalu MM, Futier E, Grocott MP, Schultz MJ, Pearse RM; StEP-COMPAC Group. A systematic review and consensus definitions for standardised end-points in perioperative medicine: pulmonary complications. *British Journal of Anaesthesia*. 2018;120(5):1066-1079.

Abdelaal GA, Eldahdouh SS, Abdelsamie M, Labeeb A. Effect of preoperative physical and respiratory therapy on postoperative pulmonary functions and complications after laparoscopic upper abdominal surgery in obese patients. *Egyptian Journal of Chest Diseases and Tuberculosis*. 2017;66(4):735-8.

Abdullah HR, Lien VP, Ong HK, Er PL, Hao Y, Khan SA, Liu CW. Protocol for a single-centre, randomised controlled study of a preoperative rehabilitation bundle in the frail and elderly undergoing abdominal surgery. *BMJ Open.* 2017;7(8).

Agostini P, Naidu B, Cieslik H, Rathinam S, Bishay E, Kalkat MS, Rajesh PB, Steyn RS, Singh S. Comparison of recognition tools for postoperative pulmonary complications following thoracotomy. *Physiotherapy.* 2011;97(4):278-83.

Ahn KY, Hur H, Kim DH, Min J, Jeong DH, Chu SH, Lee JW, Ligibel JA, Meyerhardt JA, Jones LW, Jeon JY, Kim NK. The effects of inpatient exercise therapy on the length of hospital stay in stages I-III colon cancer patients: randomized controlled trial. *International Journal of Colorectal Disease* 2013;28:643-51.

Alexander JI, Spence AA, Parikh RK, Stuart B. The role of airway closure in postoperative hypoxaemia. *British Journal of Anaesthesia.* 1973;45(1):34-40.

Ali J, Serrette C, Wood LD, Anthonisen NR. Effect of postoperative intermittent positive pressure breathing on lung function. *Chest.* 1984 Feb;85(2):192-6.

Allen S, Brown V, Prabhu P, Scott M, Rockall T, Preston S, Sultan J. A randomised controlled trial to assess whether prehabilitation improves fitness in patients undergoing neoadjuvant treatment prior to oesophagogastric cancer surgery: study protocol. *BMJ Open*. 2018;8(12):e023190.

Australian Institute of Health and Welfare (2012). "Cancer incidence projections: Australia, 2011 to 2020." *Cancer Series no. 66. Cat. No. CAN 62.* 2012. https://www.aihw.gov.au/getmedia/a79de4a1-49f5-4c93-bc59-4d181430aa69/14096.pdf.aspx?inline=true (accessed December 18, 2018).

Australian Institute of Health and Welfare (2013). "Procedures and healthcare interventions (ACHI 9th edition), Australia, 2011-2012. *Procedures data cubes"*. https://www.aihw.gov.au/hospitals-data/procedures-data-cubes/#ardrglink. (accessed September 7th, 2014).

Australian Institute of Health and Welfare (2018). "Procedures and healthcare interventions (ACHI 9th edition), Australia, 2015−16 to 2016−17. *Procedures data cubes".* 2018.

https://www.aihw.gov.au/reports/hospitals/procedures-data-cubes/contents/data-cubes. (accessed January 18, 2020).

Ball L, Battaglini D, Pelosi P. Postoperative respiratory disorders. *Current Opinion in Critical Care*. 2016;22(4):379-85.

Ball L, Bos LD, Pelosi P. High-flow nasal cannula in the postoperative period: is positive pressure the phantom of the OPERA trial? *Intensive Care Medicine*. 2017;43(1):119-121.

Ball L, de Abreu MG, Schultz MJ, Pelosi P. Neuromuscular blocking agents and postoperative pulmonary complications. *Lancet Respiratory Medicine*. 2019;7(2):102-103.

Baltieri L, Santos LA, Rasera I Jr, Montebelo MI, Pazzianotto-Forti EM. Use of positive pressure in the bariatric surgery and effects on pulmonary function and prevalence of atelectasis: randomized and blinded clinical trial. *Arquivos Brasileiros de Cirurgia Digestiva: ABCD.* 2014;27 Suppl 1:26-30.

Banerjee S, Manley K, Shaw B, Lewis L, Cucato G, Mills R, Rochester M, Clark A, Saxton JM. Vigorous intensity aerobic interval exercise in bladder cancer patients prior to radical cystectomy: a feasibility randomised controlled trial. *Support Care Cancer*. 2018;26(5):1515-1523.

Barakat HM, Shahin Y, Khan JA, McCollum PT, Chetter IC. Preoperative supervised exercise improves outcomes after elective abdominal aortic aneurysm repair: a randomized controlled trial. *Annals of Surgery*. 2016;264(1):47-53.

Barbalho-Moulim MC, Miguel GPS, Forti EMP, Campos FdA, Costa D. Effects of preoperative inspiratory muscle training in obese women undergoing open bariatric surgery: respiratory muscle strength, lung volumes, and diaphragmatic excursion. *Clinics.* 2011;66(10):1721-1727.

Barberan-Garcia A, Ubré M, Roca J, Lacy AM, Burgos F, Risco R, Momblán D, Balust J, Blanco I, Martínez-Pallí G. Personalised prehabilitation in high-risk patients undergoing elective major abdominal surgery: a randomized blinded controlled trial. *Annals of Surgery.* 2018;267(1):50-56.

Barberan-Garcia A, Ubre M, Pascual-Argente N, Risco R, Faner J, Balust J, Lacy AM, Puig-Junoy J, Roca J, Martinez-Palli G. Post-discharge impact and cost-consequence analysis of prehabilitation in high-risk patients undergoing major abdominal surgery: secondary results from a randomised controlled trial. *British Journal of Anaesthesia*. 2019;123(4):450-456.

Bauer M, Opitz A, Filser J, Jansen H, Meffert R, Germer C, Roewer N, Muellenbach R, Kredel M. Perioperative redistribution of regional ventilation and pulmonary function: a prospective observational study in two cohorts of patients at risk of postoperative pulmonary complications. *BMC Anesthesiology.* 2019;19:132.

Baxter WD, Levine RS. An evaluation of intermittent positive pressure breathing in the prevention of postoperative pulmonary complications. *Archives of Surgery.* 1969;98(6):795-8.

Bellinetti LM, Thomson JC. Respiratory muscle evaluation in elective thoracotomies and laparotomies of the upper abdomen. *Jornal Brasileiro de Pneumologia.* 2006;32(2):99-105.

Berkel AE, Van Wijk L, Bongers BC, Van Der Palen J, Buis CI, Reudink M, Liem MS, Slooter GD, Van Meeteren NL, Klaase JM. Study protocol of a single-arm pre-post study to assess the preliminary effectiveness and feasibility of a home-based bimodal prehabilitation program on preoperative aerobic fitness in high-risk patients scheduled for liver or pancreatic resection. *International Journal of Clinical Trials.* 2020;7(2):103-111.

Bilgi M, Goksu S, Mizrak A, Cevik C, Gul R, Koruk S, Sahin L. Comparison of the effects of low-flow and high-flow inhalational anaesthesia with nitrous oxide and desflurane on mucociliary activity and pulmonary function tests. *European Journal of Anaesthesiology.* 2011;28(4):279-283.

Blaney F, Sawyer T. Sonographic measurement of diaphragmatic motion after upper abdominal surgery: A comparison of three breathing manoeuvres. *Physiotherapy Theory and Practice.* 1997;13:207-215.

Bluth T, writing Committee for the PROBESE Collaborative Group of the PROtective VEntilation Network (PROVEnet) for the Clinical Trial Network of the European Society of Anaesthesiology, , Serpa Neto A, Schultz MJ, Pelosi P, Gama de Abreu M; PROBESE Collaborative Group, Bluth T, Bobek I, Canet JC, Cinnella G, de Baerdemaeker L, Gama de Abreu M, Gregoretti C, Hedenstierna G, Hemmes SNT, Hiesmayr M, Hollmann MW, Jaber S, Laffey J, Licker MJ, Markstaller K, Matot I, Mills GH, Mulier JP, Pelosi P, Putensen C, Rossaint R, Schmitt J, Schultz MJ, Senturk M, Serpa Neto A, Severgnini P, Sprung J, Vidal Melo MF, Wrigge H. Effect of intraoperative high positive end-expiratory pressure (PEEP) with recruitment maneuvers vs low PEEP on postoperative pulmonary complications in obese patients: a randomized clinical trial. *JAMA.* 2019;321(23):2292-2305.

Boden I, Browning L, Skinner EH, Reeve J, El-Ansary D, Robertson IK, Denehy L. The LIPPSMAck POP (Lung Infection Prevention Post Surgery - Major Abdominal - with Pre-Operative Physiotherapy) trial: study protocol for a multi-centre randomised controlled trial. *Trials.* 2015;16:573.

Boden I, El-Ansary D, Zalucki N, Robertson IK, Browning L, Skinner EH, Denehy L. Physiotherapy education and training prior to upper abdominal surgery is memorable and has high treatment fidelity: a nested mixed-methods randomised-controlled study. *Physiotherapy.* 2018a;104(2):194-202.

Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, Robertson IK, Story D, Denehy L. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. *BMJ.* 2018b;360:j5916.

Boden I. Critically appraised paper: Preoperative physiotherapy education halved postoperative pulmonary complications in patients after upper abdominal surgery [commentary]. Journal of Physiotherapy. 2018c;64(3):195-196.

Boden I, Sullivan K, Hackett C, Winzer B, Lane R, McKinnon M, Robertson I. ICEAGE (Incidence of Complications following Emergency Abdominal surgery: Get Exercising):

study protocol of a pragmatic, multicentre, randomised controlled trial testing physiotherapy for the prevention of complications and improved physical recovery after emergency abdominal surgery. *World Journal of Emergency Surgery*. 2018d:13(1):29.

Böhner H, Kindgen-Milles D, Grust A, Buhl R, Lillotte WC, Müller BT, Müller E,Fürst G, Sandmann W. Prophylactic nasal continuous positive airway pressure after major vascular surgery: results of a prospective randomized trial. *Langenbecks Archives of Surgery*. 2002;387(1):21-6.

Bolshinsky V, Li MH, Ismail H, Burbury K, Riedel B, Heriot A. Multimodal prehabilitation programs as a bundle of care in gastrointestinal cancer surgery: a systematic review. *Diseases of the Colon & Rectum*. 2018;61(1):124-38.

Bourn J, Conway J, Holgate S. The effect of post-operative physiotherapy on pulmonary complications and lung function after upper abdominal surgery. *European Respiratory Journal*. 1991;4(Suppl 14):325S.

Brasher PA, McClelland KH, Denehy L, Story I. Does removal of deep breathing exercises from a physiotherapy program including pre-operative education and early mobilisation after cardiac surgery alter patient outcomes? *Australian Journal of Physiotherapy*. 2003;49(3):165-73.

Bronsert MR, Henderson WG, Monk TG, Richman JS, Nguyen JD, Sum-Ping JT, Mangione MP, Higley B, Hammermeister KE. Intermediate-acting nondepolarizing neuromuscular blocking agents and risk of postoperative 30-day morbidity and mortality, and long-term survival. *Anesthesia and Analgesia*. 2017;124(5):1476-1483.

Brooks D, Parsons J, Newton J, Dear C, Silaj E, Sinclair L, Quirt J. Discharge criteria from perioperative physical therapy. *Chest*. 2002;121(2):488-94.

Brown SR, Mathew R, Keding A, Marshall HC, Brown JM, Jayne DG. The impact of postoperative complications on long-term quality of life after curative colorectal cancer surgery. *Annals of Surgery* 2014;259; 916-923.

Browning L. Phd: *Early Mobilisation Following Upper Abdominal Surgery in Australian Public Hospitals*, University of Melbourne; 2007a.

Browning L, Denehy L, Scholes RL. The quantity of early upright mobilisation performed following upper abdominal surgery is low: an observational study. *Australian Journal of Physiotherapy.* 2007b;53(1):47-52.

Bruns ER, van den Heuvel B, Buskens CJ, Van Duijvendijk P, Festen S, Wassenaar EB, van der Zaag ES, Bemelman WA, van Munster BC. The effects of physical prehabilitation in elderly patients undergoing colorectal surgery: a systematic review. *Colorectal Disease*. 2016;18(8):267-77.

Bulka CM, Terekhov MA, Martin BJ, Dmochowski RR, Hayes RM, Ehrenfeld JM. Nondepolarizing neuromuscular blocking agents, reversal, and risk of postoperative pneumonia. *Anesthesiology*. 2016;125(4):647-55.

Cabilan CJ, Hines S, Munday J. The effectiveness of prehabilitation or preoperative exercise for surgical patients: a systematic review. *JBI Database of Systematic Reviews and Implementation Reports*. 2015;13(1):146-87.

Calligaro KD, Dandura R, Dougherty MJ, DeLaurentis DA, Raviola CA. Same-day admissions and other cost-saving strategies for elective aortoiliac surgery. *Journal of Vascular Surgery*. 1997;25(1):141-4.

Campbell T, Ferguson N, McKinlay RGC. The use of a simple self-administered method of positive expiratory pressure (PEP) in chest physiotherapy after abdominal surgery. *Physiotherapy*. 1986;72(10):498-500.

Cammu G. Residual neuromuscular blockade and postoperative pulmonary complications: what does the recent evidence demonstrate? *Current Anesthesiology Reports*. 2020:1-6.

Canet J, Gallart L. Postoperative respiratory failure: pathogenesis, prediction, and prevention. *Current Opinion in Critical Care.* 2014;20(1):56-62.

Carli F, Zavorsky GS. Optimizing functional exercise capacity in the elderly surgical population. *Current Opinion in Clinical Nutrition and Metabolic Care*. 2005;8(1):23-32.

Carli F, Charlebois P, Stein B, Feldman L, Zavorsky G, Kim DJ, Scott S, Mayo NE. Randomized clinical trial of prehabilitation in colorectal surgery. *British Journal of Surgery*. 2010;97(8):1187-97.

Carli F, Bousquet-Dion G, Awasthi R, Elsherbini N, Liberman S, Boutros M, Stein B, Charlebois P, Ghitulescu G, Morin N, Jagoe T, Scheede-Bergdahl C, Minnella EM, Fiore JF Jr. Effect of multimodal prehabilitation vs postoperative rehabilitation on 30-day postoperative complications for frail patients undergoing resection of colorectal cancer: a randomized clinical trial. *JAMA Surgery.* 2020;155(3):233–42.

Carlsson C, Sondén B, Thylén U. Can postoperative continuous positive airway pressure (CPAP) prevent pulmonary complications after abdominal surgery? *Intensive Care Medicine*. 1981;7(5):225-9.

Carneiro EM, Ramos Mde C, Terra GA, Rodrigues Júnior V, Matos D, Crema E. Evaluation of breathing exercise in hormonal and immunological responses in patients undergoing abdominal surgery. *Acta Cirurgica Brasileira*. 2013;28(5):385-90.

Cash JE. *Physiotherapy in some Surgical Conditions.* London, UK: Faber and Faber Ltd; 1955.

Castelino T, Fiore JF Jr, Niculiseanu P, Landry T, Augustin B, Feldman LS. The effect of early mobilization protocols on postoperative outcomes following abdominal and thoracic surgery: A systematic review. *Surgery*. 2016;159(4):991-1003.

Castillo R, Haas A. Chest physical therapy: comparative efficacy of preoperative and postoperative in the elderly. *Archives of Physical Medicine and Rehabilitation.* 1985;66(6):376-9.

Cavalcanti AB, writing group for the Alveolar Recruitment for Acute Respiratory Distress Syndrome Trial (ART) investigators, , Suzumura ÉA, Laranjeira LN, Paisani DM, Damiani LP, Guimarães HP, Romano ER, Regenga MM, Taniguchi LNT, Teixeira C, Pinheiro de Oliveira R, Machado FR, Diaz-

Quijano FA, Filho MSA, Maia IS, Caser EB, Filho WO, Borges MC, Martins PA, Matsui M, Ospina-Tascón GA, Giancursi TS, Giraldo-Ramirez ND, Vieira SRR, Assef MDGPL, Hasan MS, Szczeklik W, Rios F, Amato MBP, Berwanger O, Ribeiro de Carvalho CR. Effect of lung recruitment and titrated Positive End-Expiratory Pressure (PEEP) vs low PEEP on mortality in patients with acute respiratory distress syndrome: a randomized clinical trial. *JAMA.* 2017;318(14):1335-1345.

Cella AS, Bush CA, Codignotto B. Same-day admission for cardiac surgery: a benefit to patient, family, and institution. *Journal of Cardiovascular Nursing.* 1993;7(4):14-29.

Celli BR, Rodriguez KS, Snider GL. A controlled trial of intermittent positive pressure breathing, incentive spirometry, and deep breathing exercises in preventing pulmonary complications after abdominal surgery. *American Review of Respiratory Disease.*1984;130(1):12-5.

Cheifetz O, Lucy SD, Overend TJ, Crowe J. The effect of abdominal support on functional outcomes in patients following major abdominal surgery: a randomized controlled trial. *Physiotherapy Canada.* 2010;62(3):242-253.

Christensen EF, Schultz P, Jensen OV, Egebo K, Engberg M, Grøn I, Juhl B. Postoperative pulmonary complications and lung function in high-risk patients: a comparison of three physiotherapy regimens after upper abdominal surgery in general anaesthesia. *Acta Anaesthesiologica Scandinavica.* 1991;35(2):97-104.

Chumillas S, Ponce JL, Delgado F, Viciano V, Mateu M. Prevention of postoperative pulmonary complications through respiratory rehabilitation: a controlled clinical study. *Archives of Physical Medicine and Rehabilitation.* 1998;79(1):5-9.

Colucci DB, Fiore JF Jr, Paisani DM, Risso TT, Colucci M, Chiavegato LD, Faresin SM. Cough impairment and risk of postoperative pulmonary complications after open upper abdominal surgery. *Respiratory Care.* 2015;60(5):673-8.

