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# Laparoscopic resection for colorectal cancer in Australia.

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## Abstract

### Introduction

Surgical resection of the primary tumour remains the mainstay of treatment for colorectal cancer (CRC), which is the most common cancer in Australia and most other affluent countries. Traditionally, CRCs were resected through a large surgical incision (open resection). In the early 1990's laparoscopic resection (minimal-access) was introduced. Large randomised clinical trials (RCT) have since shown post-operative benefits to patients, including less pain and blood loss, faster return of gastrointestinal function, lower risk of pneumonia and shorter hospital stay. RCTs with longer term follow-up have shown equivalent oncological outcomes. Additionally, economic modelling suggests that laparoscopic resection is cost-effective: it uses more resources than open resection, but these additional health system costs are offset by costs associated with shorter hospital length of stays (LOS), fewer post-operative complications and improved patient quality-of-life. Despite this, widespread adoption of laparoscopic resection for CRC has been slower than other laparoscopic procedures. Reasons for this slower uptake include early concerns about port-site metastases, a long learning curve for surgeons and the need for costly and specialised equipment.

### Aim

The overarching aim of the thesis is to utilise existing government databases to provide a better understanding of current uptake of laparoscopic surgery, especially for CRC. The results will provide evidence to assist future planning to ensure optimal uptake.

The specific research questions are:

1. What is the utility of secondary diagnosis codes in hospital morbidity data for determining summary stage of CRC?

2. What has been the uptake of laparoscopic segmental resection of the colon and laparoscopic resection of the rectum across Australia, and how does it compare between public and private hospitals?

3. What has been the uptake of laparoscopic resection for CRC by procedure type and patient characteristics in Queensland for the period from 1999/2000 to 2010/2011?

4. What is the hospitalisation costs of laparoscopic resection compared with open resection for CRC in Queensland?

5. What has been the uptake of the laparoscopic technique for colorectal resection, hysterectomy, cholecystectomy, fundoplasty and nephrectomy, across Australia from 1993/94 to 2010/11, and how has the uptake differed between cancer and non-cancer indications?

**Methods**

The government databases used in this thesis provide complete coverage of two entire geographic populations, either of Queensland (the north-eastern state of Australia) or all of Australia. The main outcome measure was the laparoscopic percentage, that is the number of resections done laparoscopically divided by the total of all resections (i.e., laparoscopic + open). Analyses were stratified by complexity of procedure, cancer stage, cancer site, public versus private hospital, and comorbidities, as well as patients' age and sex. Statistical methods used to perform analyses include: Poisson regression to estimate the annual percentage change in uptake of laparoscopic resection; and multivariable regression to analyse costs, LOS, duration of surgery, and admission to intensive care (with adjustment for prognostic factors).

**Results**

*Questions 2 and 5: Uptake of laparoscopic techniques in Australia*

In Australia, uptake of laparoscopic resection for CRC has been slow relative to other procedures. Within four years of introduction, almost all cholecystectomies were laparoscopic (9% in 1990/91; 79% in 1993/94). Similarly, more than 80% of fundoplasties were laparoscopic by 2000/01. In contrast, for laparoscopic resection for CRC, segmental resections of the colon increased from 2% in 2000/01 to 28% in 2007/08, and rectal resections increased from 1% to 22%. Uptake was faster in private than in public hospitals.

*Question 3: Uptake of laparoscopic CRC by procedure type and patients*

In contrast, Queensland experienced a rapid uptake of laparoscopic resection for CRC across all procedure types, including the complex procedures usually excluded from the RCTs. For example, the laparoscopic percentage of transverse colectomies increased from 4% to 48% between the early time period (1999/00-2002/03) and late time period (2009/10-2010/11), which was similar to laparoscopic left hemicolectomy (4% to 54%). Furthermore, other patient groups normally excluded from the RCTs (e.g., those with cardiac or pulmonary conditions, or distant spread of cancer) did not experience slower uptake in laparoscopic resection.

*Question 4: In-hospital cost of laparoscopic compared with open resection for CRC*

Queensland hospital costing data showed that, after adjusting for potential confounders, laparoscopic resection was associated with reduced LOS, fewer and shorter admissions to intensive

care, and equivalent surgical duration to open resection. In 2012, laparoscopic resection was $2,524 less expensive than open resection ($25,036 versus $27,561).

**Conclusion**

In Queensland, a jurisdiction where uptake is mature, laparoscopic resection for CRC has diffused across all patient types, including those normally excluded from the RCTs. Whether a patient with CRC receives laparoscopic resection is determined by access to hospitals with the necessary equipment, and surgical teams with the necessary training and experience. The findings from this thesis can be used by clinicians, service planners, policy-makers and budget-holders to plan and manage uptake of laparoscopic resection for CRC, and potentially other new surgical technologies.

**Declaration by author**

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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**Publications during candidature**

*Peer reviewed publications*

1. **Thompson B**, Austin R, Coory M, Aitken JF, Walpole E, Francis G, et al. Completeness of histopathology reporting of melanoma in a high-incidence geographical region. Dermatology. 2009;218(1):7-14.

2. Austin R, **Thompson B**, Coory M, Walpole E, Francis G, Fritschi L. Histopathology reporting of breast cancer in Queensland: the impact on the quality of reporting as a result of the introduction of recommendations. Pathology. 2009;41(4):361-5.

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5. **Thompson B**, Watson M, Bowman R, Fong K, Coory M. Hospital-activity data inaccurate for determining spread-of-disease at diagnosis for non-small cell lung cancer. Aust N Z J Public Health. 2012 Jun;36(3):212-7.

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7. Coory M, **Thompson B**, Jordan S. Adopting surgical innovation within activity-based funding for public hospitals. Med J Aust. 2013 Feb 4;198(2):88.

8. **Thompson BS**, Coory MD, Gordon LG, Lumley JW. Cost savings for elective laparoscopic resection compared with open resection for colorectal cancer in a region of high uptake. Surg Endosc 2013;Epub 2013 Dec 14.

9. **Thompson B**, Coory M, Gordon L, Lumley J. Uptake of laparoscopic resection for colorectal cancer by procedure type in a high-uptake region: a population-based study. (Submitted 10/02/2014).

*Conference abstracts*

1. **Thompson B**, Coory M, Lumley J. Uptake of laparoscopic resection for colorectal cancer in Queensland, 1999/2000 to 2007/2008. Asia Pac J Clin Oncol 2009;5(Suppl. 2):A160.

2. Coory M, **Thompson B**, Baade P, Fritschi L. Utility of routine data sources for feedback on the quality of cancer care: An assessment based on clinical practice guidelines. Australasian Epidemiologist 2009;16(2):5.

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7. **Thompson B**, Coory M, Gordon L, Lumley J. Cost-savings for elective laparoscopic resection compared with open resection for colorectal cancer. Australasian Epidemiologist 2013;20(2):47.

*Conference and seminar presentations*

1. **Thompson, B.**, Coory, M., Gordon, L. & Lumley, J. (October, 2013) Cost-savings for elective laparoscopic resection compared with open resection for colorectal cancer in a region of high-uptake. Accepted for oral presentation at the Australasian Epidemiological Association Annual Scientific Meeting, Brisbane, Australia
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5. **Thompson, B.**, Watson, M., Bowman, R., Fong, K. & Coory, M. (September, 2010) Hospital-activity data accurate for determining spread-of-disease at diagnosis for non-small cell lung cancer? Accepted for oral presentation at the Australasian Epidemiological Association Annual Scientific Meeting, Sydney, Australia.
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7. **Thompson, B.**, Coory, M. & Lumley, J. (November, 2009) Uptake of Laparoscopic Resection for Colorectal Cancer in Queensland, 1999/2000 to 2007/2008. Accepted for oral presentation at the Research Higher Degree Conference, School of Population Health, UQ, Brisbane, Australia.
8. Coory, M., **Thompson, B.** & Baade, P. & Fritschi, L. (September, 2009) Utility of routine data sources for feedback on the quality of cancer care: an assessment based on clinical practice guidelines. Accepted for oral presentation at the Australasian Epidemiological Association Annual Scientific Meeting, Dunedin, New Zealand.
9. **Thompson, B.**, Coory, M. & Lumley, J. (July, 2009) Uptake of Laparoscopic Resection for Colorectal Cancer in Queensland, 1999/2000 to 2007/2008. Accepted for oral presentation at the Public Health Association of Australia – Queensland Branch Conference, Brisbane, Australia.

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1. **Thompson B**, Coory M, Lumley J. National trends in the uptake of laparoscopic resection for colorectal cancer, 2000-2008. Med J Aust. 2011 May 2;194(9):443-7. Incorporated as Chapter 4.

| Contributor | Statement of contribution |
|---|---|
| Bridie Thompson (Candidate) | Designed experiments (70%)<br><br>Data acquisition (100%)<br><br>Data analysis (100%)<br><br>Wrote and edited the paper (85%) |
| Michael Coory | Designed experiments (20%)<br><br>Wrote and edited the paper (10%) |
| John Lumley | Designed experiments (10%)<br><br>Wrote and edited the paper (5%) |

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| John Lumley | Designed experiments (5%)<br><br>Wrote and edited the paper (5%) |

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A/Prof Michael Coory, Professor Annette Dobson and Dr John Lumley provided guidance in forming the research objectives and design, assisted with interpretation of the results and provided ongoing methodological advice. Dr Louisa Gordon also provided methodological advice, particularly for the chapter on hospital utilisation for laparoscopic versus open resection for colorectal cancer. Dr Louisa Gordon assisted with the interpretation of results. A/Prof Michael Coory, Professor Annette Dobson, Dr John Lumley and Dr Louisa Gordon provided feedback on the thesis before submission. Corrie Martin, Julie Turtle and Susan Walker provided assistance with the clinical diagnosis and procedure codes throughout the thesis. Col Roberts performed the data extraction for the analysis on utilisation of hospital resources, and provided information on the collection of the data within Queensland Health. of Dr Jim Nicklin provided guidance on procedures relating to hysterectomy.

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Epidemiology, colorectal cancer, laparoscopic resection, population-based data, uptake, hospitalisation cost

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**Table of Contents**

**List of Figures**

**List of Tables**

**List of Abbreviations**

| | |
|---|---|
| ACHI | Australian Classification of Health Intervention |
| ACPS | Australian clinicopathological stage |
| AIHW | Australian Institute of Health and Welfare |
| AJCC | American Joint Committee on Cancer |
| ARIA | Accessibility/Remoteness Index of Australia |
| ASA | American Society of Anaesthesiologists' |
| CI | Confidence Interval |
| CPG | Clinical Practice Guideline |
| CRC | Colorectal Cancer |
| DFS | Disease Free Survival |
| DOB | Date of Birth |
| HMD | Hospital Morbidity Data |
| HR | Hazard Ratio |
| ICD | International Classification of Diseases |
| ICU | Intensive Care Unit |
| MD | Mean Difference |
| MRI | Magnetic Resonance Imaging |
| NHMD | National Hospital Morbidity Data |
| NIS | Nationwide Inpatient Sample |
| OS | Overall Survival |
| QALY | Quality Adjusted Life Year |
| QHAPDC | Queensland Hospital Admitted Patients Data Collection |
| RCT | Randomised Clinical Trial |
| SEER | Surveillance Epidemiology and End Results database |
| SEIFA | Socio-Economic Indexes for Areas |

| | |
|---|---|
| SMD | Standard Mean Difference |
| TNM | Tumour Node Metastasis (cancer staging system) |
| UK | United Kingdom |
| US | United States |
| WMD | Weighted Mean Difference |

# Chapter 1 Introduction

Queensland is the north-eastern state of Australia with a population of 4.5 million children and adults. Queensland is geographically large with almost half of the population living outside of cities.

The Federal Government provides the majority of funding for Australia's healthcare system across the public and private healthcare sectors. It is the responsibility of state and territory governments to deliver and coordinate public health care within their respective state or territory. Patients who receive care as a public patient experience no or little out-of-pocket expenses for their medical care and do not choose their treating clinicians. Patients who elect to be treated as a private patient incur expenses, but can choose their treating clinicians. As an admitted patient, treatment in the private healthcare sector receives federal government reimbursement for a portion of their care; the remainder (gap) is subsidised by private healthcare insurance and/or directly from the patient.(1) The majority of clinical training occurs in the public healthcare sector and in public hospitals, which means that clinicians complete their training in public hospitals before commencing in the private sector. Public hospitals are only likely to invest in expensive specialised equipment in major teaching hospitals and facilities that receive a high volume of patients, at least until the equipment becomes less expensive and the procedure requiring the specialised equipment becomes the standard of care.

Each of the states and territories is responsible for the management of hospital morbidity and clinical costing data. The State Government's Department of Health in Queensland (Queensland Health) maintains the Queensland Hospital Admitted Patients Data Collection (QHAPDC), which is a comprehensive dataset for all separations of admitted patients from all public and private hospitals in Queensland. QHAPDC, along with similar datasets from each of the other Australian states and territories are collated by the Australian Institute of Health and Welfare (AIHW) to produce the National Hospital Morbidity Database (NHMD). Through this thesis, I had the support of Queensland Health and was therefore able to acquire detailed, patient level data from QHAPDC. I was able to request aggregated NHMD data from AIHW. Similarly, I was able to acquire from Queensland Health patient level data that included costs associated with the provision of services as an admitted patient.

This thesis provides analyses of the uptake, patient selection and cost associated with laparoscopic resection for colorectal cancer (CRC). Colorectal surgeons in Queensland were early adopters of the technique and uptake was rapid. Queensland is therefore further along the adoption curve for laparoscopic resection for colorectal cancer than most other jurisdictions around the world.

Queensland's population-based, government data sources were utilised throughout this thesis to describe "real-world" clinical practices in this region where surgical teams now have high levels of experience in laparoscopic resection for CRC. Additionally, NHMD data were obtained from the AIHW to study the uptake of laparoscopic resection for CRC across Australia and to compare uptake between public and private hospitals, and high and low volume hospitals. The NHMD was also used to compare the uptake of laparoscopic techniques for a range of therapeutic procedures, for malignant and non-malignant related conditions.

The overarching aim of the thesis is to utilise existing government databases to provide a better understanding of current uptake of laparoscopic surgery, especially for CRC. The results will provide evidence for policy-makers, budget-holders and service-planners in health departments throughout Australia, to assist in future planning and ensure optimal uptake of this surgery.

# Chapter 2 Background

This section provides epidemiological information about CRC in Australia, describes stages of CRC and prognosis, and identifies current clinical practice for the management of CRC. A sub-section is specifically dedicated to the description of laparoscopic resection for CRC including a summary of available evidence, surgical training and patient selection for this procedure, and data relating to laparoscopic resection for CRC in Queensland. I then describe theories around the diffusion of surgical innovation. Finally, I describe the aims and objectives, and the organisation of the thesis.

## 2.1 Colorectal cancer in Australia

CRC is the most common cancer affecting both men and women in Australia.(2) In 2012 the AIHW estimated that 15 840 newly diagnosed cases of CRC would occur in that same year.(2) CRC is more common in men than women. In 2009, the risk of diagnosis before the age of 75 years was 1 in 19 for men and 1 in 28 for women.(2) Risk increases progressively with age and the average age at diagnosis is 69.3 years.(3) Among the aging population, the number of new cases in 2025 is estimated between 22 708 and 23 548.(4)

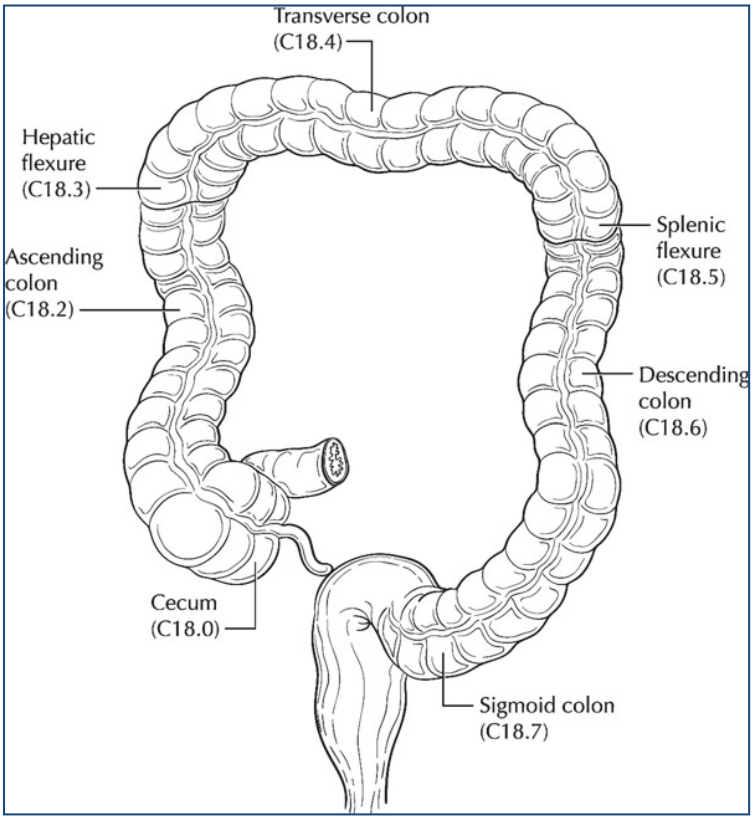
The relative 5-year survival for CRC has increased from 48% in 1982-1987 to 66% in 2006-2010,(3) mainly due to improvements in detection and treatment. However, it remains the second most common cause of cancer deaths, accounting for 3982 deaths in 2010.(3)

CRC is the 10$^{th}$ leading cause of hospital admission and was the reason for 29 263 admissions in 2010/11.(3) As a disease affecting the older population, it is expected to impose greater burden on the healthcare system as the population ages. In an effort to alleviate this burden, one of the main objectives of the National Bowel Cancer Screening Program is to reduce the incidence of CRC through the detection and subsequent removal of polyps and adenomas.(5)

According to the *National Colorectal Cancer Care Survey* report, 55% of patients with CRC in Australia have their major surgery in a public facility and 75% of the treating hospitals are in metropolitan or inner regional areas.(6) Most tumours occur in the left (descending) colon (37%), with 28% in the right (ascending) colon, 8% in the transverse colon and 27% in the rectum (Figure 2-1). In 2000, elective screening for CRC was uncommon, with only 5.9% of patients presenting with screen detected CRC.(6) The majority of patients with CRC presented with symptoms (83.4%); the remainder of admissions for CRC (10.7%) were emergency admissions. Most patients diagnosed with CRC (95%) undergo surgery.(6)

Of the 1911 patients reported to have had their CRC resected, 18% had metastatic spread of disease (Dukes' stage D); 27% had regional spread of disease (Dukes' stage C); and 51% had localised disease (Dukes' A or B).(6)

Figure 2-1 Anatomic sites of the colon.