Condie E, Hack K, Ross A. An investigation of the value of routine provision of postoperative chest physiotherapy in non-smoking patients undergoing elective abdominal surgery. *Physiotherapy.* 1993;79:547-52.

Coventry BJ. *Upper Abdominal Surgery*. London, England. Springer-Verlag London. 2014.

Craig DB. Postoperative recovery of pulmonary function. *Anesthesia and Analgesia.* 1981;60(1):46-52.

Craven JL, Evans GA, Davenport PJ, Williams RH. The evaluation of the incentive spirometer in the management of postoperative pulmonary complications. *British Journal of Surgery*. 1974;61(10):793-7.

Crawford BL, Blunnie WP, Elliott AG. The value of self-administered peri-operative physiotherapy. *Irish Journal of Medical Science.* 1990;159(2):51-2.

Cupples SA. Effects of timing and reinforcement of preoperative education on knowledge and recovery of patients having coronary artery bypass graft surgery. *Heart & Lung: the Journal of Critical Care*. 1991;20(6):654-60.

D'Antini D, Rauseo M, Grasso S, Mirabella L, Camporota L, Cotoia A, Spadaro S, Fersini A, Petta R, Menga R, Sciusco A, Dambrosio M, Cinnella G. Physiological effects of the open lung approach during laparoscopic cholecystectomy: focus on driving pressure. *Minerva Anestesiologica*. 2018;84(2):159-167.

Davies OJ, Husain T, Stephens R. Postoperative pulmonary complications following non-cardiothoracic surgery. *BJA Education*. 2017;17(9):295-300.

Dean E, Ross J. Discordance between cardiopulmonary physiology and physical therapy: toward a rational basis for practice. *Chest.* 1992*;*101:1694-1698.

de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy*. 2009;55(2):129-133.

Denehy L. PhD: *The physiotherapy management of patients following upper abdominal surgery. Melbourne*: University of Melbourne; 2001a.

Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S. A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. *Physiotherapy Research International.* 2001b;6(4):236-250.

Di Marco F, Bonacina D, Vassena E, Arisi E, Apostolo A, Banfi C, Centanni S, Agostoni P, Fumagalli R. The effects of anaesthesia, muscle paralysis, and ventilation on the lung evaluated by lung diffusion for carbon monoxide and pulmonary surfactant protein B. *Anesthesia and Analgesia.* 2015;120(2):373-80.

Dimick JB, Pronovost PJ, Cowan JA, Lipsett PA. Complications and costs after high-risk surgery: where should we focus quality improvement initiatives? *Journal of American College of Surgeons*. 2003;196:671-8.

Dohi S, Gold MI. Comparison of two methods of postoperative respiratory care. *Chest*. 1978;73(5):592-5.

Dronkers J, Veldman A, Hoberg E, van der Waal C, van Meeteren N. Prevention of pulmonary complications after upper abdominal surgery by preoperative intensive inspiratory muscle training: a randomized controlled pilot study. *Clinical Rehabilitation.*2008;22(2):134-42.

Duggan M, Kavanagh BP. Pulmonary atelectasis: a pathogenic perioperative entity. *Anesthesiology* 2005; 102(4):838-54.

Duggan M, Kavanagh BP. Atelectasis in the perioperative patient. *Current Opinion in Anaesthesiology*. 2007;20(1):37-42.

Dunne DF, Jack S, Jones RP, Jones L, Lythgoe DT, Malik HZ, Poston GJ, Palmer DH, Fenwick SW. Randomized clinical trial of prehabilitation before planned liver resection. *British Journal of Surgery.* 2016;103(5):504-12.

Dureuil B, Cantineau JP, Desmonts JM. Effects of upper or lower abdominal surgery on diaphragmatic function. *British Journal of Anaesthesia.* 1987;59(10):1230-5.

Ebeo CT, Benotti PN, Byrd RP Jr, Elmaghraby Z, Lui J. The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. *Respiratory Medicine*. 2002;96(9):672-6.

Edmark L, Kostova-Aherdan K, Enlund M, Hedenstierna G. Optimal oxygen concentration during induction of general anaesthesia. *Anesthesiology.* 2003;98(1):28-33.

Elman A, Langonnet F, Dixsaut G, Hay JM, Guignard J, Dazza F, Maillard JN. Respiratory function is impaired less by transverse than by median vertical supraumbilical incisions. *Intensive Care Medicine.* 1981;7(5):235-9.

European Commission. Eurostat. Surgical operations and procedures performed in hospitals by ICD-9-CM. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=hlth_co_proc2&lang=en. Accessed on December 18, 2018.

Fagevik-Olsén M, Hahn I, Nordgren S, Lönroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. *British Journal of Surgery*. 1997;84(11):1535-1538.

Fagevik-Olsén M, Josefson K, Lönroth H. Chest physiotherapy does not improve the outcome in laparoscopic fundoplication and vertical-banded gastroplasty. *Surgical Endoscopy*. 1999;13(3):260-3.

Fagevik-Olsén M. Chest physiotherapy in open and laparoscopic abdominal surgery. *Physical Therapy Reviews*. 2000; 5(2):25-130.

Fagevik-Olsén M, Wennberg E, Johnsson E, Josefson K, Lönroth H, Lundell L. Randomized clinical study of the prevention of pulmonary complications after thoracoabdominal resection by two different breathing techniques. *British Journal of Surgery*. 2002;89(10):1228-34.

Fagevik-Olsén M, Josefson K, Wiklund M. Evaluation of abdominal binder after major upper gastrointestinal surgery. *Advances in Physiotherapy.* 2009;11(2):104-110.

Ferrando C, Soro M, Unzueta C, Suarez-Sipmann F, Canet J, Librero J, Pozo N,Peiró S, Llombart A, León I, India I, Aldecoa C, Díaz-Cambronero O, Pestaña D,Redondo FJ, Garutti I, Balust J, García JI, Ibáñez M, Granell M, Rodríguez A,Gallego L, de la Matta M, Gonzalez R, Brunelli A, García J, Rovira L, Barrios F, Torres V, Hernández S, Gracia E, Giné M, García M, García N, Miguel L, Sánchez S,Piñeiro P, Pujol R, García-Del-Valle S, Valdivia J, Hernández MJ, Padrón O, Colás A, Puig J, Azparren G, Tusman G, Villar J, Belda J; Individualized PeRioperative Open-lung VEntilation (iPROVE) Network. Individualised perioperative open-lung approach versus standard protective

ventilation in abdominal surgery (iPROVE): a randomised controlled trial. *Lancet Respiratory Medicine.* 2018;6(3):193-203.

Fernandez-Bustamante A, Frendl G, Sprung J, Kor DJ, Subramaniam B, Martinez Ruiz R, Lee JW, Henderson WG, Moss A, Mehdiratta N, Colwell MM, Bartels K, Kolodzie K, Giquel J, Vidal Melo MF. Postoperative pulmonary complications, early mortality, and hospital stay following noncardiothoracic surgery: a multicentre study by the perioperative research network investigators. *JAMA Surgery*. 2017; 152: 157-66.

Ferreyra G, Long Y, Ranieri VM. Respiratory complications after major surgery. *Current Opinion in Critical Care.* 2009;15(4):342-348.

Fiore JF Jr, Chiavegato LD, Denehy L, Paisani DM, Faresin SM. Do directed cough maneuvers improve cough effectiveness in the early period after open heart surgery? Effect of thoracic support and maximal inspiration on cough peak expiratory flow, cough expiratory volume, and thoracic pain. *Respiratory Care.* 2008;53(8):1027-34.

Fiore JF Jr, Figueiredo S, Balvardi S, Lee L, Nauche B, Landry T, Mayo NE, Feldman LS. How do we value postoperative recovery?: A systematic review of the measurement properties of patient-reported outcomes after abdominal surgery. *Annals of Surgery*. 2018;267(4):656-669.

Fleisher LA, Linde-Zwirble WT. Incidence, outcome, and attributable resource use associated with pulmonary and cardiac complications after major small and large bowel procedures. *Perioperative Medicine (Lond)* 2014; 3:7.

Forbes AR, Gamsu G. Depression of lung mucociliary clearance by thiopental and halothane. *Anesthesia and Analgesia.* 1979;58(5):387-9.

Ford G, Whitelaw W, Rosenal T, Cruse P, Guenter C. Diaphragm function after upper abdominal surgery in humans. *American Review of Respiratory Disease.* 1983;127:431-436.

Forgiarini LA Jr, Carvalho AT, Ferreira Tde S, Monteiro MB, Dal Bosco A, Gonçalves MP, Dias AS. Physical therapy in the immediate postoperative period after abdominal surgery. *Jornal Brasileiro de Pneumologia.* 2009;35(5):455-9.

Forsmo HM, Erichsen C, Rasdal A, Tvinnereim JM, Körner H, Pfeffer F. Randomized controlled trial of extended perioperative counseling in enhanced recovery after colorectal surgery. *Diseases of the Colon & Rectum.* 2018;61(6):724-32.

Futier E, Paugam-Burtz C, Godet T, Khoy-Ear L, Rozencwajg S, Delay JM, Verzilli D, Dupuis J, Chanques G, Bazin JE, Constantin JM, Pereira B, Jaber S; OPERA study investigators. Effect of early postextubation high-flow nasal cannula vs conventional oxygen therapy on hypoxaemia in patients after major abdominal surgery: a French multicentre randomised controlled trial (OPERA). *Intensive Care Medicine.* 2016;42(12):1888-1898.

Gamsu G, Singer MM, Vincent HH, Berry S, Nadel J. Postoperative impairment of mucous transport in the lung. *American Review of Respiratory Disease.* 1976;114(4):673-679.

Gaskell DV and Webber BA. *The Brompton Hospital Guide to Chest Physiotherapy.* Oxford, England. Blackwell Scientific Publications. 1960.

Ghaferi A, Birkmeyer J, Dimick J. Variation in hospital mortality associated with inpatient surgery. *New England Journal of Medicine* 2009;361:1368-75.

Gillis C, Li C, Lee L, Awasthi R, Augustin B, Gamsa A, Liberman AS, Stein B, Charlebois P, Feldman LS, Carli F. Prehabilitation versus rehabilitation: a randomized control trial in patients undergoing colorectal resection for cancer. *Anesthesiology.* 2014;121(5):937-47.

Giroux JM, Lewis S, Holland LG, Black E, Gow S, Langlotz J. Postoperative chest physiotherapy for abdominal hysterectomy patients. *Physiotherapy Canada.* 1987;39(2):89-93.

Grams ST, Ono LM, Noronha MA, Schivinski CI, Paulin E. Breathing exercises in upper abdominal surgery: a systematic review and meta-analysis. *Revista Brasileira de Fisioterapia*. 2012;16(5):345-53.

Griffiths SV, Conway DH, Sander M, Jammer I, Grocott MP, Creagh-Brown BC, POPC-CB Investigators. What are the optimum components in a care bundle aimed at reducing post-operative pulmonary complications in high-risk patients?. *Perioperative Medicine*. 2018;7(1):7.

Grosse-Sundrup M, Henneman JP, Sandberg WS, Bateman BT, Uribe JV, Nguyen NT, Ehrenfeld JM, Martinez EA, Kurth T, Eikermann M. Intermediate acting non-depolarizing neuromuscular blocking agents and risk of postoperative respiratory complications: prospective propensity score matched cohort study. *BMJ*. 2012;345:e6329.

Güldner A, Kiss T, Serpa Neto A, Hemmes SN, Canet J, Spieth PM, Rocco PR, Schultz MJ, Pelosi P, Gama de Abreu M. Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications: a comprehensive review of the role of tidal volume, positive end-expiratory pressure, and lung recruitment maneuvers. *Anesthesiology.* 2015;123(3):692-713.

Gunnarsson L, Tokics L, Gustavsson H, Hedenstierna G. Influence of age on atelectasis formation and gas exchange impairment during general anaesthesia. *British Journal of Anaesthesia.* 1991;66(4):423-32.

Gustafsson UO, Scott MJ, Hubner M, Nygren J, Demartines N, Francis N, Rockall TA, Young-Fadok TM, Hill AG, Soop M, de Boer HD, Urman RD, Chang GJ, Fichera A, Kessler H, Grass F, Whang EE, Fawcett WJ, Carli F, Lobo DN, Rollins KE, Balfour A, Baldini G, Riedel B, Ljungqvist O. Guidelines for perioperative care in elective colorectal surgery: Enhanced Recovery After Surgery (ERAS(®)) Society recommendations: 2018. *World Journal of Surgery.* 2019;43(3):659-695.

Haines KJ, Skinner EH, Berney S; Austin Health POST Study Investigators. Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: an observational cohort study. *Physiotherapy.* 2013;99(2):119-125.

Hall JC, Tarala R, Harris J, Tapper J, Christiansen K. Incentive spirometry versus routine chest physiotherapy for prevention of pulmonary complications after abdominal surgery. *Lancet.* 1991;337(8747):953-6.

Hall JC, Tarala RA, Tapper J, Hall JL. Prevention of respiratory complications after abdominal surgery: a randomised clinical trial. *BMJ*. 1996;312(7024):148-52.

Hallböök T, Lindblad B, Lindroth B, Wolff T. Prophylaxis against pulmonary complications in patients undergoing gall-bladder surgery. A comparison between early mobilization, physiotherapy with and without bronchodilatation. *Annales Chirurgiae et Gynaecologiae.* 1984;73(2):55-8.

Hanekom SD, Brooks D, Denehy L, Fagevik-Olsén M, Hardcastle TC, Manie S, Louw Q. Reaching consensus on the physiotherapeutic management of patients following upper abdominal surgery: a pragmatic approach to interpret equivocal evidence. *BMC Medical Informatics and Decision Making.* 2012;12:5.

Hartland BL, Newell TJ, Damico N. Alveolar recruitment maneuvers under general anesthesia: a systematic review of the literature. *Respiratory Care*. 2015;60(4):609-20.

Heisterberg L, Johansen TS, Larsen HW, Holm M, Andersen B. Postoperative pulmonary complications in upper abdominal surgery. A randomized clinical comparison between physiotherapy and blow-bottles. *Acta Chirurgica Scandinavica*.1979;145(8):505-7.

Hedenstierna G, Edmark L. The effects of anaesthesia and muscle paralysis on the respiratory system. *Intensive Care Medicine.* 2005;31(10):1327-35.

Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. *Best Practice & Research Clinical Anaesthesiology.* 2010;24(2):157-169.

Hedenstierna G, Edmark L, Perchiazzi G. Postoperative lung complications: have multicentre studies been of any help? *British Journal of Anaesthesia*. 2015;114(4):541-3.

Hemmes SN, PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, , Gama de Abreu M, Pelosi P, Schultz MJ. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. *Lancet.* 2014;384(9942):495-503.

Hemmes S, Serpa Neto A, Gama de Abreu M, Pelosi P, Schultz M. Intraoperative ventilation: improving physiology, or preventing harm? *British Journal of Anaesthesia*. 2016;116(3):438-9.

Hightower CE, Riedel BJ, Feig BW, Morris GS, Ensor Jr JE, Woodruff VD, Daley-Norman MD, Sun XG. A pilot study evaluating predictors of postoperative outcomes after major abdominal surgery: physiological capacity compared with the ASA physical status classification system. *British Journal of Anaesthesia*. 2010;104(4):465-71.

Hijazi Y, Gondal U, Aziz O. A systematic review of prehabilitation programs in abdominal cancer surgery. *International Journal of Surgery*. 2017; 39:156-62.

Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, Altman DG, Barbour V, Macdonald H, Johnston M, Lamb SE, Dixon-Woods M, McCulloch P, Wyatt JC, Chan AW, Michie S. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*. 2014;348:g1687.

Huedo-Medina TB, Sánchez-Meca J, Marín-Martínez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or $I^2$ index?. *Psychological Methods*. 2006;11(2):193.

Hughes MJ, Hackney RJ, Lamb PJ, Wigmore SJ, Christopher Deans DA, Skipworth RJE. Prehabilitation before major abdominal surgery: a systematic review and meta-analysis. *World Journal of Surgery*. 2019;43(7):1661-1668.

Ireland CJ, Chapman TM, Mathew SF, Herbison GP, Zacharias M. Continuous positive airway pressure (CPAP) during the postoperative period for prevention of postoperative morbidity and mortality following major abdominal surgery. *Cochrane Database of Systematic Reviews*. 2014;(8):CD008930.

Jaber S, Lescot T, Futier E, Paugam-Burtz C, Seguin P, Ferrandiere M, Lasocki S, Mimoz O, Hengy B, Sannini A, Pottecher J, Abback PS, Riu B, Belafia F, Constantin JM, Masseret E, Beaussier M, Verzilli D, De Jong A, Chanques G, Brochard L, Molinari N; NIVAS Study Group. Effect of noninvasive ventilation on tracheal reintubation among patients with hypoxemic respiratory failure following abdominal surgery: a randomized clinical trial. *JAMA.* 2016;315(13):1345-53.

Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. Physiotherapy after coronary artery surgery: are breathing exercises necessary? *Thorax*. 1989;44(8):634-9.

Jenkins SC, Soutar SA, Loukota JM, Johnson LC, Moxham J. A comparison of breathing exercises, incentive spirometry and mobilisation after coronary artery surgery. *Physiotherapy Theory and Practice.* 1990;6(3):117-26.

Jensen BT, Petersen AK, Jensen JB, Laustsen S, Borre M. Efficacy of a multiprofessional rehabilitation programme in radical cystectomy pathways: a prospective randomized controlled trial. *Scandinavian Journal of Urology*. 2015;49(2):133-141.

Joris JL, Sottiaux TM, Chiche JD, Desaive CJ, Lamy ML. Effect of bi-level positive airway pressure (BiPAP) nasal ventilation on the postoperative pulmonary restrictive syndrome in obese patients undergoing gastroplasty. *Chest.* 1997;111(3):665-70.

Jung R, Wight J, Nusser R, Rosoff L. Comparison of three methods of respiratory care following upper abdominal surgery. *Chest.* 1980;78(1):31-5.

Kaibori M, Ishizaki M, Matsui K, Nakatake R, Yoshiuchi S, Kimura Y, Kwon AH. Perioperative exercise for chronic liver injury patients with hepatocellular carcinoma undergoing hepatectomy. *American Journal of Surgery*. 2013;206(2):202-9.

Karlsson E, Farahnak P, Franzén E, Nygren-Bonnier M, Dronkers J, van Meeteren N, Rydwik E. Feasibility of preoperative supervised home-based exercise in older adults undergoing colorectal cancer surgery–A randomized controlled design. *PloS One*. 2019;14(7):e0219158.

Kassin MT, Owen RM, Perez SD, Leeds I, Cox JC, Schnier K, Sadiraj V, Sweeney JF. Risk factors for 30-day hospital readmission among general surgery patients. *Journal of American College of Surgeons*. 2012;215(3):322-30.

Kendall F, Oliveira J, Peleteiro B, Pinho P, Bastos PT. Inspiratory muscle training is effective to reduce postoperative pulmonary complications and length of hospital stay: a systematic review and meta-analysis. *Disability and Rehabilitation*. 2018;40(8):864-82.

Kheterpal S, Vaughn MT, Dubovoy TZ, Shah NJ, Bash LD, Colquhoun DA, Shanks AM, Mathis MR, Soto RG, Bardia A, Bartels K, McCormick PJ, Schonberger RB, Saager L. Sugammadex versus neostigmine for reversal of neuromuscular blockade and postoperative pulmonary complications (STRONGER): A multicenter matched cohort analysis. *Anesthesiology.* 2020;132(6):1371-1381.

Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ, participants in the VA National Surgical Quality Improvement Program. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Annals of Surgery*. 2005;242(3):326-41.

Kim DJ, Mayo NE, Carli F, Montgomery DL, Zavorsky GS. Responsive measures to prehabilitation in patients undergoing bowel resection surgery. *The Tohoku Journal of Experimental Medicine*. 2009;217(2):109-15.

Kim SH, Na S, Choi J-S, Na SH, Shin S, Koh SO. An evaluation of diaphragmatic movement by M-mode sonography as a predictor of pulmonary dysfunction after upper abdominal surgery. *Anaesthesia & Analgesia.* 2010;110(5):1349-1354.

Kim SP, Leibovich BC, Shah ND, Weight CJ, Borah BJ, Han LC, Boorjian SA, Thompson RH. The relationship of postoperative complications with in-hospital outcomes and costs after renal surgery for kidney cancer. *BJU International*. 2013;111:580-8.

King I, Tarsitano B. The effect of structured and unstructured preoperative teaching: a replication. *Nursing Research and Practice*. 1982;31(6):324-329.

Kirmeier E, Eriksson LI, Lewald H, Jonsson Fagerlund M, Hoeft A, Hollmann M, Meistelman C, Hunter JM, Ulm K, Blobner M; POPULAR Contributors. Post-anaesthesia pulmonary complications after use of muscle relaxants (POPULAR): a multicentre, prospective observational study. *Lancet Respiratory Medicine*. 2019;7(2):129-140.

Klaiber U, Stephan-Paulsen LM, Bruckner T, Müller G, Auer S, Farrenkopf I, Fink C, Dörr-Harim C, Diener MK, Büchler MW, Knebel P. Impact of preoperative patient education on the prevention of postoperative complications after major visceral surgery: the cluster randomized controlled PEDUCAT trial. *Trials*. 2018;19(1):288.

Koivisto JM, Saarinen I, Kaipia A, Puukka P, Kivinen K, Laine KM, Haavisto E. Patient education in relation to informational needs and postoperative complications in surgical patients. *International Journal for Quality in Health Care*. 2020;32(1):35-40.

Konrad FX, Schreiber T, Brecht-Kraus D, Georgieff M. Bronchial mucus transport in chronic smokers and nonsmokers during general anaesthesia. *Journal of Clinical Anaesthesia.* 1993;5(5):375-380.

Kotani N, Hashimoto H, Sessler DI, Kikuchi A, Suzuki A, Takahashi S, Muraoka M, Matsuki A. Intraoperative modulation of alveolar macrophage function during isoflurane and propofol anaesthesia. *Anesthesiology.* 1998;89(5):1125-32.

Kulkarni S, Fletcher E, McConnell A, Poskitt K, Whyman M. Pre-operative inspiratory muscle training preserves postoperative inspiratory muscle strength following major abdominal surgery–a randomised pilot study. *Annals of the Royal College of Surgeons of England.* 2010;92(8):700.

Lång M, Niskanen M, Miettinen P, Alhava E, Takala J. Outcome and resource utilization in gastroenterological surgery. *British Journal of Surgery.* 2001;88(7):1006-1014.

Laszlo G, Archer GG, Darrell JH, Dawson JM, Fletcher CM. The diagnosis and prophylaxis of pulmonary complications of surgical operation. *British Journal of Surgery*. 1973;60(2):129-34.

Lawrence VA, Hazuda HP, Cornell JE, Pederson T, Bradshaw PT, Mulrow CD, Page CP. Functional independence after major abdominal surgery in the elderly. *Journal of the American College of Surgeons*. 2004;199(5):762-72.

Lawrence VA, Cornell JE, Smetana GW. Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians. *Annals of Internal Medicine.* 2006;144(8):596-608.

Lederer DH, Van de Water JM, Indech RB. Which deep breathing device should the postoperative patient use? *Chest.* 1980;77(5):610-3.

Lemanu DP, Singh PP, MacCormick AD, Arroll B, Hill AG. Effect of preoperative exercise on cardiorespiratory function and recovery after surgery: a systematic review. *World Journal of Surgery*. 2013;37(4):711-20.

Leslie K. Sugammadex and postoperative pulmonary complications: is stronger evidence required?. *Anesthesiology*. 2020;132(6):1299-1300.

Liang MK, Bernardi K, Holihan JL, Cherla DV, Escamilla R, Lew DF, Berger DH, Ko TC, Kao LS. Modifying risks in ventral hernia patients with prehabilitation: a randomized controlled trial. *Annals of Surgery*. 2018;268(4):674-680.

Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;339:b2700.

Lindberg P, Gunnarsson L, Tokics L, Secher E, Lundquist H, Brismar B, Hedenstierna G. Atelectasis and lung function in the postoperative period. *Acta Anaesthesiologica Scandinavica.* 1992;36(6):546-53.

Lindell P, Hedenstierna G. Ventilation efficiency after different incisions for cholecystectomy. *Acta Chirurgica Scandinavica.* 1976;142(8):561-5.

Lindner KH, Lotz P, Ahnefeld FW. Continuous positive airway pressure effect on functional residual capacity, vital capacity and its subdivisions. *Chest.* 198;92(1):66-70.

Lloréns J, Rovira L, Ballester M, Moreno J, Hernández-Laforet J, Santonja FJ, Cassinello N, Ortega J. Preoperative inspiratory muscular training to prevent postoperative hypoxemia in morbidly obese patients undergoing laparoscopic bariatric surgery. A randomized clinical trial. *Obesity Surgery*. 2015;25(6):1003-9.

Lockstone J, Parry SM, Denehy L, Robertson IK, Story D, Parkes S, Boden I. Physiotherapist administered, non-invasive ventilation to reduce postoperative pulmonary complications in high-risk patients following elective upper abdominal surgery; a before-and-after cohort implementation study. *Physiotherapy*. 2020; 106:77-86.

Lohiya ML, Malviya A, Sharma DD, Ram S, Chauhan MK, Chauhan LS. Prophylactic chest physiotherapy in major abdominal surgery among elderly patients. *Journal of the Indian Academy of Geriatrics*. 2018;14(2).

Lunardi AC, Paisani DM, Silva CCBMD, Cano DP, Tanaka C, Carvalho CRF. Comparison of lung expansion techniques on thoracoabdominal mechanics and incidence of pulmonary complications after upper abdominal surgery: a randomized and controlled trial. *Chest.* 2015;148(4):1003-1010.

Lundquist H, Hedenstierna G, Strandberg A, Tokics L, Brismar B. CT-assessment of dependent lung densities in man during general anaesthesia. *Acta Radiologica*. 1995;36(6):626-32.

Lyager S, Wernberg M, Rajani N, Bøggild-Madsen B, Nielsen L, Nielsen HC, Andersen M, Møller J, Silberschmid M. Can postoperative pulmonary conditions be improved by treatment with the Bartlett-Edwards incentive spirometer after upper abdominal surgery? *Acta Anaesthesiologica Scandinavica*. 1979;23(4):312-9.

Mackay MR, Ellis E. Physiotherapy outcomes and staffing resources in open abdominal surgery patients. *Physiotherapy Theory and Practice.* 2002;18(2):75-93.

Mackay MR. Phd: *Effect of physiotherapy on outcomes following open abdominal surgery,* University of Sydney; 2003.

Mackay MR, Ellis E, Johnston C. Randomised clinical trial of physiotherapy after open abdominal surgery in high risk patients. *Australian Journal of Physiotherapy.* 2005;51(3):151-159.

MacMahon C. Breathing and physical exercises for the use in cases of wounds in pleura, lung, and diaphragm. *Lancet.* 1915; 2:769-770

Magnusson L, Spahn DR. New concepts of atelectasis during general anaesthesia. *British Journal of Anaesthesia*. 2003;91(1):61-72.

Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy*. 2003;83(8):713-721.

Mans CM, Reeve JC, Elkins MR. Postoperative outcomes following preoperative inspiratory muscle training in patients undergoing cardiothoracic or upper abdominal surgery: a systematic review and meta analysis. *Clinical Rehabilitation.* 2015;29(5):426-38.

Manzano RM, Carvalho CR, Saraiva-Romanholo BM, Vieira JE. Chest physiotherapy during immediate postoperative period among patients undergoing upper abdominal surgery: randomized clinical trial. *Sao Paulo Medical Journal*. 2008;126(5):269-273.

Marseu K, Slinger P. Peri-operative pulmonary dysfunction and protection. *Anaesthesia.* 2016 ;71 Suppl 1:46-50.

Martinez BP, Silva JR, Silva VS, Neto MG, Forgiarini Júnior LA. Influence of different body positions in vital capacity in patients on postoperative upper abdominal. *Revista Brasileira de Anestesiologica*. 2015;65(3):217-21.

Martinez-Ubieto J, Ortega-Lucea S, Pascual-Bellosta A, Arazo-Iglesias I, Gil-Bona J, Jimenez-Bernardó T, Muñoz-Rodriguez L. Prospective study of residual neuromuscular block and postoperative respiratory complications in patients reversed with neostigmine versus sugammadex. *Minerva Anestesiologica*. 2016;82(7):735-42.

Mayo NE, Feldman L, Scott S, Zavorsky G, Kim DJ, Charlebois P, Stein B, Carli F. Impact of preoperative change in physical function on postoperative recovery: argument supporting prehabilitation for colorectal surgery. *Surgery*. 2011;150(3):505-14.

McDermott KW, Freeman WJ, Elixhauser A. Overview of Operating Room Procedures During Inpatient Stays in U.S. Hospitals, 2014. HCUP Statistical Brief #233. December 2017. Agency for Healthcare Research and Quality, Rockville, MD. www.hcupus.ahrq.gov/reports/statbriefs/sb233-Operating-Room-Procedures-United-States-2014.pdf. Accessed on December 18, 2018.

McIsaac DI, Saunders C, Hladkowicz E, Bryson GL, Forster AJ, Gagne S, Huang A, Lalu M, Lavallee LT, Moloo H, Nantel J. PREHAB study: a protocol for a prospective randomised clinical trial of exercise therapy for people living with frailty having cancer surgery. *BMJ Open*. 2018;8(6).

McLean DJ, Diaz-Gil D, Farhan HN, Ladha KS, Kurth T, Eikermann M. Dose-dependent association between intermediate-acting neuromuscular-blocking agents and postoperative respiratory complications. *Anesthesiology.* 2015;122(6):1201-13.

McTier L, Botti M, Duke M. Patient participation in pulmonary interventions to reduce postoperative pulmonary complications following cardiac surgery. *Australian Critical Care*. 2016;29(1):35-40.

Milder DA, Pillinger NL, Kam PCA. The role of prehabilitation in frail surgical patients: A systematic review. *Acta Anaesthesiologica Scandinavica*. 2018;62(10):1356-1366.

Minnella EM, Awasthi R, Loiselle SE, Agnihotram RV, Ferri LE, Carli F. Effect of exercise and nutrition prehabilitation on functional capacity in esophagogastric cancer surgery: a randomized clinical trial. *JAMA Surgery*. 2018;153(12):1081-1089.

Minschaert M, Vincent JL, Ros AM, Kahn RJ. Influence of incentive spirometry on pulmonary volumes after laparotomy. *Acta Anaesthesiologica Belgica*. 1982;33(3):203-9.

Miskovic A, Lumb A. Postoperative pulmonary complications. *British Journal of Anaesthesia.* 2017;118:317-334.

Moore J, Merchant Z, Rowlinson K, McEwan K, Evison M, Faulkner G, Sultan J, McPhee JS, Steele J. Implementing a system-wide cancer prehabilitation programme: The journey of Greater Manchester's 'Prehab4cancer'. *European Journal of Surgical Oncology*. 2020 May 1.

Moran J, Wilson F, Guinan E, McCormick P, Hussey J, Moriarty J. Role of cardiopulmonary exercise testing as a risk-assessment method in patients undergoing intra-abdominal surgery: a systematic review. BJA: *British Journal of Anaesthesia*. 2016a;116(2):177-91.

Moran J, Guinan E, McCormick P, Larkin J, Mockler D, Hussey J, Moriarty J, Wilson F. The ability of prehabilitation to influence postoperative outcome after intra-abdominal operation: a systematic review and meta-analysis. *Surgery*. 2016b;160(5):1189-201.

Morran CG, Finlay IG, Mathieson M, McKay AJ, Wilson N, McArdle CS. Randomized controlled trial of physiotherapy for postoperative pulmonary complications. *British Journal of Anaesthesia*. 1983;55(11):1113-7.

Moseley AM, Herbert RD, Maher CG, Sherrington C, Elkins MR. Reported quality of randomized controlled trials of physiotherapy interventions has improved over time. *Journal of Clinical Epidemiology*. 2011;64(6):594-601.

Moseley AM, Elkins MR, Van der Wees PJ, Pinheiro MB. Using research to guide practice: The Physiotherapy Evidence Database (PEDro). *Brazilian Journal of Physical Therapy*. 2019a;S1413-3555(19)30914-1.

Moseley AM, Rahman P, Wells GA, Zadro JR, Sherrington C, Toupin-April K, Brosseau L. Agreement between the Cochrane risk of bias tool and Physiotherapy Evidence Database (PEDro) scale: A meta-epidemiological study of randomized controlled trials of physical therapy interventions. *PLoS One.* 2019b;14(9):e0222770.

Myles PS, Bellomo R, Corcoran T, Forbes A, Peyton P, Story D, Christophi C, Leslie K, McGuinness S, Parke R, Serpell J. Restrictive versus liberal fluid therapy for major abdominal surgery. *New England Journal of Medicine*. 2018;378(24):2263-74.

Neligan PJ, Malhotra G, Fraser M, Williams N, Greenblatt EP, Cereda M, Ochroch EA. Continuous positive airway pressure via the Boussignac system immediately after extubation improves lung function in morbidly obese patients with obstructive sleep apnea undergoing laparoscopic bariatric surgery. *Anesthesiology.* 2009;110(4):878-84.

Neligan PJ, Malhotra G, Fraser M, Williams N, Greenblatt EP, Cereda M, Ochroch EA. Noninvasive ventilation immediately after extubation improves lung function in morbidly obese patients with

obstructive sleep apnea undergoing laparoscopic bariatric surgery. *Anesthesia and Analgesia*. 2010;110(5):1360-5

Neto AS, Hemmes SN, Barbas CS, Beiderlinden M, Fernandez-Bustamante A, Futier E, Hollmann MW, Jaber S, Kozian A, Licker M, Lin WQ, Moine P, Scavonetto F, Schilling T, Selmo G, Severgnini P, Sprung J, Treschan T, Unzueta C, Weingarten TN, Wolthuis EK, Wrigge H, Gama de Abreu M, Pelosi P, Schultz MJ; PROVE Network investigators. Incidence of mortality and morbidity related to postoperative lung injury in patients who have undergone abdominal or thoracic surgery: a systematic review and meta-analysis. *Lancet Respiratory Medicine.* 2014;2(12):1007-15.

Neto AS, Schultz MJ, Gama de Abreu M. Intraoperative ventilation strategies to prevent postoperative pulmonary complications: Systematic review, meta-analysis, and trial sequential analysis. *Best Practice & Research Clinical Anaesthesiology*. 2015;29(3):331-40.

Neto AS, Hemmes SN, Barbas CS, Beiderlinden M, Fernandez-Bustamante A, Futier E, Gajic O, El-Tahan MR, Ghamdi AA, Günay E, Jaber S, Kokulu S, Kozian A, Licker M, Lin WQ, Maslow AD, Memtsoudis SG, Reis Miranda D, Moine P, Ng T, Paparella D, Ranieri VM, Scavonetto F, Schilling T, Selmo G, Severgnini P, Sprung J, Sundar S,Talmor D, Treschan T, Unzueta C, Weingarten TN, Wolthuis EK, Wrigge H, Amato MB, Costa EL, de Abreu MG, Pelosi P, Schultz MJ; PROVE Network Investigators. Association between driving pressure and development of postoperative pulmonary complications in patients undergoing mechanical ventilation for general anaesthesia: a meta-analysis of individual patient data. *Lancet Respiratory Medicine*. 2016;4(4):272-80.