Source: AJCC cancer staging atlas.(7)

## 2.2 Colorectal cancer stage and prognosis

Identifying the stage of CRC is vital for determining treatment and prognosis; the earlier the stage at diagnosis, the higher the chance of survival.(8) Presently in Australia, there is no routine collection of cancer stage at a statewide or national population level. Smaller clinical cancer registries managed locally by Australian health service regions or privately by clinicians include cancer stage information. The largest collections of clinical cancer data are individually maintained for public facilities by six Area Health Services in New South Wales.(9) For CRC, the clinical cancer registries capture data for 94% of people admitted to hospitals within the Area Health Services for a procedure.(9) Stage information is available in the clinical cancer registries for 77% to 84% of these patients.(9)

The American Joint Committee on Cancer (AJCC) has assigned a staging system for CRC based on the level of infiltration of the primary tumour (Tumour), metastasis to regional lymph nodes (Node)

and metastasis to other organs or sites (Metastasis), known as the TNM classification system (Table 2-1).(10)

Table 2-1 Definitions of TNM classifications for colorectal cancers

| | |
|---|---|
| **Primary Tumour (T)** | |
| **TX** | Primary tumour cannot be assessed |
| **T0** | No evidence of primary tumour |
| **Tis** | Carcinoma in situ: intraepithelial or invasion of lamina propria |
| **T1** | Tumour invades submucosa |
| **T2** | Tumour invades muscularis propria |
| **T3** | Tumour invades through the muscularis propria into pericolorectal tissues |
| **T4a** | Tumour penetrates to the surface of the visceral peritoneum |
| **T4b** | Tumour directly invades or is adherent to other organs or structures |
| **Regional lymph nodes (N)** | |
| **NX** | Regional lymph nodes cannot be assessed |
| **N0** | No regional lymph node metastasis |
| **N1** | Metastasis in 1–3 regional lymph nodes |
| **N1a** | Metastasis in one regional lymph node |
| **N1b** | Metastasis in 2–3 regional lymph nodes |
| **N1c** | Tumour deposit(s) in the subserosa, mesentery, or nonperitonealized pericolic or perirectal tissues without regional nodal metastasis |
| **N2** | Metastasis in four or more regional lymph nodes |
| **N2a** | Metastasis in 4–6 regional lymph nodes |
| **N2b** | Metastasis in seven or more regional lymph nodes |
| **Distant metastasis (M)** | |
| **M0** | No distant metastasis |
| **M1** | Distant metastasis |
| **M1a** | Metastasis confined to one organ or site (e.g., liver, lung, ovary, non-regional node) |
| **M1b** | Metastases in more than one organ/site or the peritoneum |

Source: modified from the AJCC cancer staging manual 7th edition.(10)

In its most recent edition (7th edition), the *AJCC Cancer Staging Manual* restructured the mapping of TNM and 'anatomic stages/prognostic groups' to include better alignment with survival outcomes (Table 2-2).(10) Dukes' stage was the original and standard system of staging CRC prior to the AJCC staging(8) and was commonly reported in the published literature (Table 2-2). In Australia, CRC stage is often referred to as the Australian clinicopathological stage (ACPS).(11)

Table 2-2 Pathologic TNM staging mapped to AJCC and Dukes' and ACPS stage for colorectal cancer

| Anatomic stage/prognostic groups | | | | |
|---|---|---|---|---|
| AJCC Group | T | N | M | Dukes'/ACPS |
| 0 | Tis | N0 | M0 | – |
| I | T1 | N0 | M0 | A |
| | T2 | N0 | M0 | A |
| IIA | T3 | N0 | M0 | B |
| IIB | T4a | N0 | M0 | B |
| IIC | T4b | N0 | M0 | B |
| IIIA | T1–T2 | N1/N1c | M0 | C |
| | T1 | N2a | M0 | C |
| IIIB | T3–T4a | N1/N1c | M0 | C |
| | T2–T3 | N2a | M0 | C |
| | T1–T2 | N2b | M0 | C |
| IIIC | T4a | N2a | M0 | C |
| | T3–T4a | N2b | M0 | C |
| | T4b | N1–N2 | M0 | C |
| IVA | Any T | Any N | Any | D* |
| IVB | Any T | Any N | Any | D* |

Source: modified from the AJCC cancer staging manual 7th edition.(10)

* Modified to include clinicopathological staging identification of Dukes' stage for metastatic colorectal cancer (Dukes' D).

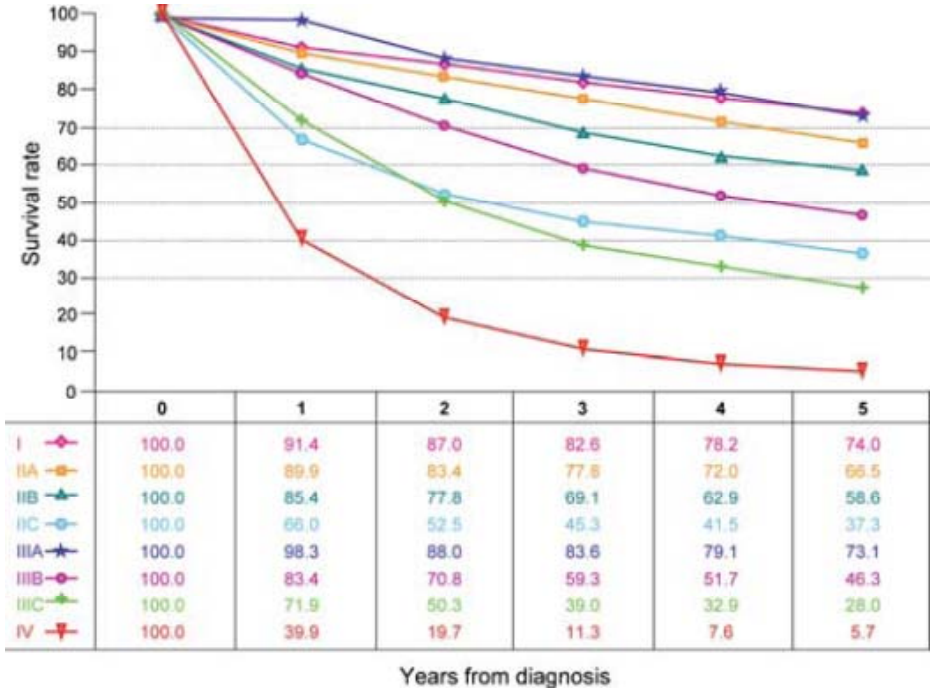
Survival directly correlates with the incremental increases in AJCC stage group, with the exception of AJCC stage III cancers, which spread to lymph nodes. While survival rates are incremental for IIIA to IIIC, they have survival rates better than those seen among cancers of some earlier stages (stage I and II). This is particularly apparent for Stage IIIA cancers for which the survival rates throughout the five years are akin to that of AJCC stage I cancers (Figure 2-2 and Figure 2-3). For cancers of the colon, this is probably due to the success of post-surgical adjuvant chemotherapy, which is highly recommended for stage III colon cancers.(11) For rectal cancers, although chemotherapy is recommended for stage II and stage III cancer, (11) a survival advantage remains for stage III over stage II.

The 7th edition of the *AJCC Cancer Staging Manual* emphasises the importance of complete documentation of all staging classifications, clinical and pathologic, for CRC.(10) Appropriate recording of clinical stage permits comparison between cases,(12) and facilitates research investigating healthcare delivery and cancer outcomes. The AJCC has developed templates for the purpose of aiding in the standardised pathologic reporting of CRC. (10)

## 2.3 Clinical management of colorectal cancer

Treatment for CRC usually consists of surgical resection with or without adjuvant treatment.(13) The objective of surgical treatment is to remove the primary tumour along with adequate surgical margins and assess any regional spread.(11) It is recommended that a minimum of 12 lymph nodes from the abdomen are resected to clearly establish stage of disease.(14) Formation of a successful anastomosis with preservation of anorectal sphincter function is standard where possible.(15) To achieve this, the conventional method for surgical resection of CRC has required a large open wound to the abdomen which could extend from the costal margin to the pubic bone (Figure 2-4).(16) Although transverse muscle-cutting incisions may be used for excision of regions such as the right colon,(16) a midline incision is often preferred(17). Open access to the abdomen via these incisions leads to considerable post-operative pain for the patient, a long recovery and hospital-stay and exposure to complications which can lead to high-dependency care.(18)

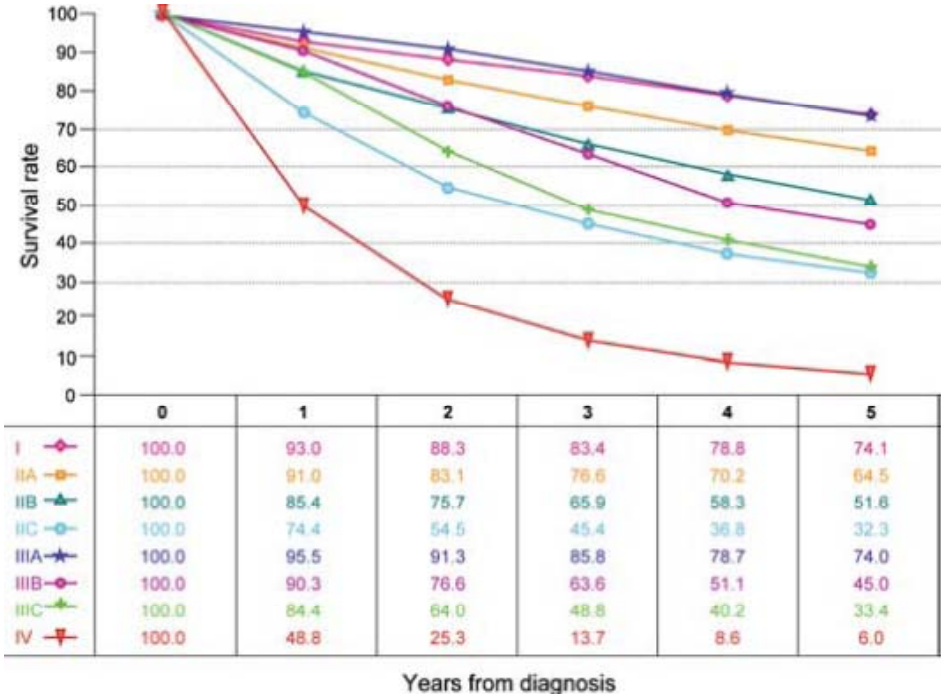
Figure 2-2 5-Year survival rates of colon cancer by stage




| | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| I | 100.0 | 91.4 | 87.0 | 82.6 | 78.2 | 74.0 |
| IIA | 100.0 | 89.9 | 83.4 | 77.6 | 72.0 | 66.5 |
| IIB | 100.0 | 85.4 | 77.8 | 69.1 | 62.9 | 58.6 |
| IIC | 100.0 | 66.0 | 52.5 | 45.3 | 41.5 | 37.3 |
| IIIA | 100.0 | 98.3 | 88.0 | 83.6 | 79.1 | 73.1 |
| IIIB | 100.0 | 83.4 | 70.8 | 59.3 | 51.7 | 46.3 |
| IIIC | 100.0 | 71.9 | 50.3 | 39.0 | 32.9 | 28.0 |
| IV | 100.0 | 39.9 | 19.7 | 11.3 | 7.6 | 5.7 |

Observed survival rates for 28 491 cases with adenocarcinoma of the colon. Data from the SEER 1973–2005 Public Use File diagnosed in years 1998–2000. Stage I includes 7 417; Stage IIA, 9 956; Stage IIB, 997; Stage IIC, 725; Stage IIIA, 868; Stage IIIB, 1 492; Stage IIIC, 2 000; and Stage IV, 5 036. Source: AJCC Cancer Staging Manual.(10)

Figure 2-3 5-Year survival rates of rectal cancer by stage




| | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| I | 100.0 | 93.0 | 88.3 | 83.4 | 78.8 | 74.1 |
| IIA | 100.0 | 91.0 | 83.1 | 76.6 | 70.2 | 64.5 |
| IIB | 100.0 | 85.4 | 75.7 | 65.9 | 58.3 | 51.6 |
| IIC | 100.0 | 74.4 | 54.5 | 45.4 | 36.8 | 32.3 |
| IIIA | 100.0 | 95.5 | 91.3 | 85.8 | 78.7 | 74.0 |
| IIIB | 100.0 | 90.3 | 76.6 | 63.6 | 51.1 | 45.0 |
| IIIC | 100.0 | 84.4 | 64.0 | 48.8 | 40.2 | 33.4 |
| IV | 100.0 | 48.8 | 25.3 | 13.7 | 8.6 | 6.0 |

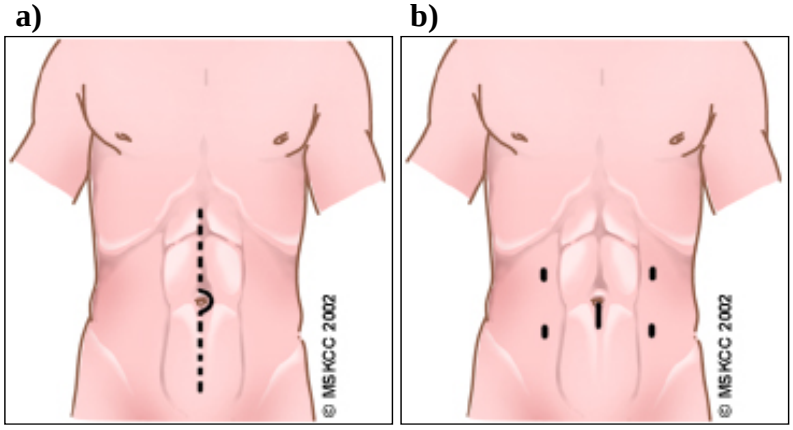
Observed survival rates for 9 860 cases with adenocarcinoma of the rectum. Data from the SEER 1973-2005 Public Use File diagnosed in years 1998-2000. Stage 1 includes 3 470; Stage IIA, 2 752; Stage IIB, 165; Stage IIC, 268, Stage IIIA, 595; Stage IIIB, 615; Stage IIIC, 761; and Stage IV, 1 234. Source: AJCC Cancer Staging Manual.(10)

### 2.3.1 Laparoscopic resection

The term “laparoscopy” refers to the visual examination of the abdominal cavity by means of a laparoscope (endoscope). “Laparoscopic surgery” includes diagnostic and therapeutic procedures after gaining access to the abdominal cavity.(19) Pneumoperitoneum is the gaseous insufflation of the abdomen that is routinely used during laparoscopic surgery to allow the surgical team to visualise the viscera and to perform the procedure.(20) This thesis focuses on the resection of tissue from organs, and laparoscopic surgery will be referred to as laparoscopic resection.

Beginning in the late 1980’s to early 1990’s, laparoscopic surgery revolutionised abdominal surgery and procedures such as laparoscopic cholecystectomy became the standard of care.(19) Beneficial short-term outcomes of laparoscopic over open colorectal resection include: less intraoperative blood loss, reduced pain, reduced postoperative ileus and hospital stay, and improved pulmonary function and quality of life.(21) Laparoscopic resection also results in fewer incisional hernias and adhesions, resulting in reduced rates of adhesional obstruction.(22) These benefits provide impetus for uptake of this technique.

Figure 2-4 Representations of incisions for: a) open colorectal resection; b) laparoscopic colorectal resection




Source: Cancer News “Laparoscopic colorectal surgery for cancer: Is it ready for prime time?”(23)

a) One large excision
b) Multiple small incisions are used for instruments and the camera. The specimen is removed by enlarging one of the incisions.

Acceptance of laparoscopic surgery for the treatment of CRC by healthcare providers was slower than for some other conditions. Reasons for delay in its uptake include less than optimal equipment, limited opportunities for training and a long learning curve. In addition, there were concerns about whether medium- to long-term outcomes were as good as those

achieved with open surgery.(19) For example, in one small but commonly cited case series, port-site metastases (tumour spread at wound site/s for laparoscopic instruments or tumour removal during surgery) were reported for 3 of 14 patients (21%).(24)

Several multi-centre RCTs were established in response to concerns about the oncological safety of laparoscopic resection for CRC (Table 2).(25-33) For example, a meta-analysis reported that across seven studies, only 3 of 826 (0.4%) colon cancer patients who were randomised to laparoscopic surgery had port-site metastases, which is similar to the 1 patient of 801 (0.12%) in the open resection group.(34)

These RCTs report short- and long-term outcomes for laparoscopic resection that are non-inferior to open resection. With regards to resection for CRC, s*hort-term outcomes* generally refer to post-operative findings for the duration of the hospital admission, but may include a short period following discharge (within 30 days). Short-term outcomes include findings relating to the procedure (e.g., duration, blood loss); the well-being of the patient (e.g., post-operative ileus, adverse events such as wound infection, pain, mortality); and matters relating hospital administration (e.g., length of hospital stay, demands on nursing staff). Long-term outcomes have been described by the RCTs at 3-years and 5-years following the hospital admission for resection for CRC and include the overall survival, disease free survival and recurrence of CRC. Table 2-3 lists the key characteristics of the major RCTs for laparoscopic resection for CRC.