Ntoumenopoulous G. Phd: *The effectiveness of cardiothoracic physiotherapy on the elderly abdominal surgery patient in the critical care setting*, La Trobe University; 1994

Ntoumenopoulos G, Greenwood K. Effects of cardiothoracic physiotherapy on intrapulmonary shunt in abdominal surgical patients. *Australian Journal of Physiotherapy*. 1996;42(4):297-303.

Nunn JF. Nunn's applied respiratory physiology (4th edition) 1997. Oxford: Butterworth-Heinemann

O'Brien J. Absorption atelectasis: incidence and clinical implications. *AANA Journal*. 2013;81(3):205-208.

O'Connor M, Tattersall MP, Carter JA. An evaluation of the incentive spirometer to improve lung function after cholecystectomy. *Anaesthesia.* 1988;43(9):785-7.

O'Doherty AF, West M, Jack S, Grocott MP. Preoperative aerobic exercise training in elective intra-cavity surgery: a systematic review. *British Journal of Anaesthesia*. 2013;110(5):679-89.

O'Donohue Jr W. Postoperative pulmonary complications. When are preventive and therapeutic measures necessary? *Postgraduate Medicine.* 1992;91(3):167-170, 173-165.

Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. *BMJ*. 2020;368:m540.

O'Gara B, Talmor D. Perioperative lung protective ventilation. *BMJ*. 2018;362:k3030.

Östberg E, Thorisson A, Enlund M, Zetterström H, Hedenstierna G, Edmark L. Positive End-expiratory Pressure Alone Minimizes Atelectasis Formation in Nonabdominal Surgery: A Randomized Controlled Trial. *Anesthesiology*. 2018;128(6):1117-1124.

Ottosen J, Evans H. Pneumonia: challenges in the definition, diagnosis, and management of disease. *Surgical Clinics of North America*. 2014;94(6):1305-17.

Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C. The effect of incentive spirometry on postoperative pulmonary complications: a systematic review. *Chest*. 2001;120(3):971-8.

Page MJ, McKenzie JE, Kirkham J, Dwan K, Kramer S, Green S, Forbes A. Bias due to selective inclusion and reporting of outcomes and analyses in systematic reviews of randomised trials of healthcare interventions. *Cochrane Database of Systematic Reviews*. 2014;(10):MR000035.

Palmer KN, Sellick BA. Effect of procaine penicillin and breathing exercises in postoperative pulmonary complications. *Lancet*. 1952;1(6703):345-6.

Parry S, Denehy L, Berney S, Browning L. Clinical application of the Melbourne risk prediction tool in a high-risk upper abdominal surgical population: an observational cohort study. *Physiotherapy*. 2014;100(1):47-53.

Pasquina P, Tramèr MR, Granier J-M, Walder B. Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: a systematic review. *Chest*. 2006;130(6):1887-1899.

Patman S, Bartley A, Ferraz A, Bunting C. Physiotherapy in upper abdominal surgery–what is current practice in Australia? *Archives of Physiotherapy* 2017;7:11.

Pereira SM, Tucci MR, Morais CCA, Simões CM, Tonelotto BFF, Pompeo MS, Kay FU, Pelosi P, Vieira JE, Amato MBP. Individual positive end-expiratory pressure settings optimize intraoperative mechanical ventilation and reduce postoperative atelectasis. *Anesthesiology*. 2018;129(6):1070-1081.

Pouwels S, Stokmans RA, Willigendael EM, Nienhuijs SW, Rosman C, van Ramshorst B, Teijink JA. Preoperative exercise therapy for elective major abdominal surgery: a systematic review. *International Journal of Surgery*. 2014;12(2):134-40.

Prielipp RC, Magro M, Morell RC, Brull SJ. The normalization of deviance: do we (un)knowingly accept doing the wrong thing? *AANA Journal*. 2010;78(4):284-7.

Pryor J, Prasad SA. *Physiotherapy for Respiratory and Cardiac Problems*. London, United Kingdom. Churchill Livingstone. 2001

Qaseem A, Snow V, Fitterman N, Hornbake ER, Lawrence VA, Smetana GW, Weiss K, Owens DK, Aronson M, Barry P, Casey DE Jr, Cross JT Jr, Fitterman N, Sherif KD, Weiss KB; Clinical Efficacy Assessment Subcommittee of the American College of Physicians. . Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic

surgery: a guideline from the American College of Physicians. *Annals of Internal Medicine.* 2006;144(8):575-580.

Raphael JH, Butt MW. Comparison of isoflurane with propofol on respiratory cilia. *British Journal of Anaesthesia.* 1997;79(4):473-5.

Rankin SL, Briffa TG, Morton AR, Hung J. A specific activity questionnaire to measure the functional capacity of cardiac patients. *American Journal of Cardiology*. 1996 Jun 1;77(14):1220-3.

Reeve JC, Nicol K, Stiller K, McPherson KM, Birch P, Gordon IR, Denehy L. Does physiotherapy reduce the incidence of postoperative pulmonary complications following pulmonary resection via open thoracotomy? A preliminary randomised single-blind clinical trial. *European Journal of Cardiothoracic Surgery*. 2010; 37(5):1158-66.

Reeve J & Boden I. The physiotherapy management of patients undergoing abdominal surgery. *New Zealand Journal of Physiotherapy*. 2016; 44(1):33-49.

Reeve J, Anderson L, Raslan Y, Grieve C, Ford J, Wilson L. The physiotherapy management of patients undergoing abdominal surgery: A survey of current practice. *New Zealand Journal of Physiotherapy*. 2019; 47:66-75.

Restrepo RD, Braverman J. Current challenges in the recognition, prevention and treatment of perioperative pulmonary atelectasis. *Expert Reviews in Respiratory Medicine*. 2015;9(1):97-107.

Ricksten SE, Bengtsson A, Soderberg C, Thorden M, Kvist H. Effects of periodic positive airway pressure by mask on postoperative pulmonary function. *Chest*. 1986;89(6):774-81.

Rigg J, Jamrozik K, Myles P, Silbert B, Peyton P, Parsons R, Collins K; the MASTER Anaesthesia Trial Study Group. Epidural anaesthesia and analgesia and outcome of major surgery: a randomised trial. *Lancet* 2002; 359:1276–82

Robin PE. Preadmission clinics. *BMJ.* 1991;302(6775):532.

Rothen HU, Sporre B, Engberg G, Wegenius G, Reber A, Hedenstierna G. Prevention of atelectasis during general anaesthesia. *Lancet.* 1995;345(8962):1387-91.

Rothen HU, Sporre B, Engberg G, Wegenius G, Hedenstierna G. Airway closure, atelectasis and gas exchange during general anaesthesia. *British Journal of Anaesthesia.* 1998;81(5):681-6.

Roukema JA, Carol EJ, Prins JG. The prevention of pulmonary complications after upper abdominal surgery in patients with noncompromised pulmonary status. *Archives of Surgery.* 1988;123(1):30-4.

Russell FM, Reyburn R, Chan J, Tuivaga E, Lim R, Lai J, Van HMT, Choummanivong M, Sychareun V, Khanh DKT, de Campo M, Enarson P, Graham S, La Vincente S, Mungan T, von Mollendorf C, Mackenzie G, Mulholland K. Impact of the change in WHO's severe pneumonia case definition on hospitalized pneumonia epidemiology: case studies from six countries. *Bulletin of the World Health Organisation*. 2019;97(6):386-393.

Samnani SS, Umer MF, Mehdi SH, Farid FN. Impact of preoperative counselling on early postoperative mobilization and its role in smooth recovery. *International Scholarly Research Notices.* 2014;2014:250536.

Santa Mina D, Hilton WJ, Matthew AG, Awasthi R, Bousquet-Dion G, Alibhai SMH, Au D, Fleshner NE, Finelli A, Clarke H, Aprikian A, Tanguay S, Carli F. Prehabilitation for radical prostatectomy: A multicentre randomized controlled trial. *Surgical Oncology*. 2018;27(2):289-298.

Santa Mina D, Clarke H, Ritvo P, Leung YW, Matthew AG, Katz J, Trachtenberg J, Alibhai SM. Effect of total-body prehabilitation on postoperative outcomes: a systematic review and meta-analysis. *Physiotherapy*. 2014;100(3):196-207.

Sasaki N, Meyer MJ, Eikermann M. Postoperative respiratory muscle dysfunction: pathophysiology and preventive strategies. *Anesthesiology*. 2013;118(4):961-78.

Schaefer MS, Wania V, Bastin B, Schmalz U, Kienbaum P, Beiderlinden M, Treschan TA. Electrical impedance tomography during major open upper abdominal surgery: a pilot-study. *BMC Anesthesiology*. 2014;14:51.

Schepens T, Janssens K, Maes S, Wildemeersch D, Vellinga J, Jorens PG, Saldien V. Respiratory muscle activity after spontaneous, neostigmine- or sugammadex-enhanced recovery of neuromuscular blockade: a double blind prospective randomized controlled trial. *BMC Anesthesiology*. 2019;19(1):187.

Schindler MB. Treatment of atelectasis: where is the evidence? *Critical Care.* 2005;9(4):341.

Scholes R. Phd: *Predicting pulmonary risk following upper abdominal surgery*, University of Melbourne; 2005.

Scholes RL, Browning L, Sztendur EM, Denehy L. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted $VO_2$ max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. *Australian Journal of Physiotherapy.* 2009;55(3):191-198.

Schuppisser JP, Brändli O, Meili U. Postoperative intermittent positive pressure breathing versus physiotherapy. *American Journal of Surgery.* 1980;140(5):682-6.

Schwieger I, Gamulin Z, Forster A, Meyer P, Gemperle M, Suter PM. Absence of benefit of incentive spirometry in low-risk patients undergoing elective cholecystectomy. A controlled randomized study. *Chest.* 1986;89(5):652-6.

Serpa Neto A, Cardoso SO, Manetta JA, Pereira VG, Espósito DC, Pasqualucci Mde O, Damasceno MC, Schultz MJ. Association between use of lung-protective ventilation with lower tidal volumes and clinical outcomes among patients without acute respiratory distress syndrome: a meta-analysis. *JAMA*. 2012;308(16):1651-9.

Serpa Neto A, Campos PP, Hemmes SN, Bos LD, Bluth T, Ferner M, Güldner A, Hollmann MW, India I, Kiss T, Laufenberg-Feldmann R, Sprung J, Sulemanji D, Unzueta C, Melo MF, Weingarten TN, Boer AM, Pelosi P, Gama de Abreu M, Schultz MJ; PROVE Network Investigators. Kinetics of plasma biomarkers of inflammation and lung injury in surgical patients with or without postoperative pulmonary complications. *European Journal of Anesthesiology*. 2017;34(4):229-238.

Shander A, Fleisher LA, Barie PS, Bigatello LM, Sladen RN, Watson CB. Clinical and economic burden of postoperative pulmonary complications: patient safety summit on definition, risk-reducing interventions, and preventive strategies. *Critical Care Medicine* 2011;39:2163-2172.

Sheill G, Guinan E, O'Neill L, Normand C, Doyle SL, Moore S, Newell J, McDermott G, Ryan R, Reynolds JV, Hussey J. Preoperative exercise to improve fitness in patients undergoing complex surgery for cancer of the lung or oesophagus (PRE-HIIT): protocol for a randomized controlled trial. *BMC Cancer*. 2020;20:1-1.

Shennib H, Mulder DS, Chiu RC. The effects of pulmonary atelectasis and reexpansion on lung cellular immune defences. *Archives of Surgery.* 1984;119(3):274-7.

Sherrington C, Herbert RD, Maher CG, Moseley AM. PEDro. A database of randomized trials and systematic reviews in physiotherapy. *Manual Therapy.* 2000;5(4):223-6.

Silva YR, Li SK, Rickard MJ. Does the addition of deep breathing exercises to physiotherapy-directed early mobilisation alter patient outcomes following high-risk open upper abdominal surgery? Cluster randomised controlled trial. *Physiotherapy*. 2013;99(3):187-93.

Sleszynski SL, Kelso AF. Comparison of thoracic manipulation with incentive spirometry in preventing postoperative atelectasis. *Journal of the American Osteopath Association.* 1993;93(8):834-8, 843-5.

Smith M, Ellis E. Is retained mucus a risk factor for the development of postoperative atelectasis and pneumonia? Implications for the physiotherapist. *Physiotherapy Theory and Practice.* 2000;16:69-80.

Smith TB, Stonell C, Purkayastha S, Paraskevas P. Cardiopulmonary exercise testing as a risk assessment method in non cardio-pulmonary surgery: a systematic review. *Anaesthesia.* 2009;64(8):883-93.

Soares SM, Nucci LB, da Silva MM, Campacci TC. Pulmonary function and physical performance outcomes with preoperative physical therapy in upper abdominal surgery: a randomized controlled trial. *Clinical Rehabilitation*. 2013;27(7):616-27.

Soares SM, Nucci LB. Association between early pulmonary complications after abdominal surgery and preoperative physical capacity. *Physiotherapy Theory and Practice*. 2019:1-9.

Squadrone V, Coha M, Cerutti E, Schellino MM, Biolino P, Occella P, Belloni G, Vilianis G, Fiore G, Cavallo F, Ranieri VM; Piedmont Intensive Care Units Network(PICUN). Continuous positive airway pressure for treatment of postoperative hypoxemia: a randomized controlled trial. *JAMA.* 2005;293(5):589-95.

Stein M, Cassara EL. Preoperative pulmonary evaluation and therapy for surgery patients. *JAMA.* 1970;211(5):787-90.

Steiner CA, Karaca Z, Moore BJ, Imshaug MC, Pickens G. Surgeries in Hospital-Based Ambulatory Surgery and Hospital Inpatient Settings, 2014. HCUP Statistical Brief #223. May 2017. Agency for Healthcare Research and Quality, Rockville, MD. www.hcupus.ahrq.gov/reports/statbriefs/sb223-Ambulatory-Inpatient-Surgeries-2014.pdf. Accessed on December 18, 2018.

Stiller KR, Munday RM. Chest physiotherapy for the surgical patient. *British Journal of Surgery*. 1992;79(8):745-9.

Stock MC, Downs JB, Gauer PK, Alster JM, Imrey PB. Prevention of postoperative pulmonary complications with CPAP, incentive spirometry, and conservative therapy. *Chest.* 1985;87(2):151-7.

Strandberg A, Tokics L, Brismar B, Lundquist H, Hedenstierna G. Atelectasis during anaesthesia and in the postoperative period. *Acta Anaesthesiologica Scandinavica*. 1986;30(2):154-8.

Stuart B, Hounkpatin H, Becque T, Yao G, Zhu S, Alonso-Coello P, Altiner A, Arroll B, Böhning D, Bostock J, Bucher HCC, de la Poza M, Francis NA, Gillespie D, Hay AD, Kenealy T, Löffler C, Mas-Dalmau G, Muñoz L, Samuel K, Moore M, Little P. Delayed antibiotic prescribing for respiratory tract infections: protocol of an individual patient data meta-analysis. *BMJ Open*. 2019;9(1):e026925.

Sullivan K, Reeve J, Boden I, Lane R. *Physiotherapy following emergency abdominal surgery*. In: Garbuzenko D, editor. Actual Problems of Emergency Abdominal Surgery [Internet]. InTechOpen; 2016 [cited 2016 Sept 21].

Tew GA, Batterham AM, Colling K, Gray J, Kerr K, Kothmann E, Nawaz S, Weston M, Yates D, Danjoux G. Randomized feasibility trial of high-intensity interval training before elective abdominal aortic aneurysm repair. *British Journal of Surgery*. 2017;104(13):1791-1801.

Thomas JA, McIntosh JM. Are incentive spirometry, intermittent positive pressure breathing, and deep breathing exercises effective in the prevention of postoperative pulmonary complications after upper abdominal surgery? A systematic overview and meta-analysis. *Physical Therapy.* 1994;74:3-16

Thompson DA, Makary MA, Dorman T, Pronovost PJ. Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. *Annals of Surgery.* 2006;243(4):547.

Thoren L. Post-operative pulmonary complications: observations on their prevention by means of physiotherapy. *Acta Chirurgica Scandinavica*. 1954;107(2-3):193-205.

Togioka BM, Yanez D, Aziz MF, Higgins JR, Tekkali P, Treggiari MM. Randomised controlled trial of sugammadex or neostigmine for reversal of neuromuscular block on the incidence of pulmonary complications in older adults undergoing prolonged surgery. *British Journal of Anaesthesia*. 2020;124(5):553-561.

Torrington KG, Sorenson DE, Sherwood LM. Postoperative chest percussion with postural drainage in obese patients following gastric stapling. *Chest.* 1984;86(6):891-5.

Touw HR, Schuitemaker AE, Daams F, van der Peet DL, Bronkhorst EM, Schober P, Boer C, Tuinman PR. Routine lung ultrasound to detect postoperative pulmonary complications following major abdominal surgery: a prospective observational feasibility study. *Ultrasound Journal*. 2019;11(1):20.

Trépanier M, Minnella EM, Paradis T, Awasthi R, Kaneva P, Schwartzman K, Carli F, Fried GM, Feldman LS, Lee L. Improved disease-free survival after prehabilitation for colorectal cancer surgery. *Annals of Surgery*. 2019;270(3):493-501.

Treschan TA, Kaisers W, Schaefer MS, Bastin B, Schmalz U, Wania V, Eisenberger CF, Saleh A, Weiss M, Schmitz A, Kienbaum P, Sessler DI, Pannen B, Beiderlinden M. Ventilation with low tidal volumes during upper abdominal surgery does not improve postoperative lung function. *British Journal of Anaesthesia.* 2012;109(2):263-71.

Tusman G, Böhm SH, Warner DO, Sprung J. Atelectasis and perioperative pulmonary complications in high-risk patients. *Current Opinion in Anesthesiology.* 2012;25(1):1-10.

Tyson AF, Kendig CE, Mabedi C, Cairns BA, Charles AG. The effect of incentive spirometry on postoperative pulmonary function following laparotomy: a randomized clinical trial. *JAMA Surgery.* 2015;150(3):229-36.