The most recent meta-analyses (which include RCT findings listed in Table 2-3) have confirmed reports from the RCTs. Laparoscopic resection is favoured over open resection for short-term outcomes (Table 2-4). Reports from the meta-analyses suggest that laparoscopic resection could result in improved intermediate-term outcomes, specifically, incisional hernia and bowel obstruction; however, the data are inconclusive.(35, 36) A current Cochrane review concluded that resection with laparoscopic access of colon cancer is associated with long-term outcomes no different to that of open colectomy, however, more randomised trials are needed to make the same assessment for rectal surgery.(37) Findings from the literature reviews and meta-analyses on laparoscopic resection for colorectal cancer are detailed in Table 2-4.

Despite reduced length of hospital stay and fewer complications, laparoscopic resection for CRC is commonly associated with increased or equivalent delivery costs; this is due to longer operating time and requirements for specialised equipment.(38-42) However, studies reporting greater costs associated with laparoscopic resection are based on data from early in

the adoption period when surgical teams were less experienced in the technique. As surgeons gain experience in laparoscopic resection, the operating time can be similar to that of open resection,(43) potentially reducing the cost of laparoscopic resection and resulting in cost savings when compared with open resection.

Laparoscopic resection for cancer of colon or rectum is endorsed by the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom,(18) the American Society of Colon and Rectal Surgeons,(44, 45) and the European Association for Endoscopic Surgery (EAES).(46) In Australia, laparoscopic resection for CRC is only recommended for colon cancer; however, the relevant guidelines have not been updated since 2005.(8)

Table 2-3 The seven largest randomised clinical trials evaluating laparoscopic resection compared with open resection for cancer of the colon and/or rectum

| RCT/Setting | Scope | Key Exclusions | Most recently published findings |
|---|---|---|---|
| CLASICC (United Kingdom) | 27 Centres<br>794 Participants | Transverse colon<br>Chronic cardiac or pulmonary disease | 2007(47) – 3-year outcomes<br>Equivalent OS, DFS and recurrence rates |
| COST<br>(United States) | 48 Centres<br>863 Participants | Stage IV<br>Rectal cancers<br>Transverse cancers | 2007(48) – 5-year outcomes<br>Equivalent OS, DFS and recurrence rates |
| COLOR (Europe) | 29 Centres<br>1076 Participants | Metastasis to liver or lung<br>Transverse colon<br>Rectal cancers | 2009(49) – 3-year outcomes<br>Unable to determine equivalence – upCI reached pre-determined non-inferiority boundary for DFS. Clinically acceptable. |
| COLORII<br>(Europe) | 30 Centres<br>1103 Participants | Colon cancers<br>T4 and some T3<br>Other than adenocarcinoma<br>ASA IV or V<br>Active Crohn's disease or ulcerative colitis | 2013(50) – short-term outcomes<br>Improved GI function following laparoscopic resection and reduced blood loss and LOS.<br>Longer operating time.<br>Equivalent oncological outcomes, morbidity and mortality. |
| ALCASS (Australasia) | 31 Centres<br>587 Participants | Stage IV<br>Rectal cancers<br>Transverse colon<br>ASA IV or V | 2012(51) – 5-year outcomes<br>Equivalent OS, DFS and recurrence rates |
| Barcelona (Spain) | 1 Centre<br>219 Participants | Stage IV<br>Rectal cancers<br>Transverse colon | 2008(52) – long-term outcomes<br>Higher OS, DFS and reduced recurrence laparoscopic group. Benefit among stage III mainly. |
| Leung<br>(Hong Kong) | 1 Centre<br>403 Participants | Stage IV<br>Colon cancers | 2004(30) – long-term outcomes<br>Probability of 5-year survival higher for laparoscopic group (not significant). Longer operating time and greater direct costs greater for laparoscopic group. Laparoscopic group had better recovery. |

***** OS = Overall Survival; DFS = Disease Free Survival; GI = Gastrointestinal; LOS = Length of stay; ASA = American Society of Anaesthesiologists' (physical status classification system)

Table 2-4 Literature reviews and meta-analyses relating to laparoscopic resection for colorectal cancer

| Review/meta-analyses | Objective | Studies included | Main outcome/s | Pooled effect | Conclusions |
|---|---|---|---|---|---|
| Theophilus 2013(53)<br>Meta-analysis<br>Colon cancer | To compare long-term outcomes by stage after laparoscopic and open colectomy (rectal cancer excluded from analysis) | 5 RCTs | OS stage I | HR 1.04 (0.69, 1.57) | Equivalent long-term survival for stage I, stage III and all stages. Insignificant trend towards a survival disadvantage for stage II cancers. |
| | | | OS stage II | HR 1.21 (0.96, 1.51) | |
| | | | OS stage III | HR 0.99 (0.81, 1.21) | |
| | | | OS all stages | HR 0.93 (0.80, 1.07) | |
| Kuhry 2008(37)<br>Cochrane review<br>Colorectal cancer | To determine long-term outcome after laparoscopically-assisted versus open surgery for non-metastatic colorectal cancer | 33 RCTs | Incisional hernia | Lap: 7.9%, Open: 10.9%, P=0.32 | Equivalent long-term outcomes for colon. More data needed for long-term outcomes following laparoscopic resection of rectal cancer. Further research needed for determine any difference in incidence of incisional hernia or adhesions. |
| | | | Local recurrence colon | OR 0.84 (0.47, 1.52) | |
| | | | Local recurrence rectum | OR 0.81 (0.61, 1.06) | |
| | | | Port-site/wound recurrence | OR 0.98 (0.14, 7.0) | |
| | | | CRM Colon | OR 0.15 (0.01, 2.94) | |
| | | | CRM Rectum | OR 0.80 (0.61, 1.06) | |
| Transatlantic Laparoscopic Assisted versus Open Colectomy Trials Study Group 2007(54)<br>Multinational<br>Colon cancer | Combine outcomes from large RCTs to enhance power for determining oncological safety of laparoscopic resection for cancer compared with open resection | 4 RCTs | Number lymph nodes | Lap: 11.8±7.4, Open: 12.2±7.8, P=0.4 | No difference in oncological outcomes between open and laparoscopic resection. |
| | | | Postoperative mortality | OR 1.3 (0.5, 3.4) | |
| | | | 3-year disease-free survival | HR 0.99 (0.80, 1.22) | |
| | | | 3-year overall survival | HR 1.07 (0.83, 1.37) | |
| | | | 3-year local recurrence | Diff.: -1.8% (-3.8, 0.3) | |
| | | | 3-year distant recurrence | Diff.: -0.5% (-3.5, 2.4) | |

| Review/meta-analyses | Objective | Studies included | Main outcome/s | Pooled effect | Conclusions |
|---|---|---|---|---|---|
| Breukink 2007(55)<br>Cochrane review<br>Rectal cancer | To evaluate differences in safety and efficacy after laparoscopic resection compared with open resection | 3 RCTs<br>3 R<br>5 CC<br>28 CS | No meta-analyses. Review discusses:<br>Surgical outcomes<br>Complications<br>Morbidity<br>Recurrence<br>Mortality<br>Cost evaluation | | No difference in DFS, local recurrence, mortality or morbidity, anastomotic leakage, resection margins or number of lymph nodes. Laparoscopic resection has reduced blood loss, pain, immune response, faster return of GI function. Laparoscopic resection has longer operating time and higher costs. |
| Abrahams 2007(56)<br>Australia<br>Colorectal cancer | To perform a review of non-randomised comparative studies of laparoscopic resection with open resection for colorectal cancer | 49 NRCTs | Conversion<br>Operating time (mins)<br>Postoperative ileus (flatus)<br>Postoperative pain (day one)<br>Postoperative hospital stay<br>No. lymph nodes<br>Early mortality<br>Total morbidity | CWR = 13.3%<br>CWD = 41, CWR = 1.28<br>CWD = 1.2, CWR = 0.67<br>CWR = 0.85 (visual analogue scale)<br>CWD = 3.4, CWR = 0.71 days<br>CWR = 0.98<br>OR 1.07 (0.67, 1.69)<br>OR 0.77 (0.63, 0.95) | Operating time longer for laparoscopic resection. Improved short-term outcomes. No difference in mortality. |

| Review/meta-analyses | Objective | Studies included | Main outcome/s | Pooled effect | Conclusions |
|---|---|---|---|---|---|
| Liang 2007(57)<br>China<br>Colorectal cancer | To compare recurrence rates between laparoscopic resection and open resection | 10 RCTs | Overall recurrence | OR 0.93 (0.71, 1.21) | Recurrence rates do not differ between laparoscopic and open resection. |
| | | | Local recurrence | OR 0.80 (0.50, 1.29) | |
| | | | Distant metastasis | OR 0.90 (0.62, 1.29) | |
| | | | Port-site/wound recurrence | OR 0.92 (0.77, 1.10) | |
| Lourenco 2007(58)<br>United Kingdom<br>Colorectal cancer | To determine the clinical effectiveness of laparoscopic resection in comparison with open resection | 19 RCTs | Length of stay (days) | WMD -2.58 (-3.12, -2.03, p<0.001) | Laparoscopic resection associated with quicker recovery and LOS. No difference in complications or long-term outcomes.<br>Sample for incisional hernia and operative mortality small. |
| | | | Anastomotic leakage | RR 1.13 (0.74, 1.73) | |
| | | | Wound breakdown | RR 0.63 (0.26, 1.52) | |
| | | | Wound infection | RR 0.86 (0.64, 1.14) | |
| | | | Urinary tract infection | RR 1.15 (0.66, 1.98) | |
| | | | Operative mortality | RR 0.84 (0.29, 2.47) | |
| | | | 30-day mortality | RR 0.57 (0.25, 1.29) | |
| | | | Recurrence | RR 0.92 (0.74, 1.14) | |
| | | | Incisional hernia | RR 1.49 (0.76, 2.92) | |
| | | | Overall survival | RR 1.03 (0.98, 1.09) | |
| | | | Disease-free survival | RR 1.01 (0.95, 1.07) | |

| Review/meta-analyses | Objective | Studies included | Main outcome/s | Pooled effect | Conclusions |
|---|---|---|---|---|---|
| NICE 2006(18)<br>United Kingdom<br>Colorectal cancer | To provide a recommendation regarding use of laparoscopic resection for colorectal cancer when compared with open resection<br>Clinical effectiveness<br>Economic effectiveness | 19 RCTs | 30-day mortality<br>Operative mortality<br>Overall survival<br>Disease-free survival<br>Tumour recurrence<br>Wound recurrence | RR 0.57 (0.25, 1.29)<br>RR 0.84 (0.29, 2.47)<br>RR 1.03 (0.98, 1.09)<br>RR 1.01 (0.95, 1.07)<br>RR 0.92 (0.74, 1.14)<br>RR 1.97 (0.18, 21.62) | Laparoscopic resection estimated to cost £265(95%CI -£3829,£4405) more than open resection.<br>Laparoscopic resection recommended. |
| Aziz 2006(35)<br>United Kingdom<br>Rectal cancer | Conduct meta-analyses to compare short- and long-term outcomes of laparoscopic with open resection for rectal cancer | 20 studies:<br>14 PNR<br>3 R<br>3 PR | Operating time (mins)<br>No. lymph nodes<br>Postoperative ileus (BM) days<br>Postoperative hospital stay days<br>Early mortality<br>Wound infection<br>Chest infection<br>Postoperative hernia<br>Bowel obstruction | WMD 40.18 (26.46, 56.13)<br>WMD -0.87 (-2.24, 0.49)<br>WMD -0.72 (-1.21, -0.22)<br>WMD -2.67 (-3.81, -1.54)<br>OR 0.6 (0.28, 1.27)<br>OR 0.84 (0.52, 1.37)<br>OR 1.47 (0.74, 2.92)<br>OR 1.28 (0.39, 4.22)<br>OR 0.40 (0.12, 1.36) | Laparoscopic longer operating time. Improved postoperative recovery for GI function, LOS. Reduced odds of early mortality, wound infection and bowel obstruction, however these did not reach statistical significance. Increased odds of chest infection and postoperative hernia; also did not reach statistical significance. |

| Review/meta-analyses | Objective | Studies included | Main outcome/s | Pooled effect | Conclusions |
|---|---|---|---|---|---|
| Noel 2006(59)<br>United States<br>Colorectal cancer | To compare short-term outcomes of laparoscopic colorectal resection with open resection (only outcomes for cancer presented here) | 49 studies<br>13 RCTs<br>36 C/CC | Sepsis | OR 0.60 (0.13, 2.80) | Although not always statistically significant, many effect measures favour laparoscopic surgery. Laparoscopic resection has a longer operating time. |
| | | | Wound infection | OR 0.70 (0.50, 0.96) | |
| | | | Urinary tract infection | OR 1.09 (0.67, 1.77) | |
| | | | Anastomotic leak | OR 0.97 (0.62, 1.50) | |
| | | | Respiratory/pneumonia | OR 0.96 (0.60, 1.54) | |
| | | | Cardiac complications | OR 0.84 (0.52, 1.36) | |
| | | | Venous-thromboembolism | OR 0.62 (0.30, 1.29) | |
| | | | Bleeding | OR 0.97 (0.54, 1.74) | |
| | | | Operating time | MR 1.27 (1.20, 1.34) | |
| | | | Incision size (mm) | MR 0.37 (0.29, 0.48) | |
| | | | Blood loss (mL) | MR 0.55 (0.44, 0.69) | |

* All outcome measures compare laparoscopic to open, i.e. WMD = laparoscopic – open (negative values favour laparoscopic), ratios = laparoscopic/open (values <1 favour laparoscopic)

** RCT = Randomised Clinical Trial, DFS = Disease Free Survival, OR = Odds Ratio, HR = Hazard Ratio, NRCT = Non randomised clinical trial, RR = Relative Risk, PNR = Prospective Non-Randomised, R = Retrospective patient identification, PR = Prospective Randomised study, CC = Case-Control, CS = Case Series, C = Cohort, BM = Bowel Movement, MR = Meta-analytic ratio, CRM = Cancer related mortality

*** CWR = Cumulative Weighted Ratio, CWD = Cumulative Weighted Difference and WMD = Weighted Mean Difference. These measures are for continuous variables adjusted for sampling variance – little explanation on statistical methods for these provided in the relevant manuscripts.

### 2.3.2 Surgeon training and patient selection

Laparoscopic colorectal resection is one of the most complex of laparoscopic procedures and requires the mobilisation of a bulky physiological structure, access to more than one quadrant of the abdomen, control of multiple large blood vessels, extraction of a large specimen and successful creation of an anastomosis.(60) Resection of malignant tumours has more demanding requirements to achieve oncologic principles: attainment of adequate surgical margins, removal of lymph nodes, proximal ligation of the vascular pedicles and minimal handling and avoidance of perforating the tumour.(60) It is paramount that surgeons have adequate training and experience to undertake laparoscopic resection of cancers of the colon or rectum.(61, 62)

There is substantial discussion in the literature regarding the learning curve associated with laparoscopic CRC resection. Studies have shown that some outcomes from surgery improve with the learning curve; that is, surgeon performance improves with the greater number of laparoscopic resections performed. These include reduced operating time,(61) shorter length of hospital stay,(62) and fewer conversions from laparoscopic to open resection.(43, 63) Other studies, however, have found operating time did not decrease with surgeon experience. This was attributed to the selection of more difficult procedures with increasing confidence rather than reflecting a lack of change in technical proficiency.(63) Buchanan and colleagues report a dramatic increase in attempted laparoscopic resection for cancers of the colon and rectum as experience in the procedure increased.(43) Reduction in conversions could also be attributed to better patient selection and confidence to complete difficult procedures with laparoscopic access.

Little has been published about which patients are suitable for laparoscopic resection. The clinical trials commonly exclude cancers of the transverse colon and rectum, and patients with metastasis or chronic comorbidities (Table 2-3). These characteristics require more complex clinical management and the outcomes may not be as favourable as for patients with less complex clinical presentation, which is likely to influence the surgical outcomes in the clinical trials. However, it is possible that these patients are having laparoscopic resection outside the clinical trial environment. For example, according to one study, about 90% of patients undergoing elective resection of CRC are suitable for laparoscopic resection, only excluding those with threatened margins as predicted with magnetic resonance imaging (MRI) and a history of complicated previous surgery (both of which are the main indicators for open resection).(43) Patients requiring emergency surgery (generally due to obstruction of the bowel) are not suitable for laparoscopic resection.

### 2.3.3 Laparoscopic resection for colorectal cancer in Queensland

In Queensland, several surgeons were early adopters of laparoscopic surgery for CRC and the first laparoscopic resection for cancer of the colon was conducted at the Royal Brisbane Hospital in July 1991.(64) Consequently, Queensland has seen a rapid increase in the percentage of resections performed with laparoscopic access. Data in Table 2-5 from the Queensland Hospital Admissions Patient Data Collection (QHAPDC) shows the annual percentages of all segmental resections of the colon and resections of the rectum for patients with CRC for the financial years 1999/2000 to 2010/2011.

Table 2-5 Percentage of all resection for cancer of the colon or rectum with laparoscopic access in Queensland; 1999/2000 to 2010/2011

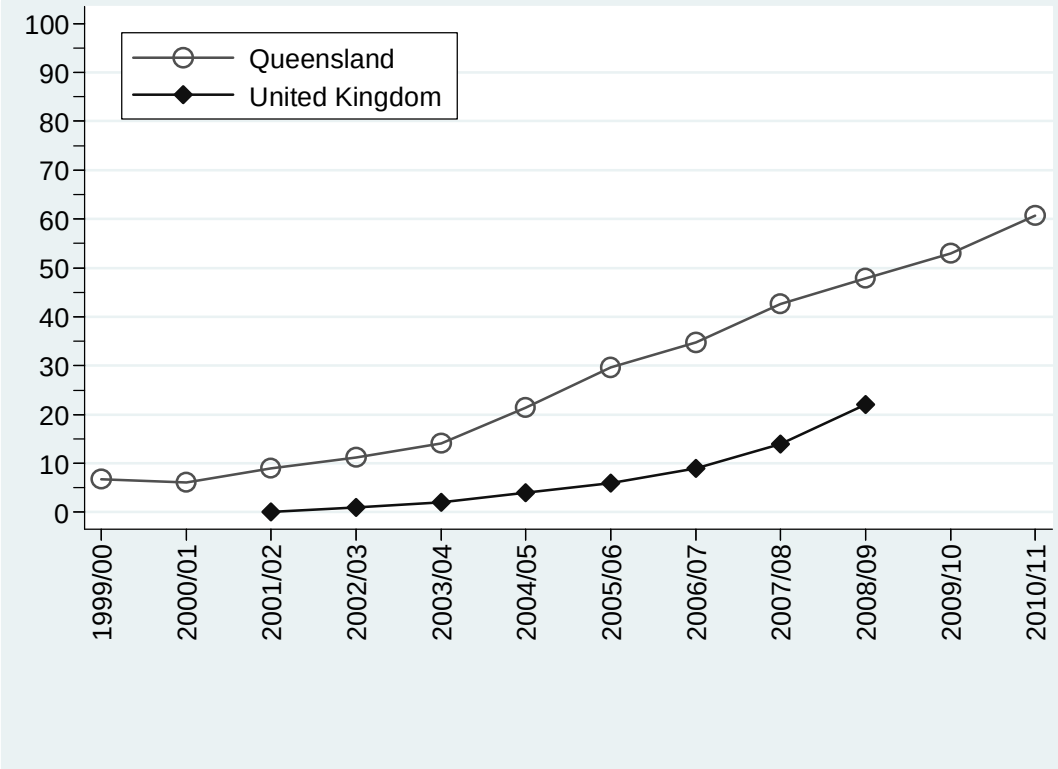
| | Segmental resections of the colon | | Resections of the rectum | |
|---|---|---|---|---|
| | Total | Laparoscopic (%) | Total | Laparoscopic (%) |
| 1999/2000 | 1055 | 70 (6.6%) | 403 | 28 (7.0%) |
| 2000/2001 | 1088 | 74 (6.8%) | 459 | 19 (4.1%) |
| 2001/2002 | 1104 | 118 (10.7%) | 477 | 23 (4.1%) |
| 2002/2003 | 1115 | 145 (13.0%) | 513 | 34 (6.6%) |
| 2003/2004 | 1068 | 141 (13.2%) | 477 | 75 (15.7%) |
| 2004/2005 | 1120 | 235 (21.0%) | 520 | 113 (21.7%) |
| 2005/2006 | 1247 | 379 (30.4%) | 542 | 148 (27.3%) |
| 2006/2007 | 1267 | 448 (35.4%) | 593 | 197 (33.2%) |
| 2007/2008 | 1286 | 537 (41.8%) | 602 | 265 (44.0%) |
| 2008/2009 | 1358 | 666 (49.0%) | 611 | 283 (46.3%) |
| 2009/2010 | 1326 | 684 (51.6%) | 580 | 324 (55.9%) |
| 2010/2011 | 1309 | 769 (58.8%) | 625 | 405 (64.8%) |
| Total | 14343 | 4266 (29.7%) | 6402 | 1914 (29.9%) |

The percentages presented above are much higher than those reported for other geographically defined populations. The NICE reported 9% of colorectal resections with laparoscopic access in the United Kingdom during 2006/07;(65) this increased to 22% in 2008/09 (Figure 2-5).(66) Laparoscopic resection for rectal cancer in Ontario, Canada, increased from 5.2% in 2002 to 19.3% in 2008.(67) There are several published studies reporting laparoscopic percentages for cancer of the colon or rectum in the United States (US) based on data from the National Inpatient Sample (NIS). One study reported that 3.3% of resections for colon cancer in 2003 and 2004 were with

laparoscopic access,(68) and another found an increase from 1.4% in 2000 to 4.3% in 2004.(69) Also based on NIS data, for the years 2008 and 2009, the laparoscopic percentage for colectomy for colon cancer was reported as 50%.(70) A publication whose data were from the Perspective Rx Comparative Database in the US, reported a laparoscopic percentage for colon cancer of 35.6% in 2004 to 2006; which is similar to the percentages found in Queensland.(38)

Queensland therefore has a large sample of patients with CRC who have received laparoscopic resection.

Figure 2-5 Annual percentages in laparoscopic resection for colorectal cancer in Queensland and the United Kingdom; 1999/00 to 2010/11

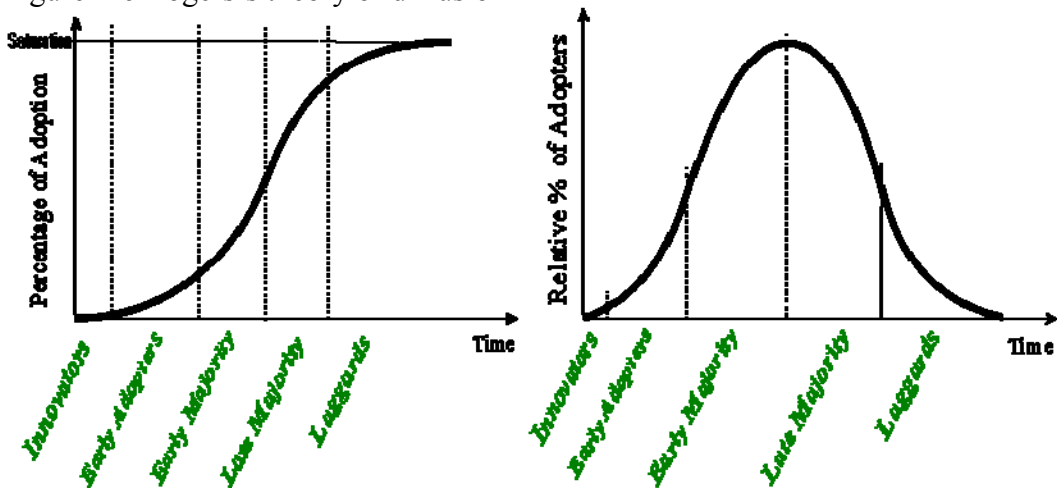



NOTE: United Kingdom data sourced from the NICE implementation uptake reports, 2008(65) and 2010(66).

## 2.4 Diffusion of surgical innovation

Rogers proposed that the diffusion of new technology can be modelled as an *S* curve (Figure 2-6).(71) Based on such a curve, laparoscopic resection for both colon and rectal cancer in Queensland has probably passed the phases of the innovators, early adopters and early majority and, assuming that Queensland has almost reached saturation in the number of CRC resections based on resource capacity, has entered the phase of the late majority (Figure 2-6).

Figure 2-6 Rogers's theory of diffusion




Source: Reproduced from Rogers (2003)(71)

Diffusion in innovation is influenced across three areas. First, innovation is affected by Rogers' characteristics of the innovation itself.(71) These characteristics and how they relate to laparoscopic resection for CRC, are listed in Table 2-6. Second, medical behaviour is contagious and local leaders and champions are important.(72) Third, innovations need to be adaptable to meet the characteristics of the local environment.(73)

With reference to the characteristics outlined in Table 2-6, by the early 2000's, laparoscopic resection was associated with advantages without added risk, and the procedure was proven to be compatible within the realm of surgical beliefs. At a time when more surgeons were gaining skills in minimal-access surgery and laparoscopic cholecystectomy had become the standard of care, laparoscopic resection for CRC was acquiring RCT evidence demonstrating short-term benefits to patients and subsequently, long-term oncological safety of the technique.

Laparoscopic colorectal resection lends itself to be tested (trialled) because surgeons can perform the technique for non-cancer related illness with relative safety prior to performing the procedure for cancer. The ability to observe laparoscopic resection for CRC in Queensland was better than in other jurisdictions because a core group of surgeons were early adopters and offered formal training in the technique. In addition, there are large numbers of colorectal resections for cancer and non-cancer related conditions.

At an organisational level, diffusion may be hindered by the resources and costs associated with innovative techniques.(71) While most of the available literature shows equivalent or increased costs for laparoscopic resection compared with open resection for CRC,(38-41, 74, 75) Chapter 7 of this thesis presents the first study to evaluate cost in a jurisdiction where the technology is widely

adopted; this consequently led to the first study to demonstrate cost benefit for laparoscopic resection.

The rapid uptake of laparoscopic resection for CRC, in combination with the large numbers of patients having this procedure in Queensland, presents a valuable opportunity to evaluate the diffusion of this technology throughout Queensland hospitals and patients with CRC.

Table 2-6 Characteristics of a new technology which influence diffusion as proposed by Rogers(71)

| Characteristic of a new technology | Description | In relation to laparoscopic resection colorectal cancer |
|---|---|---|
| 1. Reduction in uncertainty and relative advantage | The more knowledge individuals can gain about the expected consequences of an innovation the more likely they are to adopt it | RCT evidence short-term benefits and equivalent long-term outcomes |
| 2. Compatibility | Change must align with values, beliefs, past history and needs of an individual | Minimal-access surgery popular for other techniques<br>Improvement to patient outcomes |
| 3. Complexity | More complex innovations take longer to spread. Also, innovations are modified as they spread | More complex procedures introduced later (not included in RCTs – rectal resection / transverse colon) |
| 4. Trialability | Whether the innovation can be adopted/tested on a smaller scale and proceed to larger scale | Able to be performed for non-cancer related conditions prior to cancer related conditions |
| 5. Observability | The ability for potential adopters to observe others conducting the procedure | Strong community of specialist surgeons in Queensland who presented other surgeons with the opportunity to attend formalised training in the technique |

## 2.5 Aims and objectives

This thesis was funded by Queensland Department of Health (Queensland Health) and the Australian Centre for Health Services Innovation (AusHSI). Queensland Health's main role is to be the policy-makers, budget-holders and planners for Queensland's tertiary and regional hospitals, and community health centres. AusHSI receives funding from Queensland Health to support projects that are designed to show policy-makers how to improve services, ideally by making them lower cost and higher quality. Consequently, the overarching aim of this thesis was to use existing government population-based databases to develop the information necessary to assist clinicians, policy-makers, budget-holders and service-planners within Australia to manage and plan the uptake of laparoscopic surgery for CRC.

The existing literature has identified barriers to the uptake of laparoscopic resection for CRC, including a long learning curve, highly specialised and high-cost equipment and uncertainty relating to the oncological safety and long-term outcomes. Despite shorter length of hospital stay and fewer post-operative adverse events (e.g., wound infection), early studies have found that laparoscopic resection is associated with equivalent or higher cost compared with open resection, mainly due to longer operating times for laparoscopic resection.

The majority of the available evidence on laparoscopic resection for CRC comes from large, well-designed multi-centre RCTs. However, patients with CRC were recruited into these studies when laparoscopic resection for CRC was in the early phase of adoption and surgeons were not highly experienced in the technique. Furthermore, large groups of patients were excluded from the studies. The existing literature does not inform healthcare administrators about which patients with CRC are selected for laparoscopic resection and the extent to which laparoscopic resection is performed on the patients usually excluded from RCTs. It is also unknown whether the utilisation of hospital resources in the real world is the same as those which have been reported from the RCTs. Furthermore, surgeons are now more experienced in performing laparoscopic surgery than when these RCTs were performed and the techniques have evolved, probably improving outcomes.

In Queensland, laparoscopic resection for CRC is now in its post-adoption phase; that is, surgical teams are experienced in the technique and the necessary equipment is available in almost all hospitals. Cost savings are achievable as the surgical duration for laparoscopic resection is equivalent to open resection among experienced surgeons. Additionally, long-term outcomes from the RCTs have been published and demonstrate the oncological safety of laparoscopic resection for CRC. With the barriers to laparoscopic resection for CRC now overcome, Queensland presents a

good opportunity to evaluate current practices including patient selection, and to evaluate resource utilisation and costs.

The broad aim of this thesis is to characterise the uptake of laparoscopic resection for CRC by hospital and patient characteristics. A secondary aim is to present a "post-adoption" phase comparison on the hospital resource utilisation, including cost between laparoscopic and open resection for CRC. The findings from this thesis will provide details about past and current practices of laparoscopic resection for CRC. It will also provide evidence of the impact that this procedure has on the healthcare system by comparing laparoscopic versus open resection for CRC in terms of resource utilisation and costs.

Routinely collected population-based data sources have been used to examine the uptake, diffusion and costs associated with laparoscopic resection for CRC. These government databases are primarily used for budget-allocation. An additional aim of this thesis was to make use of these well-managed routinely collected data sources and to help government departments to utilise their own data to better understand the current diffusion of new health technology, and consequently, to enhance their ability to plan for its uptake.

### 2.5.1 Hypotheses

1. It is hypothesised that whether a patient diagnosed with CRC is selected for laparoscopic resection is determined by access to adequately trained and experienced surgeons rather than characteristics relating to the patient or cancer.
2. It is hypothesised that compared with their counterparts who receive open resection, patients who receive laparoscopic resection will have shorter length of hospital stay and fewer ICU admissions, and that hospital costs associated with the hospital admission will not be more.

### 2.5.2 Research questions

*Chapter 4*: What is the utility of other diagnosis codes in routinely collected hospital morbidity data for determining summary stage of CRC?

Objective: This was a methodological research question designed to evaluate the utility of hospital morbidity data for determining stage of CRC and thus identifying the value and limitations of these data sources to conduct CRC research.

*Chapter 5*: What is the uptake of laparoscopic segmental resection of the colon and laparoscopic resection of the rectum across Australia for the financial years 2000/01 to 2007/08, and how does it compare between hospital types (private/public, high/low-volume)?

Objective: This research question was designed to inform healthcare administrators of the national uptake of laparoscopic resection and any disparity in access to this procedure by hospital type.

*Chapter 6*: What is the uptake of laparoscopic resection for CRC by procedure type and patient characteristics in Queensland for the financial years 1999/2000 to 2010/2011?

Objective: This research question was designed to identify which patients receive laparoscopic resection for CRC and whether uptake has been slower for those with more complicated clinical presentation such as patients normally excluded from the RCTs. Healthcare administrators can use this information to develop policies to ensure that patients with complex clinical presentation are appropriately referred for laparoscopic resection for CRC.

*Chapter 7*: What is the cost of laparoscopic resection compared with open resection for CRC in Queensland between June 2009 and June 2011?

Objective: This research question was designed to measure costs, surgical duration, length of hospital stay and duration admitted to intensive care units (ICU) in Queensland where surgical teams are now experienced in laparoscopic resection for CRC.

*Chapter 8*: What is the uptake of the laparoscopic technique for colorectal resection, hysterectomy, cholecystectomy, fundplasty and nephrectomy across Australia between 1993/94 and 2009/10, and how does uptake differ between cancer and non-cancer indications?

Objective: This research question allows for comparison between different laparoscopic therapeutic procedures, for cancer and non-cancer indications. These findings can be used to identify differences between the procedures which are likely to influence the uptake of new technology.

### 2.5.3 Organisation of the thesis

Chapter 4 is the first of five analysis chapters presented in this thesis. Chapters 4, 5 and 7 include published manuscripts and Chapter 6 includes a manuscript which is submitted to a peer-reviewed journal for publication.

Each chapter includes an introductory section which comprises a summary of the introduction included in the published manuscript and any additional information not included in the published manuscript. The contribution of each of the authors is also outlined here. Additional methodological information and/or data analyses which were not included in the publication are then integrated into the chapter. Finally, the discussion comprises a summary of the published discussion and

commentary on any additional information presented in the chapter which was not included in the publication.

Chapter 8 is presented in the traditional thesis format, rather than as a manuscript for publication. This is a requirement of the university. Chapter 9 provides a discussion for the entire thesis.

Throughout this thesis, laparoscopic surgery relating to colorectal resection will be referred to as "laparoscopic resection". The broad term, "laparoscopic surgery", is used in Chapter 8 and Chapter 9 to describe a range of procedures commonly performed using laparoscopic techniques, including cholecystectomy, fundoplasty, hysterectomy and nephrectomy.

Throughout this thesis, laparoscopic resection is identified by a concurrent code for laparoscopy with the relevant code for segmental resection of the colon, or, rectal resection. "Laparoscopic resection" therefore refers to all resections for CRC which involved laparoscopy and may be laparoscopic-assisted or entirely laparoscopic. Laparoscopic-assisted resections for CRC were included in the laparoscopic arm of the three large RCTs.(33, 76, 77) Further information about which codes were used to identify colorectal resections, and laparoscopic colorectal resections, is included in Table 1 of the published manuscript in Chapter 5.

The terminology "healthcare administrators" is used to refer to individuals whose roles are to determine healthcare policy, education programs, resource and budget allocation, and health services planning within the Australian public healthcare system.