Ünver S, Kıvanç G, Alptekin HM. Deep breathing exercise education receiving and performing status of patients undergoing abdominal surgery. *International Journal of Health Sciences*. 2018;12(4):35.

Urell C, Emtner M, Hedenstrom H, Tenling A, Breidenskog M, Westerdahl E. Deep breathing exercises with positive expiratory pressure at a higher rate improve oxygenation in the early period after cardiac surgery--a randomised controlled trial. *European Journal of Cardiothoracic Surgery.* 2011; 40:162-167.

UK Perioperative Medicine Clinical Trials Network. "Effectiveness and cost-effectiveness of INSPIRatory musclE training (IMT) for reducing postoperative pulmonary complications (PPC): a sham controlled randomised controlled trial (RCT) (INSPIRE)" https://www. https://www.pomctn.org.uk/INSPIRE (accessed December 18, 2018).

Valkenet K, van de Port IG, Dronkers JJ, de Vries WR, Lindeman E, Backx FJ. The effects of preoperative exercise therapy on postoperative outcome: a systematic review. *Clinical Rehabilitation.* 2011;25(2):99-111.

van Beijsterveld CA, Heldens AF, Bongers BC, van Meeteren NL. Variation in preoperative and postoperative physical therapist management of patients opting for elective abdominal surgery. *Physical Therapy*. 2019;99(10):1291-303.

van der Meij E, Anema JR, Leclercq WKG, Bongers MY, Consten ECJ, Schraffordt Koops SE, van de Ven PM, Terwee CB, van Dongen JM, Schaafsma FG, Meijerink WJHJ, Bonjer HJ, Huirne JAF. Personalised perioperative care by e-health after intermediate-grade abdominal surgery: a multicentre, single-blind, randomised, placebo-controlled trial. *Lancet.* 2018;392(10141):51-59.

van Kaam AH, Lachmann RA, Herting E, De Jaegere A, van Iwaarden F, Noorduyn LA, Kok JH, Haitsma JJ, Lachmann B. Reducing atelectasis attenuates bacterial growth and translocation in experimental pneumonia. *American Journal of Respiratory Critical Care Medicine* 2004;169:1046-53

van Rooijen S, Carli F, Dalton S, Thomas G, Bojesen R, Le Guen M, Barizien N, Awasthi R, Minnella E, Beijer S, Martínez-Palli G, van Lieshout R, Gögenur I, Feo C, Johansen C, Scheede-Bergdahl C, Roumen R, Schep G, Slooter G. Multimodal prehabilitation in colorectal cancer patients to improve functional capacity and reduce postoperative complications: the first international randomized controlled trial for multimodal prehabilitation. *BMC Cancer*. 2019;19(1):98.

Vonlanthen R, Slankamenac K, Breitenstein S, Puhan MA, Muller MK, Hahnloser D, Hauri D, Graf R, Clavien PA. The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Annals of Surgery*. 2011;254:907-913

Wahba RW. Perioperative functional residual capacity. *Can J Anaesth*. 1991;38(3):384-400.

Wallis C, Prasad A. Who needs chest physiotherapy? Moving from anecdote to evidence. *Archives of Diseases in Childhood.* 1999;80(4):393-7.

Wang Q, Yuan X, Ding Z. Effect of preoperative respiratory exercise on pulmonary function and complications in elderly patients after abdominal operation. *Chinese Journal of Primary Medicine and Pharmacy*. 2018;25(2):172-5.

Warren CP, Grimwood M. Pulmonary disorders and physiotherapy in patients who undergo cholecystectomy. *Canadian Journal of Surgery*. 1980;23(4):384-386.

Weingarten TN, Whalen FX, Warner DO, Gajic O, Schears GJ, Snyder MR, Schroeder DR, Sprung J. Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery. *British Journal of Anaesthesia*. 2010;104(1):16-22.

Westerdahl E, Lindmark B, Eriksson T, Friberg O, Hedenstierna G, Tenling A. Deep-breathing exercises reduce atelectasis and improve pulmonary function after coronary artery bypass surgery. *Chest*. 2005;128(5):3482-3488.

Wijeysundera DN, Pearse RM, Shulman MA, Abbott TE, Torres E, Ambosta A, Croal BL, Granton JT, Thorpe KE, Grocott MP, Farrington C. Assessment of functional capacity before major non-cardiac surgery: an international, prospective cohort study. *Lancet*. 2018;391(10140):2631-40.

Wiklander O, Norlin U. Effect of physiotherapy on post-operative pulmonary complications; a clinical and roentgenographic study of 200 cases. *Acta Chirurgica Scandinavica*. 1957;112(3-4):246-54.

Wolthuis EK, Choi G, Dessing MC, Bresser P, Lutter R, Dzoljic M, van der Poll T, Vroom MB, Hollmann M, Schultz MJ. Mechanical ventilation with lower tidal volumes and positive end-expiratory pressure prevents pulmonary inflammation in patients without preexisting lung injury. *Anesthesiology*. 2008;108(1):46-54.

Woodfield J, Zacharias M, Wilson G, Munro F, Thomas K, Gray A, Baldi J. Protocol, and practical challenges, for a randomised controlled trial comparing the impact of high intensity interval training against standard care before major abdominal surgery: study protocol for a randomised controlled trial. *Trials.* 2018;19(1):331.

Wrigge H, Uhlig U, Zinserling J, Behrends-Callsen E, Ottersbach G, Fischer M, Uhlig S, Putensen C. The effects of different ventilatory settings on pulmonary and systemic inflammatory responses during major surgery. *Anesthesia and Analgesia*. 2004;98(3):775-81

Wright JP, Edwards GC, Goggins K, Tiwari V, Maiga A, Moses K, Kripalani S, Idrees K. Association of health literacy with postoperative outcomes in patients undergoing major abdominal surgery. *JAMA Surgery*. 2018;153(2):137-42.

Xue FS, Li BW, Zhang GS, Liao X, Zhang YM, Liu JH, An G, Luo LK. The influence of surgical sites on early postoperative hypoxemia in adults undergoing elective surgery. *Anesthesia and Analgesia.* 1999;88(1):213-9.

Yang D, Grant MC, Stone A, Wu CL, Wick EC. A Meta-analysis of intraoperative ventilation strategies to prevent pulmonary complications: is low tidal volume alone sufficient to protect healthy lungs? *Annals of Surgery*. 2016;263(5):881-7.

Young CC, Harris EM, Vacchiano C, Bodnar S, Bukowy B, Elliott RRD, Migliarese J, Ragains C, Trethewey B, Woodward A, Gama de Abreu M, Girard M, Futier E, Mulier JP, Pelosi P, Sprung J. Lung-protective ventilation for the surgical patient: international expert panel-based consensus recommendations. *British Journal of Anaesthesia*. 2019;123(6):898-913.

Zhang XY, Wang Q, Zhang S, Tan W, Wang Z, Li J. The use of a modified, oscillating positive expiratory pressure device reduced fever and length of hospital stay in patients after thoracic and upper abdominal surgery: a randomised trial. *Journal of Physiotherapy.* 2015;61(1):16-20.

Zhou L, Zhou L, Tian L, Zhu D, Chen Z, Zheng C, Zhou T, Zeng X, Jiang X, Jiang C, Bo L. Preoperative education with image illustrations enhances the effect of tetracaine mucilage in alleviating postoperative catheter-related bladder discomfort: a prospective, randomized, controlled study. *BMC Anesthesiology*. 2018;18(1):204.

Zoremba M, Dette F, Gerlach L, Wolf U, Wulf H. Short-term respiratory physical therapy treatment in the PACU and influence on postoperative lung function in obese adults. *Obesity Surgery*. 2009;19(10):1346-1354.

# Appendix

## Appendix I PEDro scale

### PEDro scale

| | | |
|---|---|---|
| 1. | eligibility criteria were specified | no ❑ yes ❑ where: |
| 2. | subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) | no ❑ yes ❑ where: |
| 3. | allocation was concealed | no ❑ yes ❑ where: |
| 4. | the groups were similar at baseline regarding the most important prognostic indicators | no ❑ yes ❑ where: |
| 5. | there was blinding of all subjects | no ❑ yes ❑ where: |
| 6. | there was blinding of all therapists who administered the therapy | no ❑ yes ❑ where: |
| 7. | there was blinding of all assessors who measured at least one key outcome | no ❑ yes ❑ where: |
| 8. | measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups | no ❑ yes ❑ where: |
| 9. | all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat" | no ❑ yes ❑ where: |
| 10. | the results of between-group statistical comparisons are reported for at least one key outcome | no ❑ yes ❑ where: |
| 11. | the study provides both point measures and measures of variability for at least one key outcome | no ❑ yes ❑ where: |

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

**Notes on administration of the PEDro scale:**

| | |
|---|---|
| All criteria | **Points are only awarded when a criterion is clearly satisfied**. If on a literal reading of the trial report it is possible that a criterion was not satisfied, a point should not be awarded for that criterion. |
| Criterion 1 | This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study. |
| Criterion 2 | A study is considered to have used random allocation if the report states that allocation was random. The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion. |
| Criterion 3 | *Concealed allocation* means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for this criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was "off-site". |
| Criterion 4 | At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups' outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables alone, by a clinically significant amount. This criterion is satisfied even if only baseline data of study completers are presented. |
| Criteria 4, 7-11 | *Key outcomes* are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure. |
| Criterion 5-7 | *Blinding* means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be "blind" if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind. |
| Criterion 8 | This criterion is only satisfied if the report explicitly states *both* the number of subjects initially allocated to groups *and* the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time. |
| Criterion 9 | An *intention to treat* analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated. |
| Criterion 10 | A *between-group* statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group × time interaction). The comparison may be in the form hypothesis testing (which provides a "p" value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval. |
| Criterion 11 | A *point measure* is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. *Measures of variability* include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group. |

# Appendix II PubMed systematic review search strategy

| Search | Terms | Hits |
|---|---|---|
| #1 | breathing exercises OR chest physiotherapy OR chest physical therapy OR respiratory therapy OR respiratory physical therapy OR physiotherapy OR physical therapy OR lung expansion exercises OR deep breathing exercises OR incentive spirometry OR intermittent positive pressure breathing OR bilevel positive airway pressure ventilation OR positive airway pressure OR non invasive ventilation OR positive expiratory pressure OR postural drainage OR preoperative OR pre-operative OR postoperative OR post-operative OR education OR respiratory rehabilitation | **58558** |
| #2 | abdominal surgery OR upper abdominal surgery OR visceral surgery OR non-cardiac surgery OR cholecystectomy OR gastrectomy OR colorectal surgery OR upper gastrointestinal surgery OR hepatobiliary surgery OR liver surgery OR pancreas surgery OR laparotomy OR colectomy OR bariatric surgery OR vascular surgery | **7545** |
| #3 | postoperative pulmonary complications OR pulmonary complications OR respiratory complications OR pneumonia OR atelectasis | **4233** |
| #4 | combined #1 AND #2 AND #3 | **164** |

**Restricted to**

- 1950 Dec 31 to 2020 June 1
- Humans >18 years
- English
- clinical trial or systematic reviews
- title/abstract

# Appendix III Human Research Ethics Committee approval letters

Office of Research Services
University of Tasmania
Private Bag 1
Hobart Tasmania 7001
Telephone + 61 3 6226 7479
Facsimile + 61 3 6226 7148
Email Human.Ethics@utas.edu.au
www.research.utas.edu.au/human_ethics/

HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK

UTAS

13 January 2014

Ms I Boden
Launceston General Hospital

*Sent via email*

Dear Ms Boden

REF NO: **H0011911**
TITLE: **The effects of pre-operative physiotherapy on the incidence of post-operative pulmonary complications in high and low risk patients following major open upper abdominal surgery: A randomised controlled trial**

| ***Document*** | ***Version*** | ***Date*** |
|---|---|---|
| Participant Information Sheet | 2.0 | - |
| Consent Form | 2.0 | - |
| Use of Health Status Questionnaire – QoL SF-36 | - | - |
| Addition of follow-up Phone call and recorded interview | - | - |

The Tasmanian Health and Medical Human Research Ethics Committee considered and approved the above amendment documentation on **12 January 2014**.

All committees operating under the Human Research Ethics Committee (Tasmania) Network are registered and required to comply with the *National Statement on Ethical Conduct in Human Research* (NHMRC 2007).

Should you have any queries please do not hesitate to contact me on (03) 6226 2764.

Yours sincerely

**Heather Vail**
Ethics Administrator
Office of Research Services
Email: Heather.vail@utas.edu.au
University of Tasmania
Private Bag 01 Hobart Tas 7001

Health and Disability Ethics Committees

Health and Disability Ethics Committees
Ministry of Health
Freyberg House
20 Aitken Street
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdecs@moh.govt.nz

23 January 2015

Dr Julie Reeve
29a Vauxhall Rd
Devonport
Auckland 0642

Dear Dr Reeve

| Re: | **Ethics ref:** | **14/NTA/233** |
|---|---|---|
| | Study title: | Lung Infection Prevention Post Surgery- Major Abdominal- with Pre Operative Physiotherapy (LIPPSMAck POP) |

I am pleased to advise that this application has been *approved* by the Northern A Health and Disability Ethics Committee. This decision was made through the HDEC-Expedited Review pathway.

Conditions of HDEC approval

HDEC approval for this study is subject to the following conditions being met prior to the commencement of the study in New Zealand. It is your responsibility, and that of the study's sponsor, to ensure that these conditions are met. No further review by the Northern A Health and Disability Ethics Committee is required.

Standard conditions:

1. Before the study commences at *any* locality in New Zealand, all relevant regulatory approvals must be obtained.

2. Before the study commences at *any* locality in New Zealand, it must be registered in a WHO-approved clinical trials registry (such as the Australia New Zealand Clinical Trials Registry, www.anzctr.org.au).

3. Before the study commences at *a given* locality in New Zealand, it must be authorised by that locality in Online Forms. Locality authorisation confirms that the locality is suitable for the safe and effective conduct of the study, and that local research governance issues have been addressed.

After HDEC review

Please refer to the *Standard Operating Procedures for Health and Disability Ethics Committees* (available on www.ethics.health.govt.nz) for HDEC requirements relating to amendments and other post-approval processes.

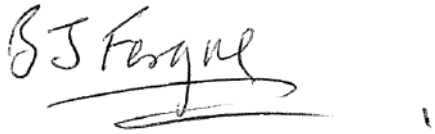
Your **next progress report** is due by **22 January 2016**.

Participant access to ACC

The Northern A Health and Disability Ethics Committee is satisfied that your study is not a clinical trial that is to be conducted principally for the benefit of the manufacturer or distributor of the medicine or item being trialled. Participants injured as a result of treatment received as part of your study may therefore be eligible for publicly-funded compensation through the Accident Compensation Corporation (ACC).

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,



Dr Brian Fergus
Chairperson
Northern A Health and Disability Ethics Committee

Encl: appendix A: documents submitted
appendix B: statement of compliance and list of members

**Appendix A**
**Documents submitted**

| *Document* | *Version* | *Date* |
|---|---|---|
| CV for CI | v1 | 27 November 2014 |
| PIS/CF | v1 | 28 November 2015 |
| Protocol | v10.5 | 28 November 2015 |
| CVs for other Investigators | v1 | 03 December 2014 |
| Survey/questionnaire: SF 36 | v1 | 03 December 2014 |
| Survey/questionnaire: SAQ | v1 | 03 December 2014 |
| Evidence of scientific review: Ethics approval Australia | v1 | 15 May 2013 |
| Participant pre operative information booklet | v1 | 03 December 2014 |
| Evidence of scientific review: Evidence of peer review - Australian ethics amendment letter | v1 | 03 December 2014 |
| Evidence of scientific review: Evidence of surgical approval from Australian sites | v1 | 03 December 2014 |
| Evidence of scientific review: Evidence of approval of amendments to Australian study | v1 | 13 January 2014 |
| Evidence of scientific review: Email detailing successful grant award for LIPPSMAck POP study | v1 | 02 April 2014 |
| Evidence of scientific review: Letter detailing Awhina grant award letter for LIPPSMAck POP study | v1 | 25 September 2014 |
| Evidence of scientific review: Peer review - grant award for LIPPSMAck POP | v1 | 20 October 2011 |
| Application | | 12 December 2014 |

**Appendix B**
**Statement of compliance and list of members**

Statement of compliance

The Northern A Health and Disability Ethics Committee:

- is constituted in accordance with its Terms of Reference
- operates in accordance with the *Standard Operating Procedures for Health and Disability Ethics Committees*, and with the principles of international good clinical practice (GCP)
- is approved by the Health Research Council of New Zealand's Ethics Committee for the purposes of section 25(1)(c) of the Health Research Council Act 1990
- is registered (number 00008714) with the US Department of Health and Human Services' Office for Human Research Protection (OHRP).

List of members

| *Name* | *Category* | *Appointed* | *Term Expires* |
|---|---|---|---|
| Dr Brian Fergus | Lay (consumer/community perspectives) | 01/07/2012 | 01/07/2015 |
| Dr Karen Bartholomew | Non-lay (intervention studies) | 01/07/2013 | 01/07/2016 |
| Ms Susan Buckland | Lay (consumer/community perspectives) | 01/07/2012 | 01/07/2015 |
| Ms Shamim Chagani | Non-lay (health/disability service provision) | 01/07/2012 | 01/07/2015 |
| Dr Christine Crooks | Non-lay (intervention studies) | 01/07/2013 | 01/07/2015 |
| Mr Kerry Hiini | Lay (consumer/community perspectives) | 01/07/2012 | 01/07/2015 |
| Mr Mark Smith | Non-lay (intervention studies) | 01/09/2014 | 01/09/2015 |
| Ms Michele Stanton | Lay (the law) | 01/07/2012 | 01/07/2015 |

http://www.ethics.health.govt.nz

# Appendix IV Patient information and consent form

Department of Health and Human Services
LAUNCESTON GENERAL HOSPITAL, PHYSIOTHERAPY DEPARTMENT
GPO Box 1963, LAUNCESTON, TAS, 7250, Australia
Ph: (03) 6348 7216 Fax: (03) 6348 7217

Tasmania

## PARTICIPANT INFORMATION SHEET

**Does education from a physiotherapist before your operation reduce your chance of getting a chest infection whilst recovering in hospital afterwards?**
**A randomised placebo blinded controlled trial.**

**Invitation**
You are invited to participate in a research study to see if your chance of getting a chest infection following your operation can be reduced by being taught how to do deep breathing, coughing and walking exercises before your operation. You will be required to do these exercises that you have been taught as soon as possible after you wake up from your operation.