# Chapter 3 Data sources

Data for the research chapters of this thesis were obtained from routinely collected population-based data sources. The research questions are based on the delivery of services to patients who have been diagnosed with CRC. The most suitable data sources for these questions were those which capture diagnosis and procedure information for all hospital admissions. Each state and territory health authority maintains a database of records for each episode of care in public and private hospital in Australia.(78) In Queensland this database is called Queensland Hospital Admitted Patients Data Collection (QHAPDC). The National Hospital Morbidity Database (NHMD) is a compilation of confidentialised summary records for QHAPDC and all other hospital morbidity databases from each of the states and territories.(78)

## 3.1 Validity of data sources

Upon receipt of hospital morbidity data from the states and territories, the Australian Institute of Health and Welfare performs extensive validations on the data including: checks for valid values, logical consistency, historical consistency, and cross-checks with other data sources.(79) However, data quality of the hospital morbidity datasets is primarily the responsibility of the states and territories.(80) In Queensland, internal and external bodies conduct audits with a focus on financial, statistical and clinical data and these checks occur at many levels: at the point of coding, data entry, processing, in the production of reports and overall monitoring of the health system activity. (80) Further checks are conducted by the Statistical Output Unit who perform comprehensive validity checks which are sent to hospitals for errors to be rectified.(81)

The NHMD contains records from each of the states and territories since the financial year 1993/94.(79) The data are based on the National Minimum Data Set for admitted patient care which is revised and implemented nationally on the 1$^{st}$ of July each year.(82) This includes common coding practices for procedures and diagnoses, as well as common standards for the collection of information relating to the episode of care and demographics, across the states and territories.(82)

A hospital clinical coder is a specialised professional who is trained in the translation of written clinical documents about patient care into code format. In Australia, this is the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM) which is based on the World Health Organisation ICD-10 system, updated with the Australian Classification of Health Interventions (ACHI), Australian Coding Standards (ACS) and ICD-O-3 (International Classification of Diseases for Oncology, 3rd

edition).(83) For major procedures like colorectal resection, clinical coding in the hospital morbidity datasets is likely to very accurate and complete because clinicians in the private sector and public hospitals rely on the documentation of these codes for funding. A study which validated the New South Wales Admitted Patients Data Collection for treatment of prostate cancer, reported sensitivity of 91%, and specificity of 100% for radical prostatectomy.(84)

## 3.2 Derived variables

### 3.2.1 Socio-Economic Indexes for Areas (SEIFA)

In the absence of measures of individual income or employment status, Socio-Economic Indexes for Areas (SEIFA) was used as a measure of socio-economic status. SEIFA provides a measure of Relative Socioeconomic Advantage/Disadvantage for a geographical area based on information from census. In QHAPDC, SEIFA is categorized into 10 categories based on a division of Statistical Local Areas.(85) For the purpose of this study, SEIFA was further collapsed into 3 categories; 1-3 (least advantaged), 4-6 and 7-10 (most advantaged), which resulted in an even distribution of the study sample.

### 3.2.2 Accessibility/Remoteness Index of Australia (ARIA+)

Accessibility/Remoteness Index of Australia Plus (ARIA+) measures were used to indicate remoteness of residence. ARIA+ is measured in five categories based on access to Service Centre (defined by the population of the urban centre) from a population locality (as defined by the population centres recognised around Australia).(86) ARIA+ was assigned to individuals based on the population locality of their residential address.(85) For the purpose of this study, these categories were further collapsed into; major city/inner regional, outer regional and remote/very remote.

### 3.2.3 High and low volume hospitals

The threshold of 40+ elective procedures for CRC was pre-specified (before analysing the data) after consultation with the Royal Australian College of Surgeons. This number was used to reflect a case load of around one resection per week (allowing for holidays). To affirm this cut-off, the total number of resections for CRC performed at each hospital per year was determined from the QHAPDC. Review of these frequencies in combination with knowledge of Queensland's tertiary hospitals and which hospitals had permanent or visiting specialist colorectal surgeons, it was determined that, in general, hospitals performing fewer than 40 resections for colorectal cancer

should be considered as low volume hospitals. This threshold was examined over the time period 1999/2000, to 2009/2010, and found to be appropriate for all years. We could not access the same data on hospital frequency of resections for CRC in the other Australian states and territories. We therefore decided that it was appropriate to apply the same threshold to the analysis of the national data (Chapter 5).

## 3.3 Data obtained for this thesis

As outlined in Appendix 1, data obtained for each of the research chapters was extracted for different date ranges. There have only been minor changes to ICD-10-AM and ACHI coding of diagnosis and procedures relating to CRC. Mapping to account for any changes was conducted in consultation with clinical coders within Queensland Health. The date range of the data extraction and analysis in Chapter 8 pre-dates ICD-10-AM and extensive mapping of diagnosis and procedure codes (with ICD-9) was conducted to ensure completeness of the extraction and accuracy of the analysis.

Detailed information about the data extracted for each of the research chapters is included in (Appendix 1).

# Chapter 4 The utility of population-based data sources for colorectal cancer research

## 4.1 Introduction

Presently in Australia, information pertaining to cancer stage is not recorded in routinely collected population-based data sources. In the US, summary stage is routinely recorded in the Surveillance Epidemiology and End Results (SEER) database for all cancer types. SEER staging uses all information available in the medical records, including clinical and pathological documentation of extent of disease, to determine a summary stage.(87) SEER stage is almost always recorded with only 5% of colorectal cancers between 2003 and 2009 coded as "9" (unknown); for breast cancer, this figure was 2%.(88) For reporting of survival, SEER stage is further collapsed into four groups: localised (confined to the primary site), regional (spread to regional lymph nodes), distant (cancer has metastasised) and unknown (unstaged).(88)

Each of the authors contributed to this study and the resulting manuscript as follows. I was responsible for the conception and design of the study in conjunction with Michael Coory. Data from the clinical cancer registry is owned and maintained by John Lumley. I was responsible for the data acquisition, linkage, analysis and interpretation of the results. Michael Coory provided guidance on the data analysis and interpretation of the results. I was responsible for the first and subsequent drafts of the manuscript under the guidance of, and with feedback from, Michael Coory and John Lumley.

This study was published in the peer-reviewed journal *Asia Pacific Journal of Clinical Oncology* in 2012.

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First Impact Factor released in June 2010 and now listed in MEDLINE!

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ORIGINAL ARTICLE

# Hospital morbidity data for determining spread of disease at diagnosis for colorectal cancer: A validation study

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## Abstract

***Aims*:** There is currently no routine collection of cancer stages in population-based data in Australia. This study evaluates the accuracy of International classification of diseases (ICD) codes for secondary neoplasms recorded in hospital morbidity data to assign spread of disease at diagnosis for colorectal cancer.

***Methods*:** The reference (gold) standard was the Australian clinicopathological stage (ACPS) documented by a treating colorectal surgeon and derived from histopathology and clinical findings. To allow comparison with stages derived from the hospital morbidity data (HMD), ACPS was mapped to the spread of disease (local, regional and distant). Sensitivity, specificity and positive-predictive values were calculated to compare the accuracy of stage derived from HMD.

***Results*:** Data from both the reference standard and HMD were available for 499 patients. HMD slightly overestimated patients with local disease (62.3 *vs* 56.9%). There was a corresponding underestimation of regional and distant spread of disease. While sensitivity for regional and distant disease was moderate (66.4 and 71.4%, respectively), specificity was high (92.7 and 96.6%, respectively).

***Conclusion*:** ICD codes for secondary neoplasms in HMD are limited in their utility for determining the spread of disease for colorectal cancer. Clinicians need to ensure that clinical coders are provided with enough information to accurately code for spread of disease. We recommend reporting histopathology in a synoptic format which includes background information on the presence or absence of distant metastasis and the tumor node metastasis stage.

**Key words:** colorectal, epidemiology, ICD coding, pathology, stage.

## INTRODUCTION

Colorectal cancer (CRC) is the most common cancer among men and women in Australia.[1] Surgery is the mainstay of treatment for CRC, of which there are a variety of established and emerging techniques.[2] Population-based monitoring of the delivery and outcomes of these techniques is important to ensure consistency in the quality of care. Routinely collected, population-based databases are being increasingly used to examine outcomes of surgery for CRC, particularly in the USA[3,4] and the UK.[5–7] While Australia has similar population-based databases, they lack information on the stage of cancer. Stage at diagnosis is a prognostic variable that critically affects management and outcomes. The absence of stage information drastically limits the utility of the existing population-based databases in Australia for monitoring oncological outcomes.

Each state and territory of Australia maintains hospital morbidity databases (HMD) which include unit record information for every admission to all public and private hospitals.[8] As well as detailed information

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relating to the admission (such as dates of admission and separation), HMD include diagnosis, procedure and socio-demographic data.[8] The HMD uses the International classification of diseases (ICD) to code all diagnoses for every hospital admission.[8] This includes codes for metastases to lymph nodes in specific locations (e.g., secondary malignant neoplasm of intra-abdominal lymph nodes [C77.2]) and codes for metastases to specific organs (e.g., secondary malignant neoplasm of the liver [C78.7]),[9] which can be mapped to a summary staging system of the degree of spread, similar to surveillance epidemiology and end results (SEER) staging in the USA.[10] However, this is dependant on the accuracy of coding for the secondary neoplasm. The ability to derive the degree of spread from HMD would fill the gap in the availability of stage information at a population level.

There have been two published studies that examined the utility of secondary diagnosis codes in hospital administration data, similar to HMD, for determining the summary stage of cancer.[11,12] Neither of these was based in Australia and only one included CRC.[12]

Clinicians at three private and one tertiary public hospital in Brisbane, Australia, have been recording the stage at diagnosis for their patients with CRC. This offered a unique opportunity to determine whether ICD codes for cancer spread in HMD can be reliably used to derive the degree of spread of CRC.

## METHODS

The clinical cancer registry maintains information for patients treated for CRC by clinicians in three private and one public hospital, which includes the Australian clinicopathological stage (ACPS),[13] which is transcribed from histopathology reports or derived from clinical and histopathology reports. To enable the pathologist to report the complete ACPS in the histopathology, the clinician must include information about the presence or absence of distant metastasis when asking for the pathological review of a specimen.[14] ACPS recorded in the registry was used as the reference or gold standard of stage at diagnosis for all patients who had a resection for cancer of the colon or rectum between 30$^{h}$ June 2001 and 31 April 2009.

Record linkage was used to ascertain the accuracy of coding of the spread of CRC in the HMD. In Australia, clinical coders use the hard-copy and electronic clinical notes to assign International classification of diseases and health related problems, 10$^{th}$ revision, Australian modification (ICD-10-AM) codes to primary and secondary diagnosis fields in HMD.[15] Particularly in private hospitals where clinical coders may not have access to complete clinical notes, the histopathology report can be the primary or the only source of information for the spread of cancer. While there are no specific data fields for cancer stage, there are ICD-10-AM codes for the metastatic spread of malignant diseases.[9] In Queensland, clinical coders are instructed to code for metastatic spread to the lymph nodes or distant organs if there is confirmation of such spread from histopathology reports, imaging reports or other documentation by a clinician.[15]

Deterministic linkage requires that predefined variables agree exactly between two data sources to form a linked pair.[16] Records from the clinical cancer registry were deterministically matched to the HMD by hospital, date of birth and date of procedure. Probabilistic linkage applies weights for agreement and disagreement for each variable based on the difference in probability that a variable agrees among matches and non-matches.[16] Probabilistic linkage was used to identify an additional 9% of patients based on the date of procedure, sex and type of procedure. Excluded from analysis were 64/857 (7.5%) of patients in the clinical cancer registry, who were unstaged.

The ACPS system for staging CRC requires clinical information that is more specific than ICD-10-AM coding allows (e.g., the level of local invasion in submucosa and muscularis propria). Therefore, ACPS from the clinical cancer registry and ICD diagnostic codes in the HMD were mapped into localized, regional and distant spread of disease (Table 1).

The spread of disease, as derived from ACPS in the clinical cancer registry, was taken to be the reference standard and was used to obtain estimates of sensitivity, specificity and positive predictive value (PPV) for the spread of disease as derived from the ICD codes in the HMD. Sensitivity, specificity and PPV were calculated separately for local, regional and distant spread of disease.[17] Exact 95% confidence intervals (CI) for these proportions were obtained using Stata statistical software (Stata Corporation, College Station, TX, USA).[18]

Ethics approval for this study was granted by the Queensland Health Human Research Ethics Committee and the School of Population Health Research Ethics Committee of the University of Queensland.

## RESULTS

The clinical and socio-demographic characteristics of patients included in the study are shown in Table 2.

 

**Table 1** Mapping of Australian clinicopathological stage (ACPS) from the clinical cancer registry and International Classification of Diseases and Health Related Problems, 10th Rev., Australian Modification codes in inpatient hospital morbidity data to local, regional and distant spread of disease

| | Local† | Regional‡ | Distant§ |
|---|---|---|---|
| Clinical Cancer Registry | ACPS A or ACPS B | ACPS C | ACPS D |
| Hospital morbidity data | | Lymph nodes | Lymph nodes |
| | | C77.2 Intra-abdominal | C77.0 Head, face & neck |
| | | C77.5 Intra-pelvic | C77.1 Intrathoracic |
| | | | C77.3 Axillary & upper limb |
| | | | C77.4 Inguinal & lower limb |
| | | | C77.8 Multiple regions |
| | | | C77.9 Unspecified |
| | | | Respiratory & digestive organs |
| | | | C78.0 Lung |
| | | | C78.1 Mediastinum |
| | | | C78.2 Pleura |
| | | | C78.3 Other & unspecified respiratory organs |
| | | | C78.4 Small intestine |
| | | | C78.5 Large intestine & rectum |
| | | | C78.6 Retroperitoneum & peritoneum |
| | | | C78.7 Liver |
| | | | C78.8 Other & unspecified digestive organs |
| | | | Other sites |
| | | | C79.0 Kidney & renal pelvis |
| | | | C79.1 Bladder & other unspecified urinary organs |
| | | | C79.2 Skin |
| | | | C79.3 Brain & cerebral meninges |
| | | | C79.4 Other & unspecified nervous system |
| | | | C79.5 Bone & bone marrow |
| | | | C79.6 Ovary |
| | | | C79.7 Adrenal gland |
| | | | C79.8 Secondary malignant neoplasm of other specified sites |
| | | | C80 Malignant neoplasm without specification of site |

†Primary tumor only. ‡Local lymph nodes and apical lymph nodes involved. §Secondary tumor to distant organ/s or tumor transected.

There were very few patients falsely identified with metastases by HMD, as shown by specificity of 96.6% for the category of distant spread of disease (Table 3). Specificity for regional spread of disease was also high (92.7%), while specificity for local disease was only moderate (81.9%).

In contrast to high specificity for distant spread of disease, sensitivity for this category was only moderate at 71.3% (Table 3). Sensitivity for regional spread was poor at 66.4%, while sensitivity for local disease was high at 95.8%. Taken together, the results for specificity and sensitivity indicate that HMD tend to allocate too many patients to local disease and not enough to regional or distant spread; as compared to the gold standard of the clinical cancer registry.

Table 4 shows the distribution of HMD stage by clinical registry stage. The percentages on the diagonals are the sensitivities shown in Table 3. The other percentages show the distribution of false negatives across the other two categories. Of note, most misclassified regional cases were misclassified to local in HMD, not to distant spread.

Sensitivity for regional disease among public patients was significantly poorer than among private patients (difference: difference: –25.1%; 95% CI –49.7%, –0.7%). Conversely, sensitivity for metastatic disease was slightly poorer among the private patients than the public patients. However, this finding was not statistically significant. There was no material difference in specificity among private and public patients.

 

**Table 2** Clinical description and characteristics of patients

| Colorectal cancer patients | *N* = 499 |
|---|---|
| Age median (range) | 67 (19–92) |
| Sex *n* (%) | |
| Male | 253 (50.7) |
| Female | 246 (49.3) |
| Hospital type *n* (%) | |
| Public | 77 (15.4) |
| Private | 422 (84.6) |
| ACPS *n* (%) | |
| A | 121 (24.3) |
| B | 164 (32.9) |
| C | 130 (26.1) |
| D | 84 (16.8) |
| Procedure *n* (%) | |
| Right hemi-colectomy/extended hemi-colectomy | 146 (29.3) |
| Left hemi-colectomy, sigmoid colectomy | 34 (6.8) |
| High anterior resection | 94 (18.8) |
| Total colectomy, proctocolectomy | 8 (1.6) |
| Transcolectomy | 6 (1.2) |
| Anterior resection, low anterior resection, ultra-low anterior resection | 189 (37.9) |
| Abdoperineal resection | 28 (5.6) |

ACPS, Australian clinicopathological stage.

**Table 3** Accuracy of spread of disease from International classification of diseases codes in inpatient hospital morbidity data with spread of disease from clinical cancer registry as reference standard

| | Local | Regional | Distant |
|---|---|---|---|
| Sensitivity (95% CI) | 95.8 (92.7, 97.8) | 66.4 (57.6, 74.4) | 71.4 (60.5, 80.8) |
| Specificity (95% CI) | 81.9 (76.0, 86.8) | 92.7 (89.5, 95.1) | 96.6 (94.4, 98.1) |
| Positive predictive value (95% CI) | 87.5 (83.3, 90.9) | 76.3 (67.4, 83.8) | 81.1 (70.3, 89.3) |

**Table 4** Spread of disease at diagnosis as mapped from International classification of diseases codes in inpatient hospital morbidity data and Australian clinicopathological stage from clinical cancer registry

| | | Clinical cancer registry (gold standard) | | |
|---|---|---|---|---|
| Colorectal cancer patients | | Local (*N* = 284) *n* (%) | Regional (*N* = 131) *n* (%) | Distant (*N* = 84) *n* (%) |
| Hospital morbidity data | Local | 272 (95.8) | 34 (26.0) | 5 (6.0) |
| | Regional | 8 (2.8) | 87 (66.4) | 19 (22.6) |
| | Distant | 4 (1.4) | 10 (7.6) | 60 (71.4) |

## DISCUSSION

Spread of CRC to regional lymph nodes or distant organs is underreported in the HMD, leading to understaging. While only 66% of patients with regional and 71% of patients with distant CRC at diagnosis are identified in the HMD, those who are identified are accurate because regional or distant spread of CRC is rarely coded for in HMD when the patient does not actually have regional or distant spread.

 

There is only one other published study that has assessed the utility of a large population-based data source for determining the stage of CRC.[12] In 1999 Cooper *et al*. published results from a study in the USA that determined the relative accuracy of ICD codes (9th rev.) in Medicare claims for measuring the stage of disease for six cancers, using summary stage reported in SEER registry.[12] They report a sensitivity of 34.3% for regional CRC, which is almost half that found in the present study. This difference may be due to changes in practices in the harvesting and reporting of lymph nodes with the release of surgical guidelines for CRC in 2000.[19] ICD coding for secondary malignancies in regional lymph nodes in the HMD is more accurate when there is an adequate documentation of lymph node involvement in histopathology reports.

CRC staging is required for determining patient management.[13] For the occasional case where the stage of cancer is not established prior to surgery, surgeons and clinical coders alike will not have access to information about secondary malignant neoplasm. These cases will not affect the results of this study but may account for some of the cases in the clinical cancer registry that were unstaged.

Patients who had neoadjuvant therapy were included in the analysis. Any change to the extent of the primary tumor as a result of neoadjuvant therapy will not change the broad categories of stage used in this study because local spread of disease included tumor status 1–4, provided that the nodal status was 0. That is, neoadjuvant therapy would not cause patients to move between the three categories of stage used in this study: local, regional and distant.

We did not conduct an audit of coding in this sample of patients and cannot verify that coding for a secondary neoplasm was complete even when the information was available to the clinical coders. Such an audit may reveal that clinical coders need to be educated in the importance of accurate coding of spread of disease as secondary neoplasms.

This study has the advantage that many of the histopathology reports were completed by a single pathologist in a synoptic report format which included all the information required to accurately determine the stage of CRC: the number of lymph nodes in the specimen, the number of involved nodes, tumor node metastasis (TNM) and/or ACPS stage, the presence of vascular, perineural or serosal invasion and the extent of local spread.

Synoptic histopathology reporting enables the reader, usually a clinician, to locate the required prognostic information more readily than with free text reporting.[20] This presumably can be extended to clinical coders. In this study the histopathology reports for patients treated in private hospitals were often in synoptic format, unlike the public patients whose histopathology reports were in free text. This may explain the difference in sensitivity for the regional spread of CRC between the public and private patients. Clinical coders code secondary lymph node involvement when it is clearly reported in the histopathology report. It is therefore possible that clinical coders miss information indicating lymph node involvement when the histopathology report was in free text format. The clear documentation of information, such as synoptic histopathology reporting, would assist clinical coders in identifying spread of disease, potentially resulting in more accurate coding.

In this particular group of surgeons it is usual practice to include the presence or absence of distant metastasis on the pathology request form, such as "liver clear", "liver metastasis" or "nodal metastasis". Among the private patients this information was often included in the histopathology report as TNM or ACPS stage and as free text in the history section. However, these do not always include a specification of site of metastatic spread, as is required for best coding practice. A code for a secondary malignant neoplasm with the site unspecified (C79.9) was introduced in a later edition of ICD-10-AM to allow clinical coders to allocate a code when they are unable to determine the site of metastatic spread. However, this code was not available for the patients in this study and the accuracy of HMD for identifying the distant spread of disease for CRC may have increased with the introduction of this code.

The TNM stage is a globally accepted method for staging cancers.[21] Provided that the information related to the presence or absence of distant metastasis is included in the pathology request form, the TNM stage can be routinely documented in the histopathology report of the primary tumor specimen; which was the case for many patients in this sample. There is the potential for the ICD coding system to incorporate cancer stage-specific codes to indicate the TNM stage as well as codes for site-specific spread of cancer.

Clinical coders have access to clinical notes and results of investigations (e.g., imaging, cytology and histology) to assist with identifying the spread of CRC. Because of this, HMD might be the most cost effective way of collecting population-based data on the spread of disease for cancers like CRC, where nearly all patients

 

are admitted to hospital. For other cancers, such as prostate cancer, where up to 30% of patients may not be admitted; other sources of data for the spread of disease might be required.

ICD codes for a secondary neoplasm in HMD are limited in their utility for determining the spread of disease for CRC and should be used with caution. While changes to ICD codes to include TNM stage would improve the utility of HMD for determining spread of disease, the onus lies with the clinicians to ensure that clinical coders are provided with the information to accurately code for the spread of disease. We recommend reporting histopathology in a synoptic format which includes background information on the presence or absence of distant metastasis and TNM stage.

## ACKNOWLEDGMENTS

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## 4.2 Additional results

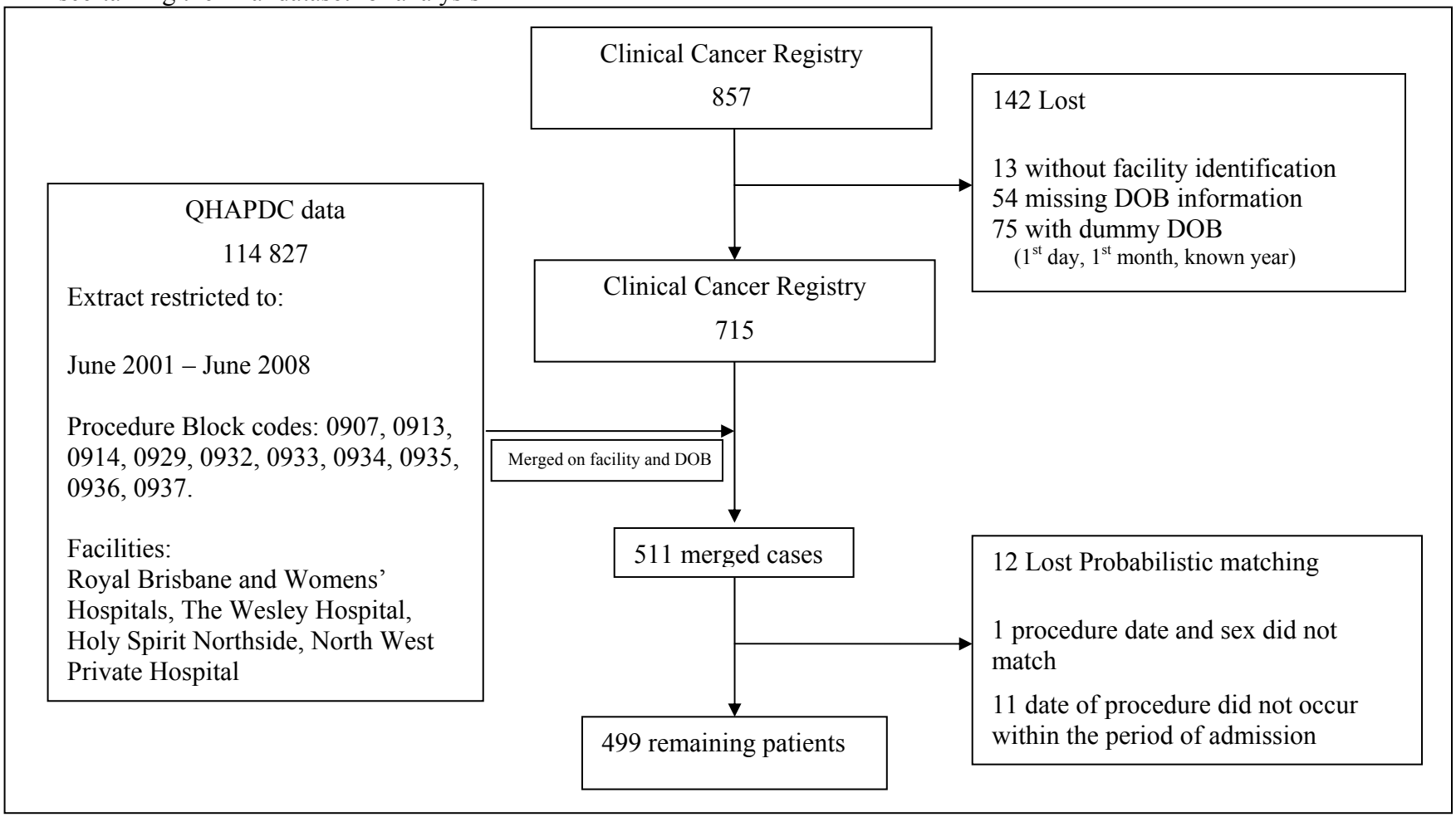
The tables and figures below provide additional detail about results presented in the published manuscript. In the interest of maintaining the requirements of the publishing journal, these tables and figures are referred to in the text of the manuscript, but were not included in the manuscript as they are appear here.

Figure 4-1 provides details about the clinical cancer registry used as the "gold standard" for this chapter. Of the 857 records available in the clinical cancer registry, 142 (17%) did not have adequate information to enable linkage with QHAPDC and were excluded from further analysis. Hospital episodes in QHAPDC were restricted to those with procedure codes for resection of the colon or rectum and these were successfully matched to 70% of records in the clinical cancer registry based on the hospital facility and data of birth. Further review identified that 12 of the matched records did not match on dates of admission and sex. This resulted in a total number of 499 successfully matched records.

The clinical cancer registry was considered the "gold standard" because all data were entered by the treating surgeon who had performed the procedure and, with this, had a thorough knowledge of the clinical findings including evidence of spread of disease. As the primary clinician, the surgeon had access to all clinical findings and therefore cancer stage entered into the clinical cancer registry was considered the "gold standard". The purpose of this study was to determine whether coding of spread of disease in QHAPDC could be used to determine a summary stage, and to measure how this compared with the clinical cancer registry. The results found that spread of disease was under-staged in QHAPDC, and almost never over-staged. This indicates that the clinical findings known by the surgeon were not available to the clinical coders coding for spread of disease in QHAPDC.

The exclusion of records from the clinical cancer registry because of incomplete data for matching or because they did not successfully match, should have no material impact on the findings. We were unable to access patient identified information in QHAPDC, which limited the success of linkage. This was not a limitation of the clinical cancer registry. Data entry into the clinical cancer registry was independent of clinical coding for the QHAPDC. Clinical coders entering data into QHAPDC have the same information available to them in the clinical notes and medical records regardless of completeness of information in the clinical cancer registry.

Figure 4-1 Ascertaining the final dataset for analysis




QHAPDC = Queensland Hospital Admitted Patients Data Collection, DOB = date of birth

Table 4-1 Sensitivity for two groupings of summary stage (spread of disease) at diagnosis as mapped from International Classification of Disease Codes (Version 10) in inpatients hospital morbidity data and Australian clinicopathological stage from clinical cancer registry

| | Local | Regional/distant |
|---|---|---|
| Sensitivity (%; 95%CI) | 272/284 (95.8%; 92.7, 97.8) | 176/215 (81.9%; 76.0, 86.8) |
| | Local/regional | Distant |
| Sensitivity (%; 95%CI) | 401/415 (96.6%; 94.4, 98.1) | 60/84 (71.4%; 60.5, 80.8) |

Table 4-2 Spread of disease with measures of accuracy of summary stage (spread of disease), by hospital type.

| Public hospital | | Clinical cancer registry (gold standard) | | |
|---|---|---|---|---|
| | | Local (n = 45) | Regional (n = 18) | Distant (n = 14) |
| Hospital morbidity data | Local | 43 | 9 | 2 |
| | Regional | 2 | 8 | 1 |
| | Distant | 0 | 1 | 11 |
| | Total | 45 | 18 | 14 |
| | Sensitivity | 95.6% | 44.4% | 78.6% |
| | Specificity | 65.6% | 94.9% | 98.4% |
| | Positive predictive value | 79.6% | 72.7% | 91.7% |
| Private hospital | | Clinical cancer registry (gold standard) | | |
| | | Local (n = 239) | Regional (n = 113) | Distant (n = 70) |
| Hospital morbidity data | Local | 229 | 25 | 3 |
| | Regional | 6 | 79 | 18 |
| | Distant | 4 | 9 | 49 |
| | Total | 239 | 113 | 70 |
| | Sensitivity | 95.8% | 69.9% | 70.0% |
| | Specificity | 84.7% | 92.2% | 96.3% |
| | Positive predictive value | 89.1% | 76.7% | 79.0% |

* Differences in the sensitivity for regional and metastatic disease between public and private hospitals are mentioned in the results section of the published manuscript, however data are not provided in the manuscript.

## 4.3 Discussion and implications of findings

Hospital morbidity data may become more accurate for determining stage with improved documentation of information in medical records. This may be achieved by ensuring clear documentation of spread to lymph nodes in distant organs in the clinical notes. However, at present hospital morbidity data are limited in their utility for researching outcomes for CRC.

Routinely collected population-based data sources such as hospital morbidity data are useful for conducting observational studies because they have a large sample size, include all treated patients within a jurisdiction (rather than selection based on inclusion/exclusion criteria) and provide information on the "real world" of clinical practice.(89) For studies that require stage as a key determinant of the outcome, such as survival analysis, hospital morbidity data does not provide stage information that is adequately reliable. For the purpose of this thesis, stage of CRC is a potential confounding factor for the outcomes measured in Chapter 7. In the absence of reported cancer stage information, determining summary stage of CRC from other diagnosis codes accurately identifies the majority of patients with spread of disease beyond the primary tumour.

**Conclusion**

This study was performed to evaluate the utility of hospital morbidity data for determining stage of CRC and thus identifying limitations of these data sources to conduct CRC research. Hospital morbidity data provides adequate summary stage information for the purpose of adjusting for spread of CRC as a potential confounder in research, and is used in this capacity in Chapter 6 and Chapter 7. As distant and regional spread are under-staged in about one third of the cases, using summary stage determined from other diagnosis codes in the hospital morbidity for performing analyses on colorectal survival and recurrence, should be avoided or performed with caution. Healthcare administrators may find improvement in coding of other diagnosis codes for spread to lymph nodes and distant organs if more complete and definitive documentation of clinical findings relating to spread of CRC was available to clinical coders in the clinical notes.

# Chapter 5 Current trends in laparoscopic resection for colorectal cancer in Australia

## 5.1 Introduction

This chapter includes a published manuscript that reports the uptake of laparoscopic resection for colorectal cancer across Australia. Of particular interest is whether there has been equal uptake in laparoscopic resection for CRC between public and private hospitals and high-volume and low-volume hospitals. The study is based on National Hospital Morbidity Data (NHMD) from 2000 to 2008. Laparoscopic resection for rectal cancer is supported by considerably less evidence and is a technically more difficult procedure than laparoscopic colon resection; trends were therefore stratified into segmental resection of the colon and resections of the rectum.

Each of the authors contributed to this study and the resulting manuscript as follows. I was responsible for the conception and design of the study in conjunction with Michael Coory. I was responsible for the data acquisition, analysis and interpretation of the results. Michael Coory provided guidance on the data analysis and interpretation of the results. John Lumley provided clinical expertise and knowledge to determine the procedure groups (segmental resection of the colon and rectal resection) and to interpret the results. I was responsible for the first and subsequent drafts of the manuscript under the guidance of, and with feedback from, Michael Coory and John Lumley.

This study was published in the peer-reviewed journal *Medical Journal of Australia* in 2011.

# National trends in the uptake of laparoscopic resection for colorectal cancer, 2000–2008

Bridie S Thompson, Michael D Coory and John W Lumley


## ABSTRACT

**Objective:** To examine the trends in the uptake of laparoscopic resection for colorectal cancer.

**Design and setting:** Retrospective analysis of Australia-wide data on elective resections for colorectal cancer over the 8 financial years 2000–01 to 2007–08, obtained from the National Hospital Morbidity Database.

**Main outcome measures:** National trends in annual percentage of colorectal resections for cancer that were conducted laparoscopically for each year, stratified by hospitals conducting a high volume of elective resections (40 or more/year) versus a low volume, and by public versus private hospitals.

**Results:** For all Australian hospitals combined, the percentage of resections for colon cancer conducted laparoscopically increased from 2.4% in 2000–01 to 27.5% in 2007–08. For rectal cancer, this increase was from 1.1% to 21.5%. The largest increases were seen in high-volume private hospitals (colon cancer, 2.7% to 34.1%; rectal cancer, 1.5% to 26.2%), but increases also occurred in high-volume public hospitals (colon cancer, 2.7% to 32.2%; rectal cancer, 0.5% to 20.3%), low-volume private (colon cancer, 3.8% to 27.1%; rectal cancer, 2.4% to 25.5%) and low-volume public (colon cancer, 1.1% to 17.0%; rectal cancer, 0.5% to 13.8%) hospitals.

**Conclusions:** The use of laparoscopic resection for colorectal cancer has increased throughout Australian hospitals. Our findings provide the data necessary to ensure adequate resource allocation by the appropriate medical bodies to achieve optimal success in the uptake of laparoscopic resection for colorectal cancer in Australia.


MJA 2011; 194: 443–447

Since around 1990, laparoscopic surgery has revolutionised abdominal surgery. Procedures such as laparoscopic cholecystectomy and Nissen fundoplication were quickly adopted and their use diffused rapidly through health systems around the world.[1] However, the widespread adoption of laparoscopic surgery for colorectal cancer (CRC) has been much slower despite proven short-term benefits over open resection. These benefits included less blood loss, reduced pain, shorter postoperative ileus, reduced hospital stay and better postoperative pulmonary function.[2] Specifically, time to first bowel movement is 1 day shorter with laparoscopic resection compared with open resection (3.5 v 4.5 days; $P = 0.01$), and length of hospital stay is reduced by about 3 days (8.1 v 11.8 days; $P = 0.01$).[3]

Reasons for the delay in uptake of laparoscopic surgery for CRC included less than optimal equipment and the long learning curve associated with the procedure; but perhaps most importantly, there were concerns about whether long-term oncological outcomes (eg, recurrence, overall survival) were as good as for open surgery.[4]

These concerns have subsequently been allayed. For example, a recent meta-analysis reported that across seven studies, only three of 826 patients with colon cancer (0.4%) who were randomly allocated to laparoscopic surgery had port-site metastases,[5] and a Cochrane review concluded that resection with laparoscopic access resulted in cancer-related mortality equivalent to that for open surgery.[5] Data from randomised trials in rectal cancer are not as mature,[5] but the evidence that is available suggests that the oncological outcomes are equivalent for laparoscopic and open access surgery.[6]

In this article, we aim to examine trends in the uptake of laparoscopic surgery for CRC in Australia, and to consider the implications for the organisation of surgical services for patients with CRC. We were particularly interested in whether there were differences in the uptake of laparoscopic resection for colon cancer compared with rectal cancer because resection for rectal cancer is technically more difficult. We were also interested in whether there was differential uptake across the public and private sectors and whether this varied by the volume of patients with CRC treated at a particular hospital.

## METHODS

We obtained data for eight financial years, 2000–01 to 2007–08, from the National Hospital Morbidity Database (NHMD), in which administrative inpatient data from all of the Australian states and territories is collated.[7] The data extraction was restricted to patients with CRC who had had an elective surgical resection. Patients who had undergone emergency resections (eg, for bowel obstruction, bleeding or perforation secondary to CRC) were excluded because emergency surgery for complications of CRC and elective surgery for CRC are two distinct and different groups of surgical procures. Currently, laparoscopic surgery is only routinely considered for elective surgery — randomised controlled trials of laparoscopic surgery include only elective cases.