The study is being conducted by Ianthe Boden, Cardiorespiratory Supervisor Physiotherapist from the Physiotherapy Department of the Launceston General Hospital.

Before you decide whether or not you wish to participate in this study, it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish.

**1. 'What is the purpose of this study?'**
The purpose is to investigate whether or not receiving instructions before your operation on how to do physiotherapy breathing, coughing and walking exercises following your operation reduces your chance of getting a chest infection afterwards.

**2. 'Why have I been invited to participate in this study?'**
You are eligible to participate in this study because you have been put on the waiting list by your surgeon for major surgery on some part of your abdomen and will be attending Pre-Operative Admission Unit at the Launceston General Hospital.

**3. 'What if I don't want to take part in this study, or if I want to withdraw later?'**
Participation in this study is voluntary. It is completely up to you whether or not you participate. If you decide not to participate, you will still receive routine care for a person attending this hospital for surgery on your abdominal region. It will not affect your relationship with the staff caring for you and will not affect the care you receive from hospital staff following your operation

If you wish to withdraw from the study once it has started, you can do so at any time without having to give a reason.

Department of Health and Human Services
LAUNCESTON GENERAL HOSPITAL, PHYSIOTHERAPY DEPARTMENT
GPO Box 1963, LAUNCESTON, TAS, 7250, Australia
Ph: (03) 6348 7216 Fax: (03) 6348 7217

Tasmania

However, it may not be possible to withdraw your data from the study results if these have already had your identifying details removed.

**4. 'What does this study involve?'**

If you agree to participate in this study, you will be asked to sign the Participant Consent Form. Your involvement starts from the time you attend your scheduled Pre-Operative Admission Unit appointment and will continue until 6 weeks following your discharge from hospital. If you agree to participate in this trial it will involve:

- Attending your scheduled Pre-Operative Assessment Unit appointment and being assessed by a Physiotherapist. This will comprise of answering questions on your current fitness level and current state of health. You will also have your grip strength measured and lungs listened to.
- You will be provided with some information about what you can do to prevent getting a chest infection after your operation. Currently, pre-operative education on how to perform your post-operative deep breathing, coughing and walking exercises is not provided at the Launceston General Hospital.
- Following your operation, your care will not differ from current standard care and your lungs will be assessed daily by a physiotherapist. You will be required to participate in the standard recovery walking program expected of all people following abdominal surgery. If you do not consent to be part of this trial your participation in the walking program will still be required as this is standard, mandatory care for abdominal surgery patients.
- Following your operation and just before you are ready to leave the hospital you will be asked to answer some questions about what you remember from the Pre-Operative Assessment session with the physiotherapist. This session will be recorded.
- 6 weeks after you have left hospital you will receive a phone call from the research team at the hospital to answer questions about your recovery and your current state of health and fitness.

In addition, the researchers would like to have access to your medical record to obtain information relevant to the study.

Department of Health and Human Services
LAUNCESTON GENERAL HOSPITAL, PHYSIOTHERAPY DEPARTMENT
GPO Box 1963, LAUNCESTON, TAS, 7250, Australia
Ph: (03) 6348 7216 Fax: (03) 6348 7217

Tasmania

**5. 'How is this study being paid for?'**
The study is being sponsored by the Clifford Craig Medical Research Trust. All of the money being paid by the sponsor to run the trial will be deposited into an account managed by the Launceston General Hospital. No money is paid directly to individual researchers.

**6. 'Are there risks to me in taking part in this study?'**
There are no known risks to this study. However, you may feel inconvenienced by being asked personal questions about your current fitness and health conditions.

**7. 'What happens if I suffer injury or complications as a result of the study?'**
It is extremely unlikely you will suffer any injuries or complications as a result of this study. However, if you have any questions about any perceived detrimental impact of your pre-operative education on deep breathing, coughing, or walking exercises please do not hesitate to contact the study co-ordinator.

**8. 'Will I benefit from the study?'**
This study aims to further medical knowledge and may improve future prevention of post-operative chest infections following major abdominal surgery; however it may not directly benefit you.

**9. 'Will taking part in this study cost me anything, and will I be paid?**
Participation in this study will not cost you anything extra outside the usual expected costs associated with attendance at the Pre-Operative Admission Unit. You will not be paid.

**11. 'How will my confidentiality be protected?'**
Of the people treating you, only the Pre-Operative Admission Unit nurse and physiotherapist will know whether or not you are participating in this study. Any identifiable information that is collected about you in connection with this study will remain confidential and will be disclosed only with your permission, or except as required by law. Only the researchers named above will have access to your details and results will be held securely at the Launceston General Hospital. Your personal details (name and address) will not appear in any study database or publication of the study results.

**12. 'What happens with the results?'**
If you give us your permission by signing the consent document, we plan to discuss, present, or publish the results of this study with the following organizations:

Department of Health and Human Services
LAUNCESTON GENERAL HOSPITAL, PHYSIOTHERAPY DEPARTMENT
GPO Box 1963, LAUNCESTON, TAS, 7250, Australia
Ph: (03) 6348 7216 Fax: (03) 6348 7217

Tasmania

- Clifford Craig Medical Research Trust, the funding body for this study, for monitoring purposes
- Health Research Ethics Committee for monitoring of ethical requirements of this study
- Selected scientific peer-reviewed journals
- Presentation at Physiotherapy and Medical conferences and other professional forums

In any publication or presentation about this study, information will be provided in such a way that you cannot be identified. All personal details (name, date of birth, address, medical conditions etc) are removed from the information and it is impossible for anyone to identify who you are through any results that are published. Results of the study will be provided to you, via the Clifford Craig Medical Research Trust newsletter, if you are interested in receiving this mail out.

**13. 'What should I do if I want to discuss this study further before I decide?'**
When you have read this information, the pre-operative Physiotherapy educator, will discuss it with you and any queries you may have. If you would like to know more at any stage, please do not hesitate to contact the Principle Researcher, Ianthe Boden, at the Launceston General Hospital, Physiotherapy Department, 6348 7212.

**14. 'Who should I contact if I have concerns about the conduct of this study?'**
This study has been approved by the Tasmanian Health and Medical Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study should contact the Executive Officer of the HREC (Tasmania) Network on (03) 6226 7479 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. You will need to quote H0011911.

- **Thank you for taking the time to consider this study.**
- **If you wish to take part in it, please sign the attached consent form.**
- **This information sheet is for you to keep.**

Department of Health and Human Services
LAUNCESTON GENERAL HOSPITAL, PHYSIOTHERAPY DEPARTMENT
GPO Box 1963, LAUNCESTON, TAS, 7250, Australia
Ph: (03) 6348 7216 Fax: (03) 6348 7217

Tasmania

withdraw from the project at any stage. My withdrawal will not affect my legal rights, my medical care or my relationship with the hospital or my doctors.

8. I understand that I will be given a signed copy of this patient information sheet and consent form. I am not giving up my legal rights by signing this consent form.

9. I understand that the trial will be conducted in accordance with the latest versions of the *National Statement on Ethical Conduct in Human Research 2007* and applicable privacy laws.

This trial is funded through the Clifford Craig Medical Research Trust, if you would like to receive information on the results of this clinical trial, you would be able to get this through regular newsletters from the Clifford Craig Medical Research Trust.

Please tick this box if you would like to receive this newsletter ☐

Name of participant: _____

Signature of participant: _____

Date: _____

Name of witness (if required) _____

Signature of witness _____ Date _____

---

**(To be completed by research staff)**
I have explained this project and the implications of participation in it to this participant and I believe that the consent is informed and that he/she understands the implications of participation.

Name of investigator _____

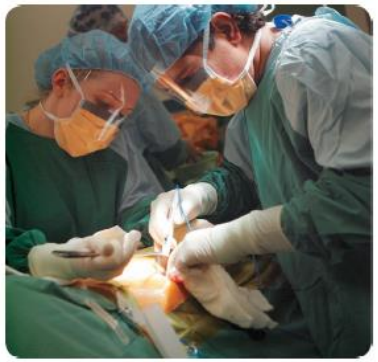
Signature of investigator _____ _____

# Appendix V Information booklet

Launceston General Hospital

## Physiotherapy following your abdominal surgery

## How to prevent chest infections and other complications



Department of Health and Human Services

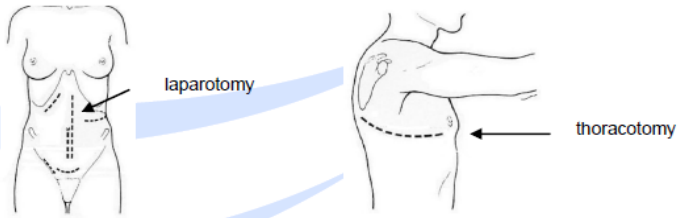
Tasmania
Explore the possibilities

## Introduction

This booklet provides information on what to **expect** after your operation. It outlines some potential problems, such as a chest infection or deep vein thrombosis, that might happen after your operation and what **you** must do, with a bit of help from your physiotherapist, to assist in preventing these. We encourage you to share this information with your family and friends to help them understand.

### Your Operation

During your operation you will receive one or more incisions in your abdomen or chest wall. The site of the incision will depend on the type of operation you have. The following diagrams demonstrate the possible sites of these incisions.




### How long does the operation take?

Depending on the type of surgery and how complex it is, the operation can be as quick as 30 minutes or could last many hours.

### How long will I be in hospital?

If everything goes smoothly and there are no complications, most people are in hospital from between 9 and 14 days.

### Drips and drains

After the operation it is normal to have many, many drips and drains coming in and out of your body! We have listed some of them here:

1

- Wound Drain
  One or more drains in your abdomen to remove any excess fluid and blood.
- Chest Drain
  If you have had a cut through your rib cage (thoracotomy) you may also have a tube inserted into your chest during surgery to drain any fluid or excess air from the chest
- Intravenous (IV) Line
  In one, or both of your arms, to provide you with fluid and medications
- Epidural
  a line into your back to help with your pain relief
- Nasogastric Tube
  a tube inserted up and into your nose then down into your stomach to help with delivery of food or draining excess air/fluid from your stomach
- Catheter
  A tube in your urethra to drain your bladder of urine whilst you find it difficult to get up and get to the toilet.

As you can imagine, getting up and out of bed can be quite difficult with all these things hanging around!

## Pain relief

The staff at the hospital will work hard to keep any pain felt after this operation to a minimum.

There are many different types of pain relief available - epidurals, patient controlled analgesia drips, tablets, injections, constant infusions to the wound, and others. Your doctors will choose the types best for you and your condition.

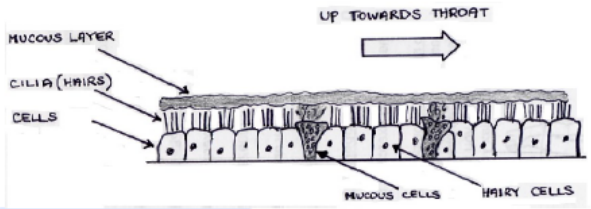
It is quite important that any pain doesn't limit your ability to do your exercises after the operation. Please don't hesitate to alert a nurse or doctor if your pain levels are stopping you from walking and doing your breathing and coughing exercises after the operation.



# Chest infections-why am I at risk?

Your lungs are normally kept clean by a thin layer of mucous that lines your airways. Dust particles and germs that you inhale with each breath stick to this layer of mucous. Tiny hairs (cilia) sit underneath this dirty mucous (phlegm) and sweep it out of your lungs and to the back of the throat where it is then swallowed and disposed of. This process happens every day of your life without you even knowing about it! It is normal to produce about 120mls or a ¼ of a cup of phlegm a day.

**CROSS SECTION OF AN AIRWAY IN THE LUNGS**




After major surgery, however, more than the normal amount of mucous is produced. Too much for your normal cleaning mechanisms to deal with. Extra help is now required to clear the phlegm. This is when you need to **cough or huff** to get rid of it all.

If the phlegm remains in your lungs for too long it can become a growth site for bacteria. This can lead to a chest infection.

## What increases my chances of getting a chest infection?

- Being a smoker
- Having a lung condition (eg asthma, emphysema, bronchitis, bronchiectasis)
- Not being very fit
- The type of operation you will be requiring. The closer the operation is to the lungs the higher your risk of a chest infection
- A long operation, especially over 3 hours
- A longer or higher cut in your abdomen
- Slow to get walking soon after the operation
- Not doing much walking in hospital following your operation

### What happens if I get a chest infection?

If you get a chest infection after your operation you will become quite sick. You will get a fever, probably a bad cough, have difficulty breathing, and you may need to go to the Intensive Care Unit to be looked after. At worst, you could die.

The doctors will take x-rays of your chest, take blood tests and will provide you with strong antibiotics to help fight the infection. A physiotherapist will give you special breathing and coughing exercises to help try to clear the infection.

You will spend a lot longer in hospital and your recovery from your operation will be slower.

### What can I do to prevent getting a chest infection?

**Walking and getting active** as early as possible after an operation is **the most effective way to prevent complications** like chest infections and blood clots.

Regular movement also prevents **deep vein thrombosis** and **pressure ulcers** (bed sores) developing, and promotes bowel function.

Walking increases your lung volumes and helps prevent and reduce any lung collapse. Walking also pumps blood faster around your body and prevents blood clots from forming

Physiotherapy treatment after your operation is aimed at minimising problems like chest infections and blood clots.

Expect to:

- Start walking with the help of your physiotherapist, or nurse, **as soon as possible** after your operation. This can even occur on the day you wake up from your operation. The earlier the better.
- Do your own breathing and coughing exercises every day to assist in reinflating you lungs and prevent the build up of phlegm
- Do your own leg exercises to prevent blood clots from forming



# Exercises to do after your operation

It is important to take your pain medication regularly to ensure you can participate in the following exercises during your stay.

### 1. GET OUT OF BED

You will be helped out of bed on the first day after the operation.

The easiest way to get out of bed is as follows:

1.Roll onto your side
(if your incision is on your side, roll onto the opposite side).

2. Drop your legs over the side of the bed and push up into a sitting position with your arms.

3. Keeping your hands on the bed, lean forward and push up into a standing position.

### 2. GET WALKING

A physiotherapist, or one of their assistants, will visit you most days whilst you are in hospital and help you to get walking to start with.

They will help you to walk at a pace that helps reinflate the lungs and prevent blood clots in the legs. You will need to walk fast enough that it feels like "light" to "moderate" type of hard work.

You will be encouraged to walk as far as possible each time you walk with them.

To start with, it may be as little as **3** to **5** minutes of walking and as you improve may even be as long as **15** minutes of walking.

You might also be given a walking frame to help you get going in the beginning and also to help carry all the drips and drains you will have.

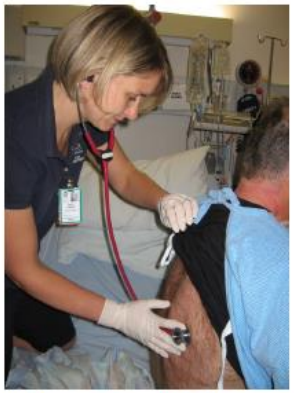
The more times you go for a walk away from your bedside during the day the better. It doesn't just have to be with a Physiotherapist or one of their assistants. Ask one of the nurses to help you get up to go for a walk. When you are a bit more confident, go for a walk with one of your visitors.

The **earlier** you get up and out of bed and walking the better

The **more** walking you do in hospital recovering from your operation the better



# Exercises to do after your operation



## 3. DEEP BREATHING

After your operation your lungs will be a little deflated and your breathing will be a bit shallower than usual.

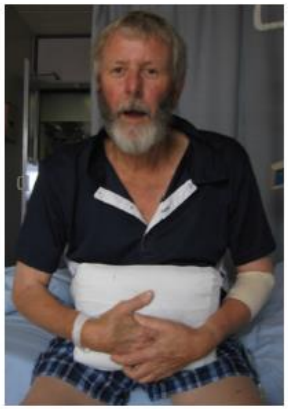
This is due to a combination of reasons:

- use of a breathing machine called a
- ventilator during the operation
- use of pain relief medications afterwards
- lying in bed more than usual and not being as active

It is important that you do your best to reinflate and exercise your lungs as soon as possible after your operation to reverse these changes. Do as many as you can on the first few days after the operation.

## 4. COUGHING

It is very important to clear your lungs of any secretions. A build up of sputum can harbour infections and cause you breathing difficulties. Unfortunately due to the incision in your abdomen it can be a bit uncomfortable to perform an good cough. You will be provided with support for your tummy—your "cough pillow", which you will use whenever you cough to help reduce the discomfort. Your physiotherapist may also show you how to "huff", an alternative to a cough. It tends to hurt a little less.
Please alert your nurse if your pain levels are preventing you from coughing or moving.



## BREATHING AND COUGHING EXERCISES

- Take 10 slow deep breaths
- Hold each one for 5 seconds
- Gently press your "cough pillow" to your wound
- Large breath in and cough or huff 3 times through.
- Repeat all of this over again

(All up 20 deep breaths with 6 coughs/huffs)

Do this once **every hour** during the day

8

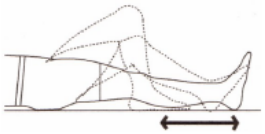
## Exercises to do after your operation

### 5. CIRCULATION EXCERCISES

When in bed it is important to perform the following ankle and leg exercises to keep the blood flowing through your body. This helps maintain good circulation and prevents clots, or thromboses, forming in your legs.