No data that could identify (or re-identify) an individual patient or hospital were provided. Information was provided on two hospital characteristics: public versus private and high (40 or more elective resections for CRC per year) versus low volume. The state or territory of the hospital was not provided because, when stratified by public versus private and high versus low volume, this might have permitted identification of individual hospitals in some of the less populous states and the territories.

The NHMD uses Australian Classification of Health Interventions (ACHI) codes (*International statistical classification of diseases and related health problems. 10th revision, Australian modification*; ICD-10-AM),[8] which are derived from the Medicare Benefits Schedule to indicate the procedure performed. There are currently no specific item numbers for laparoscopic resection of the colon or rectum. Instead, item numbers for laparoscopy (3039000 and 3039300) are used in combination with those for open resection of the colon or rectum to indicate a laparoscopic resection (Box 1).[8]

**1 *International statistical classification of diseases and related health problems. 10th revision, Australian modification* (ICD-10-AM)[8] codes used to define laparoscopic resections for colon and rectal cancer***

| Procedure category and description | ICD-10-AM code | Additional ICD-10-AM codes indicating laparoscopic resection |
|---|---|---|
| Segmental resections of colon | | |
| Right hemicolectomy | 3200301, 3200001 | 3039000 or 3039300 |
| Left hemicolectomy | 3200600, 3200601 | |
| High anterior resection | 3202400 | |
| Extended right hemicolectomy | 3200501, 3200401 | |
| Sub-total colectomy | 3200500, 3200400 | |
| Sigmoidectomy | 3200300, 3200000 | |
| Resections of rectum | | |
| Low anterior resection | 3202500, 3202600 | |
| Ultra-low anterior resection | 3202800 | |
| Abdominoperineal resection | 3203900 | |
| **Excluded procedures** | | **Reason for exclusion** |
| Hartmann's procedure | 3203000 | Emergency procedure |
| Proctocolectomy | 3205100, 3205101, 3201500 | Not usually conducted with laparoscopic access |
| Total colectomy | 3201200, 3200900 | Not usually conducted with laparoscopic access |

* All cases included a principal diagnosis code of C18.0–C20.0. ◆

To simplify and clarify the presentation of results, we grouped procedures into two categories: those for elective segmental resection of the colon and those for elective resection of the rectum (Box 1). Total colectomy and proctocolectomy were not included in the data extracted because they are uncommon. Cases of Hartmann's procedure were also excluded from the data extracted because, in Australia, this is typically an emergency procedure.

Ethical approval for this analysis was granted by the University of Queensland's School of Population Health Research Ethics Committee.

## RESULTS

There were 5424 elective segmental resections for colon cancer in Australian hospitals in 2000–01 and 6523 in 2007–08; elective resections for rectal cancer increased from 2530 to 3072 in the same period. There was no change in the percentage of elective resections for CRC done in public versus private hospitals between 2000–01 and 2007–08. However, within the private sector, an increasing percentage of resections were performed in low-volume compared with high-volume hospitals. For public hospitals, the percentage of resections performed in low-volume compared with high-volume hospitals remained about the same (Box 2).

Over the 8 years of the study, the percentage of elective resections for colon cancer that were performed laparoscopically increased from 2.4% to 27.5%; the corresponding increase for elective resections for rectal cancer that were performed laparoscopically was from 1.1% to 21.5% (Box 3).

There was an increase in the percentage of laparoscopic resections across all hospital types and for cancer of both the colon and rectum, with the largest increases in high-volume private hospitals (Box 4). For both colon and rectal cancer, the rate of uptake of laparoscopic resection appeared to increase in 2003–04 (Box 5).

## DISCUSSION

Laparoscopic colorectal resection is a very complex procedure, requiring mobilisation of a bulky structure, access to more than one quadrant of the abdomen, control of multiple large blood vessels, extraction of a large specimen, and successful creation of an anastomosis.[9] Resection for malignant tumours has even more demanding requirements than resection for benign disease, because the surgeon must adhere to oncological principles — attainment of adequate surgical margins, removal of lymph nodes, proximal ligation of the vascular pedicles, minimal handling, and avoidance of perforation.[9] Surgeons therefore need adequate training and experience to undertake laparoscopic resection for CRC.[10]

In Australia by 2007–08, about a quarter of elective resections for CRC were laparoscopic. Barring capacity constraints, it is likely that the percentage of laparoscopic resections will continue to increase because such minimally invasive surgery is probably feasible in about 90% of elective resections for CRC performed by experienced surgeons.[11] Also, the number of elective resections are likely to increase as early detection of CRC through screening (either with faecal occult blood tests or colonoscopy) and the use of colonic stenting for obstruction reduce the need for emergency resections.

Compared with open resection, there is a much longer learning curve associated with

**2 Absolute numbers and percentage of elective resections for colorectal cancer by hospital volume and sector, Australia, 2000–01 and 2007–08**

| | Financial year | |
|---|---|---|
| | 2000–01 | 2007–08 |
| Segmental resections of the colon | | |
| Low-volume public hospitals | 1601 (29.5%) | 1675 (25.7%) |
| High-volume public hospitals | 1065 (19.6%) | 1504 (23.1%) |
| Low-volume private hospitals | 709 (13.1%) | 1628 (25.0%) |
| High-volume private hospitals | 2050 (37.8%) | 1716 (26.3%) |
| Resections of the rectum | | |
| Low-volume public hospitals | 649 (25.7%) | 768 (25.0%) |
| High-volume public hospitals | 562 (22.2%) | 770 (25.1%) |
| Low-volume private hospitals | 286 (11.3%) | 703 (22.9%) |
| High-volume private hospitals | 1033 (40.8%) | 831 (27.1%) |

**3 Laparoscopic resections as a percentage of all elective resections for colorectal cancer, Australia, 2000–01 and 2007–08**

| | Segmental resections of colon | | Resections of rectum | |
|---|---|---|---|---|
| Financial year | All | Laparoscopic | All | Laparoscopic |
| 2000–01 | 5425 | 130 (2.4%) | 2530 | 28 (1.1%) |
| 2001–02 | 5629 | 200 (3.6%) | 2544 | 39 (1.5%) |
| 2002–03 | 5561 | 251 (4.5%) | 2596 | 57 (2.2%) |
| 2003–04 | 5616 | 302 (5.4%) | 2583 | 119 (4.6%) |
| 2004–05 | 5709 | 619 (10.8%) | 2717 | 234 (8.6%) |
| 2005–06 | 5921 | 1047 (17.7%) | 2745 | 365 (13.3%) |
| 2006–07 | 6247 | 1462 (23.4%) | 2979 | 518 (17.4%) |
| 2007–08 | 6523 | 1796 (27.5%) | 3072 | 659 (21.5%) |
| Total | 53 300 | 5952 (11.2%) | 24 174 | 2062 (8.5%) |
| Absolute % increase* (95% CI) | | 25.10% (24.0%–26.3%) | | 20.30% (18.8%–21.9%) |

* 2007–08 percentage minus 2000–01 percentage. ◆

laparoscopic resection for CRC; the required number of cases has been estimated to be up to 60–100.[10,12] In Australia, uptake of laparoscopic resection for CRC across all hospital types is a reflection of continued postfellowship education and training of surgeons in this technique.

The training of surgeons and the assessment of their competency in laparoscopic CRC needs to be hierarchical because laparoscopic surgery for CRC involves a range of complexities, which are dependent on the anatomical site. Training typically begins with segmental resections of the right or left colon and then progresses to the more difficult resections of the rectosigmoid colon, transverse colon, and extraperitoneal rectum. A surgeon's application for credentialling at each level of laparoscopic colorectal surgery should be accompanied by evidence of appropriate experience in the relevant procedures in open surgery. It is important that emerging specialists are also proficient in performing open resections for emergency cases and in cases where the laparoscopic technique is relatively contraindicated, such as when there are bowel adhesions. Progression through the levels needs to rely on objective evaluations from teachers and peers.[13]

The increasing uptake of laparoscopic resection for CRC in Australia is probably related to both better equipment and increasing evidence that long-term oncological outcomes are equivalent to those of open resection. The ultrasonic tissue dissector was introduced around the late 1990s, and better endoscopic stapling devices and high-definition videoendoscopy were introduced in the early 2000s. These devices improved laparoscopic access, particularly for resections within the pelvis. The increase in laparoscopic surgery for CRC in low-volume hospitals indicates that smaller centres outside the major cities are acquiring the technical facilities to perform laparoscopic resections. For both colon and rectal cancer, the rate of uptake increased in 2003–04. Publication of the Clinical Outcomes of Surgical Therapy trial[14] for colon cancer and of the first randomised data for rectal cancer[15] might have contributed to this.

A strength of our study is that it is based on data for all of Australia. At the same time, this is also a limitation because of the limited data items available nationally. In particular, we could not obtain data on items that might be used to assess quality, such as conversion rates (ie, the rates of planned laparoscopic resections being converted to open resections), circumferential resection margin, local recurrence, distant recurrence, and overall survival. Further research evaluating such outcomes for patients undergoing laparoscopic surgery in everyday clinical practice (as opposed to clinical trials) would assist in developing service capability frameworks. For example, should complex laparoscopic surgery (eg, for cancers of the transverse colon or extraperitoneal rectum) be restricted to major cancer centres?

We could only find one other study of population-based trends in the rates of laparoscopic resection for cancers of the colon and rectum. That publication, from the National Institute for Clinical Excellence in the United Kingdom, reported a percentage of laparoscopic procedures for elective resections for CRC of 9.0% in 2006–07,[16] compared with 21.5% from our Australian study for the same year.

Four publications from the United States reported the percentage of laparoscopic resections for cancers of the colon only.[17-20] These population-based studies used data from three different sources and reported a wide range in the percentage of CRC resections performed laparoscopically. Three of these studies reported a percentage of around 5%, which is very similar to that for Australia at the same time (2003–04).[17,19,20] However, another study reported a percentage of 33.7% for the period 1 July 2004 to 30 June 2006,[18] which is higher than the 14.3% for Australia over the same period (Box 3).

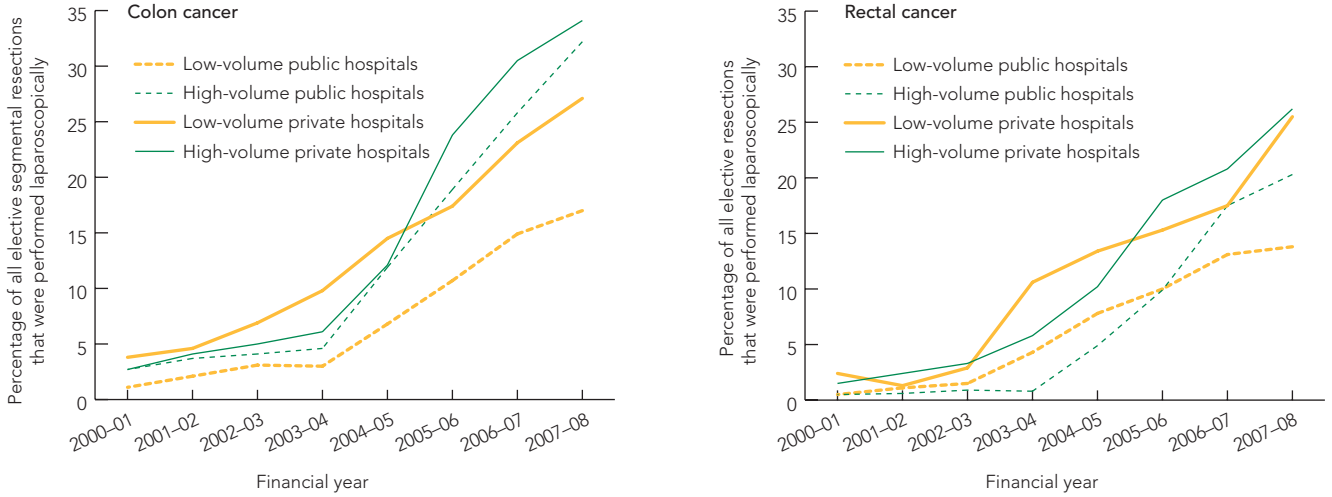
The short-term benefits of laparoscopic resection shown by international studies

**4 Laparoscopic resections as a percentage of all elective resections for colorectal cancer by hospital volume and sector, Australia, 2000–01 and 2007–08**

| | Financial year | | Absolute % increase* (95% CI) |
|---|---|---|---|
| | 2000–01 | 2007–08 | |
| Segmental resections of the colon | | | |
| Low-volume public hospitals | 1.1% (18/1601) | 17.0% (285/1675) | 15.9% (14.0%–17.8%) |
| High-volume public hospitals | 2.7% (29/1065) | 32.2% (484/1504) | 29.5% (26.0%–32.0%) |
| Low-volume private hospitals | 3.8% (27/709) | 27.1% (441/1628) | 23.3% (20.7%–25.9%) |
| High-volume private hospitals | 2.7% (56/2050) | 34.1% (586/1716) | 31.4% (29.1%–33.8%) |
| Resections of the rectum | | | |
| Low-volume public hospitals | 0.5% (3/649) | 13.8% (106/768) | 13.3% (10.8%–15.8%) |
| High-volume public hospitals | 0.5% (3/562) | 20.3% (156/770) | 19.7% (16.8%–22.6%) |
| Low-volume private hospitals | 2.4% (7/286) | 25.5% (179/703) | 23.0% (19.3%–26.7%) |
| High-volume private hospitals | 1.5% (15/1033) | 26.2% (218/831) | 24.8% (21.7%–27.9%) |

* 2007–08 percentage minus 2000–01 percentage. ◆

**5 Trends in the uptake of laparoscopic surgery for colon cancer and rectal cancer in Australian hospitals, 2000–01 to 2007–08**




probably provide impetus for the uptake of this technique in Australia. Short-term outcomes from the Australian Laparoscopic Colon Cancer Surgical trial indicate that laparoscopic resection is associated with faster return of bowel function and shorter hospital stay.[21] However, whether these and other short-term benefits such as reduced blood loss and better postoperative pulmonary function are being experienced outside the clinical trial environment would be of interest, and these questions should be the subject of future research. Also of interest in the real world of clinical practice is operating time. In a meta-analysis of randomised and non-randomised data, the mean operating time for laparoscopic surgery was 27% longer than for open surgery (175 minutes versus 147 minutes).[3] Operating time is related to conversion rates, and it is possible that, as surgeons become more experienced with laparoscopic techniques, conversion rates will decrease and operating time will reduce to that of open surgery.

Impetus for the increased uptake of laparoscopic surgery for CRC comes not just from good quality evidence from randomised trials and recommendations by medical bodies,[22-24] but also from the positive experiences of surgeons and their patients in everyday clinical practice. Given equivalent long-term oncological outcomes, patients with CRC prefer laparoscopic resections because of the proven short-term benefits.[2]

CRC is the most common internal cancer diagnosed in Australia.[25] It is therefore likely that laparoscopic resection for CRC will be a procedure in high demand. The results from our article provide information to help the appropriate medical bodies achieve optimal success in the uptake of laparoscopic resection for CRC in Australia by providing the data necessary to ensure adequate resource allocation.

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## COMPETING INTERESTS

None identified.

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***For editorial comment, see page 441***

## 5.2 Discussion and implication of findings

The objective of this study was to inform healthcare administrators of the national uptake of laparoscopic resection and any disparity in access to this procedure by hospital type. This is the first study to report on the uptake of laparoscopic resection for CRC across Australia. While there have been increases in laparoscopic resection for colorectal cancer across all hospitals, a disparity in access to the procedure between the hospitals exists; specifically, the uptake of laparoscopic resection for resection was slower in public hospitals and low-volume public hospitals. This study is valuable because it provides the data necessary to aid healthcare administrators responsible for resource allocation to ensure further uptake of the technique and equitable access to patients with CRC in Australia.(90)

# Chapter 6 Determinants of uptake of laparoscopic resection for colorectal cancer

## 6.1 Introduction

Laparoscopic resection of colorectal cancer includes procedures of varying technical difficulty; it is more difficult to perform resections of the rectosigmoid colon and transverse colon compared with segmental resections of the right or left colon. Uptake of some procedures may therefore be slower than others.

The large numbers of laparoscopic resections for CRC in Queensland provide a sample size that is large enough to accurately determine the characteristics of patients having laparoscopic resection for CRC. Hospital morbidity data were utilised to determine whether differences in the uptake of laparoscopic resection exist across different procedure types and patient characteristics.

Each of the authors contributed to this study and the resulting manuscript as follows. Michael Coory, John Lumley and I were each responsible for the conception and design of the study. I was responsible for the data acquisition, and performed the data analysis. Under the guidance of Michael Coory and John Lumley, I interpreted the results. I was responsible for the first and subsequent drafts of the manuscript under the guidance of, and with feedback from, Michael Coory, John Lumley and Louisa Gordon.

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**Abstract**

Introduction: Laparoscopic surgery for colorectal cancer (CRC) includes procedure types of varying technical difficulty. The aim of this paper is to assess whether there is differential uptake of laparoscopic surgery by procedure type in a geographically-defined area; where uptake is relatively mature; and where there are clear referral pathways to colorectal surgeons, who specialise in laparoscopic surgery.

Method: This is a population-based study of trends (1999/2000 – 2010/2011) in laparoscopic resection for elective surgery for CRC. Trends are assessed in subgroups, based on technical difficulty, over four time periods. The main outcome measure is the "laparoscopic percentage"; the number of resections performed with laparoscopic access divided by number of all relevant resections (laparoscopic + open).