Moving foot up and down. Feel calf muscle working

Tighten and relax thigh muscles.



Slide leg up and down bed. Keep heel on bed.

NOTES

9

NORTHERN AREA HEALTH SERVICE

LAUNCESTON GENERAL HOSPITAL

PHYSIOTHERAPY DEPARTMENT

6348 7216

## How to comment on our service

We would like to improve our services - please help us by advising us of:

**Compliments or Complaints**

If you wish to compliment or complain about a department or service, please *either:*

* Request to see the staff member in charge, *or*
* Telephone the Compliments/ Complaints line in the Clinical Effectiveness Service.

**Free call — 1800 008 001** or write to -

**Patient Advice and Liaison Officer**
Launceston General Hospital
P.O.Box 1963, Launceston ,Tasmania 7250

This information sheet has been prepared by staff at the Launceston General Hospital to assist you with queries related to operation.

***Review Date: February 2015***



Tasmania
Explore the possibilities

Launceston
General Hospital

P.O. Box 1963
Launceston TAS 7250
Ph: (03) 6348 7111

# Appendix VI Data collection forms

NB: This is a PDF copy of the electronic data collection form. As such it is not possible to represent the extensive data validation rules, formulas, dropdown menus, and data collection instructions embedded within the file.

**LIPPSMAck POP TRIAL**

ID no 0
Surname: 0
DOB: 00/01/1900

**PRE-OPERATIVE PHYSIOTHERAPY SESSION**

**Height** cm **Weight** kg **BMI** #DIV/0! BMI=weight/height$^2$

**Reason for operation:**
**Surgical category:** #N/A

**Co-morbidities:** Enter "y" in the first column for a past or present diagnosis OR 'n' for condition not present
2nd column: Does this condition significantly limit your walking ("y" in the appropriate box)?

| | | |
|---|---|---|
| Athritis | | |
| Osteoporosis | | |
| Asthma | | |
| COPD, ARDS, chronic resp dx | | |
| Angina | | |
| Congestive cardiac failure/disease | | |
| Heart Attack | | |
| Neurological disease | | |
| Stroke or TIA | | |
| Diabetes Type I or 2 | | |
| Peripheral vascular disease | | |
| Upper GI disease (eg reflux, cystitis, ulcers) | | |
| Depression | | |
| Anxiety/panic disorders | | |
| Visual impairment | | |
| Hearing Impairment | | |
| Degenerative Disc disease | | |
| Obesity BMI>30 | #DIV/0! | |

**Cancer diagnosis?** y/n
Is there a current Dx of cancer?

**Current chest infection?** y/n
Have you had a chest infection in the past 2 weeks?

Have you been prescribed an antibiotic for this by a Dr?

**ASA (0-5, from aneasthetic report):**

Pre-operative chemotherapy in last 6 wks

Pre-operative NGT

FCI score/18: 0
(1 point for each co-morbidity)

**Smoking history:**

Ever smoked? y/n
Are you still smoking? y/n
How old when ceased smoking?
How old when started smoking?
On ave, how many cigs per day?

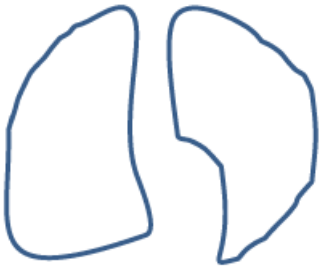
No = quit > 8 weeks ago
If current smoker enter current age

**Pack years** 0
Years since quiting 0

Physiotherapist name: Signature: Date:

**PRE-OPERATIVE PHYSIOTHERAPY ASSESSMENT:**

**SpO2 on RA:** % **HR at rest:**



**Auscultation:** Please record location of findings on diagram

Please document your findings and location found below:

| | Sign: | Location: |
|---|---|---|
| Air entry: | | |
| Breath sounds: | | |
| Added sounds: | | |

| Key: | | |
|---|---|---|
| Air entry: | (Equal bilaterally, unequal, other) | ↓ Decreased breath sounds |
| Breath sounds: | (Normal, Absent, Quiet, Harsh/Bronchial) | Harsh (bronchial) breath sounds |
| Added sounds: | (Nil, Crackles, Wheeze, other) | x Crackles |
| | | o Wheeze |

**Cough:** Whilst in sitting, ask patient to perform 3 strong coughs in a row as hard as they can

Please grade the cough as follows:

| | Key: |
|---|---|
| Strength: | Subjective judgement of cough power |
| Effectiveness: | Subjective judgement on whetheror not cough could clear secretions |
| Moistness: | Wet=sound of secretions in cough |
| Productiveness: | Production of sputum following a cough (expectorated or swallowed) |

**Sputum:** If patient has a productive cough please use colour chart to classify it — Colour

If unable to expectorate, get patient to class colour of phelgm last visualised — Classification #N/A

**Exercise tolerance/mobility:**

**RAPA** Aerobic — #N/A

Strength/stretching

"How many minutes can you walk along the flat at your own pace without stopping for a rest?"

"What stops you from walking any further?"

Do you use anything to walk with?

**Self-administered Physical Activity Questionnaire (SAQ)** VO2 -12.65

**PPC risk assessment:**

| | | Score |
|---|---|---|
| Estimated duration of anaesthetic | | #N/A |
| Surgical category | #N/A | #N/A |
| Diagnosis of a Respiratory co-morbidity | n | 0 |
| Current smoker | n | 0 |
| V02 max score as calculated from SAQ | -12.65 | -0.962 |
| | TOTAL | #N/A |
| | **Risk** | **#N/A** |

**Handgrip:** Performed on dominant hand, in sitting with elbow at 90 degress, forearm in neutral.

Dominant hand:

Grip strength: kg best of 3 repetitions

**LIPPSMAck POP TRIAL**

**POST OPERATIVE DATA COLLECTION**

Med record no

Surname:

DOB:

| | | | |
|---|---|---|---|
| **Date of operation:** | | **Operation performed:** | |
| **Anaesthetic time** | mins | **Incision used:** | |

**Protocol:** **Physio first session post-op. PTA assisted ambulation from then on. All patients ar**

**WEEK 1**

| POD | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Date | | | | | | | |
| Weekday | | | | | | | |
| Location | | | | | | | |
| Oxygen/ventilation | | | | | | | |
| Analgesia (1-6) | | | | | | | |
| Analgesia (1-6) | | | | | | | |
| Analgesia (1-6) | | | | | | | |

**Assess patient for a PPC EVERY DAY for 7 days or until d/c from hospital**

**1: Does the patient have a PPC? If no, progress to D/C Ax. If yes, treat as necessary.**

| **Observations:** Mark presence of sign or symptom for each day that it is present (y/n/not avail) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ausc changes | | | | | | | |
| Sputum changes | | | | | | | |
| SpO2 < 90% on RA | | | | | | | |
| Temp > 38 | | | | | | | |
| CXR changes | | | | | | | |
| WCC >11 or AB's | | | | | | | |
| sputum culture +ve | | | | | | | |
| Dr dx of a PPC | | | | | | | |
| **PPC diagnosis** | | | | | | | |

**Assess patient for d/c from Physio services EVERY DAY until score =14**

**2: Can patient be d/c from Physiotherapy services? If yes, cont with daily PPC Ax for 2/52; No: Step 3**

| **Discharge from Physiotherapy scoring (d/c when score is 14 or 15)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Mobility | | | | | | | |
| Breath Sounds | | | | | | | |
| Secretion clearance | | | | | | | |
| SpO2 | | | | | | | |
| Resp rate | | | | | | | |
| **D/C from Physio (6-15)** | | | | | | | |

**Enter ambulation information EVERY DAY until discharge from Physio services**

**3: Ambulation protocol: Physio First occasion, PTA from then on.**

| **Ambulation protocol - Record most successful attempt on that day** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Who provided it? | | | | | | | |
| Time provided | | | | | | | |
| Pain score (0-10) | | | | | | | |
| Mobility stage attained (1-7) | | | | | | | |
| Reason for not achieving at least Stage 3 or ideally Stage 6 (1-6) | | | | | | | |
| Max Borg (0-10) | | | | | | | |

**STEP 4: Document any adverse events, breaks to protocol, or reasons for trial withdrawal**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Adverse event** | | | | | | | |
| **Breaks to protocol** | | | | | | | |
| **Withdraw from trial** | | | | | | | |
| Notes: | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| D/C date | D/C Time | D/C Destination |
|---|---|---|
| | | |

LOS ____ days

'e to be checked for a PPC every day until d/c or POD 7

**WEEK 2**

| 8 | 9 | 10 | 11 | 12 | 13 | 14 | POD |
|---|---|---|---|---|---|---|---|
| | | | | | | | Date |
| | | | | | | | Weekday |
| | | | | | | | Location |
| | | | | | | | Oxygen/ventilation |
| | | | | | | | Analgesia (1-6) |
| | | | | | | | Analgesia (1-6) |
| | | | | | | | Analgesia (1-6) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | CXR changes |
| | | | | | | | Temp > 38 |
| | | | | | | | SpO2 < 90% on RA |
| | | | | | | | Sputum changes |
| | | | | | | | sputum culture +ve |
| | | | | | | | WCC >11 or AB's |
| | | | | | | | Ausc changes |
| | | | | | | | Dr dx of a PPC |
| | | | | | | | **PPC diagnosis** |

**Assess patient for d/c from Physio services EVERY DAY until score =14**

**2: Can patient be d/c from Physiotherapy services? If yes, cont with daily PPC Ax for 2/52; No: Step 3**

| **Discharge from Physiotherapy scoring (d/c when score is 14 or 15)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Mobility |
| | | | | | | | Breath Sounds |
| | | | | | | | Secretion clearance |
| | | | | | | | SpO2 |
| | | | | | | | Resp rate |
| | | | | | | | **D/C from Physio (6-15)** |

**Enter ambulation information EVERY DAY until discharge from Physio services**

**3: Ambulation protocol: Physio First occasion, PTA from then on.**

| **Ambulation protocol** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Who provided it? |
| | | | | | | | Time provided |
| | | | | | | | Pain score (0-10) |
| | | | | | | | Mobility stage attained (1-7) |
| | | | | | | | Reason for not achieving at least Stage 3 or ideally Stage 6 (1-6) |
| | | | | | | | Max Borg (0-10) |

**STEP 4: Document any adverse events, breaks to protocol, or reasons for trial withdrawal**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | **Adverse event** |
| | | | | | | | **Breaks to protocol** |
| | | | | | | | **Withdraw from trial** |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Keys:**

**Location:**
ICU (Intensive Care Unit)
Surg Ward (Surgical Ward)
D/C (Discharged)

**Discharge Destination:**
1. Home
2. Rehab facility
3. Nursing home
4. Other hospital

**Incision:**
Midline laparotomy
Bilateral Subcostal (Chevron)
Subcostal (Kocher)
Transverse
Abdo incision + thoracotomy
Other

**Oxygen/Ventilation:**
Mechanically ventilated
Non-invasive ventilation
High flow nasal prongs
Humidified mask
Mask
Nasal prongs
Nil

**Analgesia:**
1. Epidural
2. Constant opioid infusion
3. PCA
4. PCEA
5. Oral
6. Other (specify)

**PPC Diagnosis:**

*When 4 or more of the following criteria are present*

- CXR report of collapse/consolidation
- Raised max temp >38°C on more than one consecutive day
- SpO2 <90% on room air on more than one consecutive day
- Productive of yellow or green sputum different to pre-operative
- Presence of infection on sputum culture report
- Anotherwise unexplained WCC > 11 **OR** Rx of an antibiotic specific for respiratory infection
- New abnormal breath sounds on auscultation different to preoperative
- Physician's diagnosis of postoperative pulmonary complication

**Discharge from Physiotherapy (Score of 14 or 15 = discharge):**

| | | |
|---|---|---|
| Mobility: | 3 | Reached pre-op ambulation status |
| | 2 | Requires supervision, status has plateaued |
| | 1 | Requires assistance, status is improving |
| | 0 | Unable to ambulate |
| Breath Sounds: | 3 | Reached pre-op levels and within expecatitions for that patient |
| | 2 | Slightly decreased breath sounds or presence of a few added sounds |
| | 1 | Markedly abnormal breath sounds and/or significant added sounds |
| Secretion Clearance: | 3 | Able to clear secretions independently OR at pre-op status |
| | 1 | Requires assistance to clear secretions |
| SpO2: | 3 | Sats > 92% or > 88% (exsisting resp condition) |
| | 2 | Sats < 92% or < 88% (exsisting resp condition) |
| Resp rate (rest & activity): | 3 | Within normal expectations |
| | 2 | Outside acceptable range for individual |

**Keys:**

**Mobility Stages:**

*Attempted sequentially every treatment session*

0. Unable
1. SOEOB 2 minutes (sit on each of bed)
2. MOS 0-1 minute (marching on the spot)
3. MOS/walk 1-3 minutes
4. MOS/walk 3-6 minutes
5. Walk 6-10 minutes
6. Walk 10-15 minutes
7. Walk > 15 minutes

**Reason for not achieving stage 6 ambulation:**

1. Hypotension (dizzy, BP<100/60, in sitting after 2 min ankle pumping and rest)
2. Pain (> 7/10, analgesia active, distressed)
3. Nausea, vomiting
4. Patient unavailable
5. Physio/assist unavailable
6. Patient non consent
7. Other (specify)
8. Fatigue

**Adverse event:**

Vasovagal/collapse/faint
Ileus
PE
DVT
Cardiovascular event
Haemorrage
Death
Other (Specify)

**Withdraw from trial:**

Lower abdominal surgery only
Laparoscopic surgery
Thoracic surgery only
Ventilated for more than 48 hours post-operatively
Return to surgery within 5 post-op days of initial surgery
Withdrew self from trial
Death

**Breaks to protocol:**

1. Physio coached deep breathing and coughing exercises and/or PEP
2. Physio provided directed ambulation > once
3. Nurse provides PEP
4. Other (specify)

# Appendix VII Protocol badge cards for ward physiotherapists

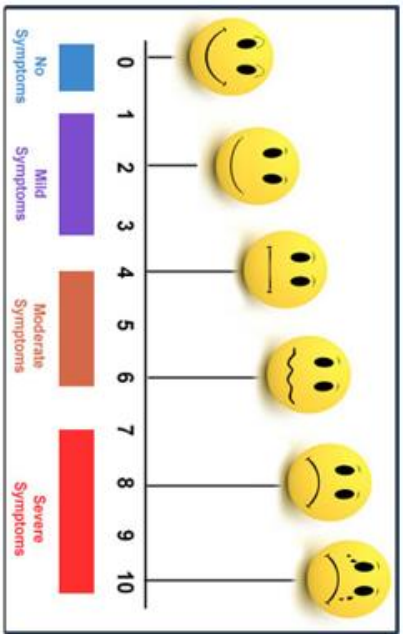
**Protocol badge cards for ward physiotherapists**

b) Pain visual analogue scale

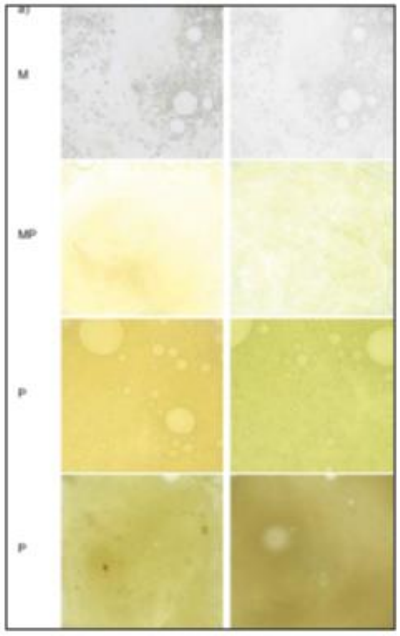
c) Borg rating of perceived exertion scale

d) Sputum colour chart

e) LIPPSMAck POP postop protocol card




| 1 - 10 Borg Rating of Perceived Exertion Scale | |
|---|---|
| 0 | Rest |
| 1 | Really Easy |
| 2 | Easy |
| 3 | Moderate |
| 4 | Sort of Hard |
| 5 | Hard |
| 6 | |
| 7 | Really Hard |
| 8 | |
| 9 | Really, Really, Hard |
| 10 | Maximal: Just like my hardest race |



**LIPPSMAck POP trial**
**Protocol:**
Physio once only, ASAP post-op.

- Provide mob aid and cough pillow. Briefly remind pt on DB&C as per booklet
- **Ambulation stages**

1. (safety) Sitting min 2 min
2. (safety) MOS 0-1 min
3. (Physio) MOS/walk 1-3 mins
4. (Physio) MOS/walk 3-6 mins
5. (Physio) Walk 6-10 mins
6. (Physio) Walk 10-15 mins
7. (Physio) Walk >15 mins

Goals - increase RR, **RPE 3-4/10**, achieve min of 1 minute, ideally 10 min or more total walk time (cont or intervals). Record why, if not able.

- Tell pt to amb as often as able.
- Handover to PTA current

# Appendix VIII Interview transcript scoring template

QUANTITATIVE: Please score each interview on the below scoring schema. For answers that can have multiple responses please score each response as appropriate. If a participant elaborates later in the interview and reports knowledge and awareness that could also answer a prior question you may backtrack and score the response of the previous question based on the responses to later questions.
Please also make a judgement from the transcript whether you believe that the participant was in the control or intervention group.

QUALITATIVE SECTION: Now that you are familiar with the transcript, start analysing the participant's responses for themes about HOW the preoperative information is provided and factors that make information delivery helpful or a hindrance.

| | | |
|---|---|---|
| Was physiotherapy the most memorable component of preoperative assessment clinic? Circle one only. | Yes | No |
| Did the participant remember meeting a physiotherapist? Circle one only. | Yes | No |
| What did the participant remember about the physiotherapy session? Circle as many as appropriate for this participant. | Nothing<br>Booklet<br>Research<br>Breathing exercises<br>Coughing<br>Early ambulation<br>Lung physiology or mucociliary clearance<br>Circulation exercises<br>Preventing pneumonia<br>Preoperative fitness optimisation<br>Other: _____ | |
| What did the participant remember about the information in the booklet?<br>Please subjectively categorise the answer to this question into the following categories. | No recall<br>Vague recall<br>Good recall | |
| What did the participant remember about early ambulation? | Every day/as much as possible (frequency) | |

| | |
|---|---|
| | Next day after surgery (timeliness)<br>How long to walk for (duration or distance)<br>How hard (intensity)<br>Importance |
| What did the participant remember about the breathing exercises?<br>Please subjectively categorise the answer to this question into the following categories. | No recall<br>Vague recall<br>Good recall<br>Cough pillow<br>Deep breathing |
| Was the participant able to recall reps, sets, or frequency of breathing exercises? | Reps:<br>Sets:<br>Frequency:<br>Inspiratory hold:<br>Cough: |
| What did the participant report as why these exercises were important? | Prevent respiratory/lung complications<br>Mucociliary clearance<br>Lung recovery<br>Improve general recovery<br>Heart/Circulation<br>Other:_____ |
| Do you believe that the participant was in the control or intervention group? Circle. | CONTROL / INTERVENTION |

# Appendix IX Standards of reporting qualitative research checklist

| Standards of reporting qualitative research (SRQR) checklist | | | |
|---|---|---|---|
| No. | Topic | Description | Line |
| 1 | Title | Concise description of the nature and topic of the study Identifying the study as qualitative or indicating the approach (e.g., ethnography, grounded theory) or data collection methods (e.g., interview, focus group) is recommended | 2 |
| 2 | Abstract | Summary of key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results, and conclusions | 43-64 |
| **INTRODUCTION** 3 | Problem formulation | Description and significance of the problem/phenomenon studied; review of relevant theory and empirical work; problem statement | 114-115 |
| 4 | Research question | Purpose of the study and specific objectives or questions | 107-113 |
| **METHODS** 5 | Qualitative approach/research paradigm | Qualitative approach (e.g., ethnography, grounded theory, case study, phenomenology, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g., postpositivist, constructivist/ interpretivist) is also recommended; rationale | 197-203 |
| 6 | Researcher characteristics and reflexivity | Researchers' characteristics that may influence the research, including personal attributes, qualifications/experience, relationship with participants, assumptions, and/or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results, and/or transferability | 149-154 |
| 7 | Context | Setting/site and salient contextual factors; rationale | 125-138 |
| 8 | Sampling strategy | How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g., sampling saturation); rationale | 122-123, 145 |
| 9 | Ethical issues pertaining to human subjects | Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues | 318<br>124 |
| 10 | Data collection methods | Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources/methods, and modification of procedures in response to evolving study findings; rationale | 128-143<br>197-203 |

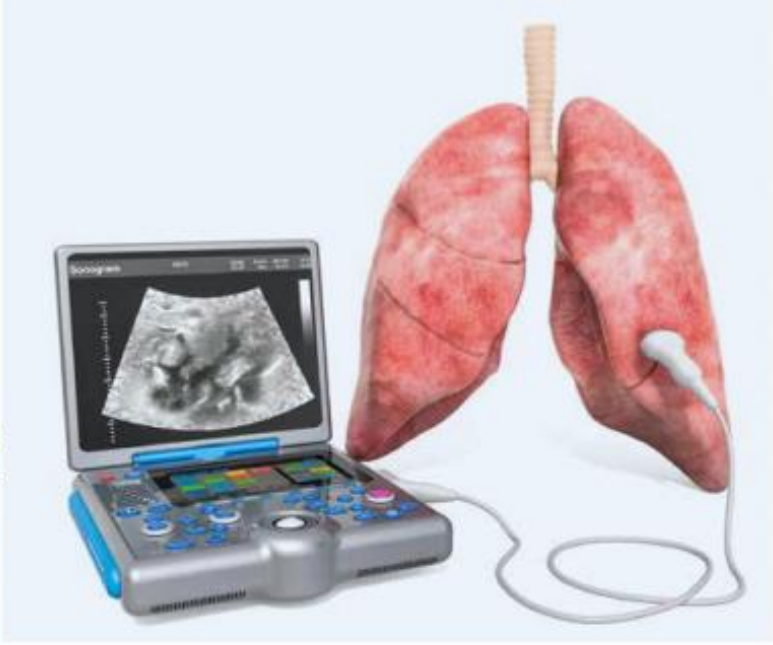
| | | | |
|---|---|---|---|
| 11 | Data collection instruments and technologies | Description of instruments (e.g., interview guides, questionnaires) and devices (e.g., audio recorders) used for data collection; if/how the instrument(s) changed over the course of the study | 128-143 Supplementary material Box 1 |
| 12 | Units of study | Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results) | 206-213 |
| 13 | Data processing | Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymization/deidentification of excerpts | 197-203 |
| 14 | Data analysis | Process by which inferences, themes, etc., were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale | 197-203 |
| 15 | Techniques to enhance trustworthiness | Techniques to enhance trustworthiness and credibility of data analysis (e.g., member checking, audit trail, triangulation); rationale | 197-203 |
| **RESULTS** 16 | Synthesis and interpretation | Main findings (e.g., interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory | 239-295 |
| 17 | Links to empirical data | Evidence (e.g., quotes, field notes, text excerpts, photographs) to substantiate analytic findings | 239-295 Supplementary material |
| **DISCUSSION** 18 | Integration with prior work, implications, transferability, and contribution(s) to the field | Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application/ generalizability; identification of unique contribution(s) to scholarship in a discipline or field | 297-379 |
| 19 | Limitations | Trustworthiness and limitations of findings | 297-379 |
| | Conflicts of interest | Potential sources of influence or perceived influence on study conduct and conclusions; how these were managed | 134-138 |
| 21 | Funding | Sources of funding and other support; role of funders in data collection, interpretation, and reporting | 383-384 |

# Appendix X Invited commentary – 5 facts about cardiorespiratory physiotherapy


## 5 facts about ... cardiorespiratory physiotherapy

George Ntoumenopoulos, Danni Dunlop, Ianthe Boden, Marie Williams, Kylie Johnston and Lara Edbrooke discuss five lesser known facts about cardiorespiratory physiotherapy and what you can implement in your current practice.

**5 FACTS**



lexaLMX/iStock via Getty Images

## 1 Lung ultrasound can improve decision making

The limited diagnostic accuracy of lung auscultation and the portable chest radiograph in critical care is a challenge physiotherapists must address. The reduced diagnostic accuracy of the portable chest radiograph compared to lung ultrasound (LUS) for the detection of common lung pathology, such as lung collapse, pulmonary oedema, consolidation, pleural effusion or pneumothorax (Xirouchaki et al 2011), questions the findings of previous landmark trials and critical care physiotherapy recommendations (Stiller et al 2013, Stiller 2013). LUS is a diagnostic tool that should be adopted by critical care physiotherapists, with the increasing evidence-base for its excellent diagnostic accuracy and real-time monitoring capabilities (Via et al 2012, Volpicelli et al 2012, Hew & Tay 2016). Physiotherapists can acquire the preliminary knowledge and skills in LUS (Ntoumenopoulos et al 2017) but there may be potential barriers such as time, mentors, perceived scope of practice issues to the uptake and use of LUS in clinical practice (Ntoumenopoulos & Hough 2014) that need to be addressed.

Beyond the potential for LUS to better discern whether chest physiotherapy is indicated (Leech et al 2015), it may also be of use to non-invasively assess the effect of the intervention, such as manual or ventilator hyperinflation to recruit collapsed lung (Cavaliere et al 2011). With issues around physiotherapy in critical care (eg, 24/7 access, respiratory vs rehabilitation focus, limited physiotherapy staffing-to-patient ratios, skill mix), it will be a challenge to feasibly incorporate another diagnostic tool with busy caseloads. LUS should enable us to determine the prevalence of acute pulmonary conditions amenable to physiotherapy and allow clinicians to use their time more appropriately.

## 2 Cardiorespiratory physiotherapists work in advanced practice roles

With additional training programs, cardiorespiratory physiotherapists now have opportunities to work in innovative advanced scope roles. In 2015, the Austin Health physiotherapy department in Victoria received a grant to develop an individualised, integrated model of care led by a critical care-trained physiotherapist for high-risk surgical patients in the detection, surveillance and treatment of postoperative pulmonary complications (PPC).

High-risk surgical patients experienced a high rate of PPC at Austin Health (Story 2011, Austin Health POST Investigators 2010), two-thirds of which occurred in the first two postoperative days. This represents a threefold increase compared to low-risk patients undergoing upper abdominal surgery (Haines et al 2013). PPCs were related to increased hospital stay and costs,

gorodenkoff/iStock via Getty Images

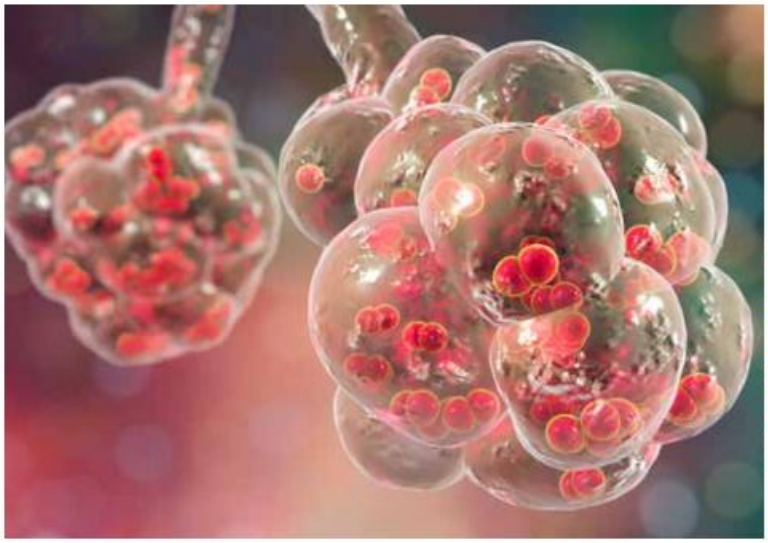
and patients were also more likely to have a medical emergency team review and utilise critical care outreach resources (Story 2011, Haines et al 2013). Most of these patients had a delay to mobilisation (Haines et al 2013).

A physiotherapy-led model of care was implemented in 2016 to increase the detection of deterioration and promote early mobility in this patient cohort. A senior critical care physiotherapist monitors high-risk surgical patients, identifies barriers to mobility, and remediates them to ensure mobilisation occurs. The advanced practice physiotherapist coordinates postoperative care alongside an intensive care fellow and an acute pain service team, which assist with fluid boluses and pain medication titration. PPC incidence has decreased to 19.2 per cent in the high-risk surgical cohort, with a concurrent decrease in mean length of hospital stay by five days (Dunlop & Berney 2016).

## 3 Pre-operative physiotherapy prevents postoperative pneumonia

More than 150,000 major abdominal surgery procedures are performed every year in Australia (Australian Institute of Health & Welfare). An upper abdominal incision has negative effects on respiratory mechanics, with 90 per cent of patients having significant atelectasis within 24 hours of surgery (Strandberg et al 1986). If not ameliorated, a postoperative pulmonary complication can occur in up to 50 per cent of patients. Over the past 70 years, physiotherapy has focused on coaching patients in deep breathing and coughing exercises to reverse atelectasis and prevent airway bacterial stagnation (Reeve & Boden 2016).

Until 20 years ago, patients were admitted to hospital the day before surgery when ward-based physiotherapists prepared patients to start breathing exercises immediately after surgery. With a change to hospitals admitting patients on the morning of surgery, pre-operative assessments switched to outpatient-based clinics within a month of surgery. At this time, physiotherapy services remained primarily ward-based and pre-operative preparation by physiotherapists effectively ceased.

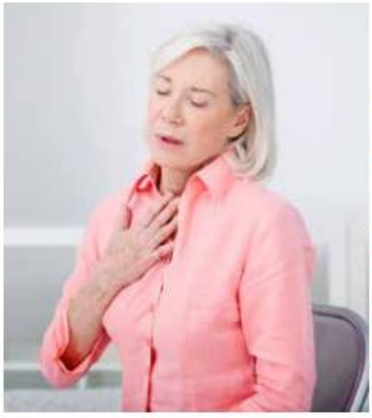


Kateryna Kon/Science Photo Library via Getty Images

Research challenges the paradigm of a postoperative-alone physiotherapy service. A recent international double-blinded, placebo-controlled, multi-centre trial involving 441 patients (PEDro 9/10) found that a single pre-operative physiotherapy session reduced postoperative pneumonia rates by half, within the context of standardised early ambulation and no postoperative chest physiotherapy (Boden et al 2018). This confirms three previous trials (Castillo & Has 1985, Fagevik Olsen et al 1997, Samnani et al 2014), and may support preliminary findings that postoperative chest physiotherapy in some cohorts is unnecessary as long as pre-operative physiotherapy is provided (Denehy 2001, Condie et al 1993). Consistent evidence supporting the benefit pre-operative physiotherapy suggests that hospitals may need to reconsider the timing of physiotherapy to best prevent the onset of serious postoperative complications.

## 4 Breathlessness is not a single generic sensation

Distress with breathing is not a normal part of ageing or an inevitable consequence of having a chronic cardiorespiratory, musculoskeletal or neurological condition. Breathlessness includes distress/discomfort and distinct sensory qualities (eg, air hunger, tightness, work/effort) reflecting different mechanisms which vary in intensity and emotional and behavioural



BSIP/UIG/Collection Mix: Subjects via Getty Images

consequences. Chronic breathlessness is distressing, disabling and persists despite optimal management.

Chronic breathlessness is not just a result of underlying disease and does not have a direct 1:1 relationship with severity of pathology. This perception is generated through complex interplay of sensory information from multiple systems, affective state and expectations or beliefs. Fear, anxiety and pain makes the experience of breathlessness worse. While most chronic breathlessness has a pathological origin, this sensation is maintained and increased by cognitive, emotional and behavioural adaptations.

Chronic breathlessness is under-recognised, assessed and managed. Things you can implement in clinical practice include asking about breathlessness and assess using multidimensional instruments, using evidence-based therapies that target multiple domains of breathlessness (eg, pulmonary rehabilitation improves exercise capacity and reduces anxiety related to breathlessness-related activities; hand-held fans reduces breathlessness recovery time and support exercise), and challenging unhelpful breathlessness beliefs.

Dean Mitchell/iStock via Getty Images

## 5 Rehabilitation in inoperable lung cancer improves patient outcomes

Advances in diagnostic procedures and treatments have resulted in increasing management options for people with inoperable lung cancer and have led to improvements in survival for this population (National Comprehensive Cancer Network 2018). People with inoperable lung cancer continue to experience high levels of symptom burden, including dyspnoea, cancer-related fatigue, weight loss and pain (Sung 2017). Routine symptom monitoring has been found to improve outcomes for people with advanced cancer (Basch 2016).

Exercise is safe for people with lung cancer. Several international hospital-based exercise trials are being conducted. Mixed setting approaches may be feasible; largely home-based but also including supervised sessions to ensure correct exercise technique and adherence to training principles, including intensity.

A recent randomised controlled trial of home-based rehabilitation demonstrated improvements in health-related quality of life and symptom severity, but not physical function, six months after commencing medical treatment. The program included aerobic and resistance exercises, behaviour change techniques and symptom support (Edbrooke 2019a). Importantly, the program was reported by participants to be highly acceptable (Edbrooke 2019b). Physiotherapists should individually prescribe and modify exercise programs based on assessment findings (including physical function and symptoms) and patient preferences.

▶▶ Email **inmotion@australian.physio** for references.

Dr George Ntoumenopoulos, APAM, is a consultant physiotherapist in the intensive care unit at St Vincent's Hospital, Sydney. His main areas of research include the investigation of novel outcome measures for secretion retention and lung aeration using ultrasound in the intubated and ventilated patient.

Danni Dunlop has worked at Austin Health since 2011. She currently holds an advanced scope of practice role in high-risk surgical patient management, as well as working in the Austin intensive care unit.

APA Cardiorespiratory Physiotherapist Ianthe Boden is the cardiorespiratory clinical supervisor at the Launceston General Hospital. Ianthe is completing her PhD at the University of Melbourne on preventing respiratory complications after major abdominal surgery.

Associate Professor Marie Williams, APAM, is Associate Head, Research, School of Health Sciences at the University of South Australia. Marie has interests in education, research training, management chronic respiratory disease and mechanisms underpinning the perceptual experience of breathlessness and how or whether this sensation can be altered.

Dr Kylie Johnston, APAM, is a senior lecturer in the School of Health Sciences at the University of South Australia. With a clinical background in cardiorespiratory physiotherapy, Kylie's research focuses on implementation of care for people with chronic lung conditions and consumer perspectives.

Dr Lara Edbrooke, APAM, completed her PhD this year on rehabilitation in inoperable lung cancer. She is a lecturer at the University of Melbourne and the Grade 4 of Allied Health Research at Peter MacCallum Cancer Centre.

University Library

A gateway to Melbourne's research publications

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:
Boden, Ianthe Josephine

Title:
Preoperative physiotherapy to prevent postoperative pulmonary complications after major abdominal surgery

Date:
2020

Persistent Link:
http://hdl.handle.net/11343/242247

File Description:
Final thesis file

Terms and Conditions:
Terms and Conditions: Copyright in works deposited in Minerva Access is retained by the copyright owner. The work may not be altered without permission from the copyright owner. Readers may only download, print and save electronic copies of whole works for their own personal non-commercial use. Any use that exceeds these limits requires permission from the copyright owner. Attribution is essential when quoting or paraphrasing from these works.