Results: The laparoscopic percentage for sigmoid colectomy/high anterior resection increased from 10.4% in 1999/2000-2002/2003 to 61.4% in 2009/2010-2010/2011. Similarly, the laparoscopic percentage for right hemicolectomy increased from 10.7% to 54.5%; and left-hemicolectomy increased from 4.0% to 54.0%. There were also large increases in the percentages of more difficult procedures: transverse colectomy (4.1% to 47.6%); extended right hemicolectomy (5.8% to 40.3%); and restorative proctectomy (5.5% to 63.2%). Length of stay was shorter by 1.7 days in the laparoscopic groups.

Discussion: The laparoscopic approach has diffused across all procedure types, regardless of technical difficulty and regardless of factors such as cancer stage, cancer site and co-morbidities. In the real-world of everyday clinical practice, surgeons are judging the results from RCTs can be validly generalised to nearly all patients with CRC.

Word count: 238

## Introduction

Laparoscopic resection for the management of colorectal cancer (CRC) is one surgical intervention for which there are well-designed, large, multi-centre randomised clinical trials (RCT). For colon cancer, high quality randomised evidence has confirmed that, compared to open surgery, laparoscopic resection has equivalent long-term oncologic outcomes with superior short-term outcomes (i.e., less post-operative pain, lower risk of post-operative complications, shorter length of stay).[1] For rectal cancer, the randomised data are not as mature as for colon cancer; however, the available evidence suggests a similar favourable benefit-risk profile.[2-4] The National Institute for Health and Clinical Excellence (NICE) recommends laparoscopic resection for both colon and rectal cancer[5], while other guidelines recommend laparoscopic resection of colon cancer only[6-8]. Recently the European Association for Endoscopic Surgery (EAES) recommended laparoscopic resection of rectal cancer.[9]

Although RCTs provide the most internally valid measure of the benefits and risks of a new surgical technique, they are based on a sample of patients who meet inclusion/exclusion criteria and who are treated in specialised centres.[10] In the real world of everyday clinical practice, surgeons have to judge whether the average results reported from RCTs apply to a particular individual patient, who is seeking advice and treatment. The RCTs for laparoscopic resection commonly excluded patients with cancer of the transverse colon[11-14] and rectum,[11, 13, 14] those with metastasis,[11, 13, 14] poor overall health,[13, 15] and chronic cardiac or pulmonary disease[12]. With the exception of one single-surgeon study, which reported that 90% of elective CRC patients are suitable for laparoscopic resection,[16] little is known about the type of patients who are being selected for laparoscopic resection, in the real world of everyday clinical practice.

Queensland (north-east part of Australia; population 4.2 million) has a group of surgical opinion leaders, who were innovators and early-adopters of laparoscopic resection for CRC.[17] Queensland is therefore further along the S-curve[18] for uptake of this technology than most other jurisdictions. Specifically, in Queensland in the financial year 2008/09, 48% of resections for CRC were performed laparoscopically, whereas in the United Kingdom the corresponding figure was 22%.[19] In the United States, 20% of resections for rectal cancer were laparoscopic in 2009 compared with 46% in Queensland.[20] Also, surgeons in Queensland who were experienced in laparoscopic surgery were well-known to other clinicians and there were well-established referral pathways.[17]

This study is the first to report on the uptake of lap surgery for CRC across different procedure types in a region where uptake is relatively mature. Increases in the percentage of laparoscopic resections into all patient groups; including, patients requiring technically difficult resections (transverse colectomy, resections of the rectum), patients with cardiac or pulmonary disease, and patients with metastases, would imply that, in the future, most CRC patients will be considered eligible for laparoscopic resection.

**Methods**

Data for this study were obtained from the Queensland Hospital Admitted Patients Data Collection (QHAPDC) for the twelve financial years 1999/2000 – 2010/2011. QHAPDC maintains inpatient data for all admissions to all hospitals in Queensland. Similar routinely-maintained, inpatient databases exist in the other Australian states and territories; these databases are similar to hospital administrative databases in the United States,[21] the United Kingdom[22] and Canada[23].

In Queensland and Australia, about 60% of major resections are performed in private hospitals; the remainder are done in the public sector.[24] Patients admitted to public hospitals receive treatment supervised by specialists (or advanced trainees) nominated by the hospital.[25] Specialist surgical training is predominantly conducted at public hospitals.[25]

Procedures were grouped into seven categories based on technical difficulty;[26] the additional codes, *3039000* and *3039300*, signified a laparoscopic resection (International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification; ICD10-AM).[27] Cancer patients (as opposed to those who had a resection for benign disease) were identified as those whose principle diagnosis field contained an ICD10-AM code between C18.0 – C20.9.[28] Only elective (booked) resections were considered for the study; emergency procedures were excluded. Total colectomy, proctocolectomy and Hartmann's procedure (4.5%) were not included because they are rarely performed laparoscopically.

Restorative proctectomy includes anterior resections extending from the anal verge to 10cm from the anal verge (low and ultra-low anterior resections). Comorbid cardiac and pulmonary diseases were identified from secondary diagnosis codes and included any ICD-

10AM codes for the broad diagnoses of: congestive heart failure, acute myocardial infarction and chronic obstructive pulmonary disease.[29]

The main outcome measure is the "laparoscopic percentage"; the number of resections performed with laparoscopic access divided by the number of all relevant resections (laparoscopic + open). The analysis was stratified over four time periods; 1999/2000 – 2002/2003, 2003/2004 – 2005/2006, 2006/2007 – 2008/2009 and 2009/2010 – 2010/2011. Confidence intervals for the difference in laparoscopic percentage over time were calculated using the Wald method.[30]

Ordinary least squares regression analysis was used to estimate differences in the length of hospital stay between open and laparoscopic resections for rectal resection, laparoscopic segmental resection of the colon, and all resections (rectal and segmental combined). The analysis was adjusted for categories of age, time period, Charlson Comorbidity Index and stage.

All analyses were performed using STATA Statistical Software.[31]

Socio-economic status (SES) was defined using Socio-Economic Indexes for Areas (SEIFA) which provides a measure of SES for small geographically defined neighbourhoods based on information from the Australian Census.[32] Accessibility/Remoteness Index of Australia Plus (ARIA+) measures were used to indicate remoteness of residence. ARIA+ is based on the National Localities Index from the Australian Bureau of Statistics and determined from the residential address of the patient. ARIA+ categorises individuals in the following categories; major cities, inner regional, outer regional, remote and very remote.[33] For the purpose of this study, these categories were further collapsed into; major city, inner regional, outer regional/remote.

Ethical approval to conduct this study was provided by The Queensland Health Human Research Ethics Committee and The University of Queensland School of Population Health Ethics Committee.

**Results**

The data set included 14,343 patients who had a segmental resection for cancer of the colon and 6,402 patients who had resection for rectal cancer between July 1st 1999 and June 30th 2011. Patients with rectal cancer were younger and more likely to be male than colon cancer patients (Tables 1 and 2). Over the entire study period, about 47% of resections of the rectum and segmental resections of the colon were conducted in high-volume private hospitals (Tables 1 and 2). Right hemicolectomies were the most common segmental resection of the colon (Table 1). More than 80% of resections for rectal cancer were restorative proctectomies, the remaining rectal resections were abdomino-perineal resections and these decreased slightly over time. For resections of both rectal and colon cancers, Charlson co-morbidity index decreased over time along with decreases in the percentage of patients with co-morbid cardiac or pulmonary disease (Tables 1 and 2). Otherwise, the baseline characteristics of patients did not change materially over time.

The number of elective segmental resections for colon cancer increased from 1,055 in 1999/2000 to 1,309 in 2010/2011; the corresponding increase for rectal cancer was from 403 to 625. The laparoscopic percentage increased from 7% to 59% over this time for all segmental resections of the colon; and from 7% to 65% for all rectal resections. The laparoscopic percentage for rectal resections remained at a low level of 4% to 7% from 1999/2000-2003/2004. In 2003/2004 there was an abrupt and large increase to 15.7% (Figure 1). In contrast, the laparoscopic percentage for segmental resections of the colon increased steadily over the entire 12-year period, although, as with resections of the rectum, the increase was more marked from 2003/2004 (Figure 1).

The laparoscopic percentage for sigmoid colectomy/high anterior resection increased from 10.4% in 1999/2000-2002/2003 to 61.4% in 2009/2010-2010/2011. Similarly, right-

hemicolectomy increased from 10.7% to 54.5% and left-hemicoloectomy from 4.0% to 54.0%. There were also large increases for more difficult procedures: transverse colectomy (4.1% to 47.6%); extended right hemicolectomy (5.8% to 40.3%); and restorative proctectomy (5.5% to 63.2%) (Figure 2).

Increases in the percentage of laparoscopic resections were smallest for patients with distant disease for cancer of the colon or rectum; however, laparoscopic percentages approached 50% in the latest time period. Likewise, while patients with cardiac or pulmonary disease had smaller increases in laparoscopic resections between the first and last time periods, the laparoscopic percentages for this subgroup were: rectal resections 53%; segmental colon resections 44%. Laparoscopic percentages were highest across all time periods for those living in the most advantaged areas and those treated in private hospitals. Further details are available in Supplementary Tables 1 and 2.

After adjusting for potential confounders, the length of hospital stay was significantly shorter following rectal resection (-1.7 days; 95% CI -2.3 days, -1.2 days) and segmental resections of the rectum (-1.7 days; 95%CI -2.0 days, -1.4 days).

There were 271 deaths within 30 days of the procedure; 50/6402 (1%) following rectal resection, and 166/14343 (1.2%) following segmental resection of the colon. For rectal cancer patients, the percentage who died within 30 days of discharge was less than 1% in the laparoscopic and open groups. Percentages were similarly low for segmental resections of the colon; 1.2% in the open group and 1.0% in the laparoscopic group. These low percentages reflect the fact that this study only included patients booked for elective resection of their colorectal cancer; patients requiring non-booked (emergency) operations were excluded.

## Discussion

This population-based study, across all hospitals in a defined geographic area, found only marginally slower uptake of laparoscopic surgery for more difficult operations; and similarly for patients with metastases and cardio-pulmonary disease. These results suggest that surgeons are judging that the results from RCTs can be validly generalised to nearly all patients with CRC. These data also confirm a reduced length of hospital stay for laparoscopic resection.

There are no other published studies which have considered the type of procedures performed laparoscopically over time. A study based on data from non-profit academic medical centres of the United States, reports laparoscopic percentages for the time period 2007-2009 less than half those found in this study for the same period.[34] While both studies found smallest laparoscopic percentages for abdomino-perineal resection and transverse colectomy, this current study identified substantial increases in the laparoscopic percentages of these procedures following this period, such that by 2009/2010 – 2010/2011, they were similar to the percentages for right-hemicolectomy and sigmoid colectomy.

A strength of this study is that it is population-based and includes all patients treated for CRC across all hospitals in a geographically defined area. This study does not take into account planned laparoscopic resections which were converted to open resection at the time of surgery, although this is likely to have occurred in less than 7% of the cohort.[17]

The four years prior to 2003/04 represent the early period, before outcomes from most RCTs were reported[12, 14, 35, 36] and prior to advances in available technical equipment. This has allowed for comparison between the early phase of adoption and the time periods following, when uptake was more rapid.

Improvements in surgical equipment, specifically high-quality videoendoscopic equipment around 2003, played a major role in increasing the laparoscopic percentage of resections of

the rectum. Not only did this equipment allow for improved visualisation within the pelvis, it arguably allowed for better visualisation than obtainable in an open resection. This, combined with the advancement of skills among the surgical teams, resulted in a steady and rapid uptake of laparoscopic resection of the rectum from the early 2000s. This experience led to confidence in selecting other complicated procedures for laparoscopic resection, including the transverse colectomy and extended right hemicolectomy.

High-risk patients are not well represented in the RCTs assessing the efficacy of laparoscopic surgery for CRC of these patients following laparoscopic resection for CRC.[11, 12, 14, 37, 38] While there were fewer laparoscopic resections for patients with co-morbid chronic cardiac or pulmonary disease, by the last time period, almost half had laparoscopic resection. With the current constraints on the number of laparoscopic resections that can be performed, it is possible that patients with fewer co-morbidities are preferred for laparoscopic resection. Only recently, the European Association for Endoscopic Surgery stated that cardiopulmonary impairment is not a contraindication for laparoscopic resection of rectal cancer[9] and with improvements in anaesthetic techniques and monitoring, including adjustment to intra-abdominal pressure, laparoscopic resection for CRC can have minimal adverse anaesthetic events with improved patient outcomes[38]. With this in mind, these patients will be specifically selected for laparoscopic resection in coming years.

Even in high-volume private hospitals where surgeons are the most experienced in laparoscopic resections for CRC and where (compared with public hospitals) there should be few capacity or systemic constraints, the percentage of patients selected for laparoscopic resection falls short of the previously suggested 90% of patients[16]. This is probably a consequence of the technical difficulty of this intervention and the associated long learning curve. It takes a number of years for a surgeon to become experienced in conducting

laparoscopic resections for cancers of the colon and rectum. When a surgeon is willing to conduct laparoscopic resection for complicated cases depends on the individual surgeon and the operating teams and may not occur until both have gained ample experience. There will always be surgeons in the earlier phase of the learning curve and the training regime requires that they also learn techniques in open resection. The percentage increase of laparoscopic segmental resections of the colon among high-volume private hospitals has slowed; even in hospitals where surgeons are fully-trained and have adequate experience, surgeons are choosing to perform open resections on 38% of colon cancer patients.

A group of specialist colorectal surgeons drove the uptake of laparoscopic resection in Queensland and from the early phase of adoption offered training courses in laparoscopic colorectal surgery. In doing so, they developed clear referral pathways whereby more difficult procedures were referred to the most experienced surgeons. The likelihood of patients requiring rectal resections, transcolectomies or extended right hemicolectomies having their procedure with laparoscopic access, was similar to patients requiring less complicated procedures. We postulate that clear referral pathways mean that patients are consulting with surgeons who have the experience appropriate for the complexity of their presenting clinical circumstances and condition.

In experienced hands, perhaps the only patients not suitable for laparoscopic resection for colorectal cancer, will be those with threatened margins (detected on magnetic resonance imaging) or with a history of complicated previous surgery.[16] Which patients receive laparoscopic surgery may depend not so much on characteristics of the cancer (e.g., site stage) or patient (e.g., age, co-morbidities), but on the experience of the surgical team and available resources. This raises the problem of how to ensure equitable access to this

technology for all patients, because suitably experienced surgeons might not be available in the local area.

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**Table 1:** Baseline characteristics of patients having segmental resection for cancer of the colon by four time periods.

| | 1999/00 – 2002/03 (4) | 2003/04 – 2005/06 (3) | 2006/07 – 2008/09 (3) | 2009/10 – 2010/11 (2) | P-value‡ |
|---|---|---|---|---|---|
| N | 4362 | 3435 | 3911 | 2635 | |
| Age group | | | | | 0.808 |
| ≤50 | 286 (6.6) | 239 (7.0) | 256 (6.6) | 202 (7.7) | |
| 51-75 | 2724 (62.5) | 2100 (61.1) | 2354 (60.2) | 1517 (57.6) | |
| ≥76 | 1352 (31.0) | 1096 (31.9) | 1301 (33.3) | 916 (34.8) | |
| Sex | | | | | 0.660 |
| Male | 2237 (51.3) | 1783 (51.9) | 2026 (51.8) | 1335 (50.7) | |
| Female | 2125 (48.7) | 1652 (48.1) | 1885 (48.2) | 1300 (49.3) | |
| ARIA | | | | | <0.001 |
| Major city | 2169 (49.7) | 1691 (49.2) | 1934 (49.5) | 1239 (47.0) | |
| Inner regional | 1355 (31.1) | 1119 (32.6) | 1230 (31.5) | 863 (32.8) | |
| Outer regional/remote | 838 (19.2) | 625 (18.2) | 747 (19.1) | 533 (20.2) | |
| SEIFA | | | | | 0.023 |
| 3 (most adv.) | 1448 (33.9) | 1163 (34.8) | 1260 (33.2) | 764 (30.0) | |
| 2 | 1457 (34.1) | 1090 (32.6) | 1307 (34.4) | 929 (36.5) | |
| 1 (least adv.) | 1365 (32.0) | 1088 (32.6) | 1233 (32.5) | 854 (33.5) | |
| Hospital type† | | | | | <0.001 |
| High-volume private | 1840 (42.2) | 1643 (47.8) | 1896 (48.5) | 1254 (47.6) | |
| Low-volume private | 692 (15.9) | 398 (11.6) | 461 (11.8) | 324 (12.3) | |
| High-volume public | 1340 (30.7) | 1054 (30.7) | 1105 (28.3) | 748 (28.4) | |
| Low-volume public | 490 (11.2) | 340 (9.9) | 449 (11.5) | 309 (11.7) | |
| Procedure | | | | | <0.001 |
| Right hemicolectomy | 2032 (46.6) | 1523 (44.3) | 1808 (46.2) | 1239 (47.0) | |
| Transverse colectomy | 340 (7.8) | 148 (4.3) | 183 (4.7) | 103 (3.9) | |
| Extended right hemicolectomy | 86 (2.0) | 270 (7.9) | 309 (7.9) | 201 (7.6) | |
| Left hemicolectomy | 423 (9.7) | 364 (10.6) | 439 (11.2) | 304 (11.5) | |
| Sigmoid colectomy / high anterior resection of rectum | 1481 (34.0) | 1130 (32.9) | 1172 (30.0) | 788 (29.9) | |
| Extent of disease | | | | | 0.018 |
| Local | 2789 (63.9) | 2198 (64.0) | 2555 (65.3) | 1783 (67.7) | |
| Regional | 1038 (23.8) | 834 (24.3) | 952 (24.3) | 605 (23.0) | |
| Distant | 535 (12.3) | 403 (11.7) | 404 (10.3) | 247 (9.4) | |
| Charlson score | | | | | 0.011 |
| 0 | 2081 (47.7) | 1665 (48.5) | 1991 (50.9) | 1503 (57.0) | |
| 1 | 499 (11.4) | 373 (10.9) | 382 (9.8) | 185 (7.0) | |
| 2+ | 1782 (40.9) | 1397 (40.7) | 1538 (39.3) | 947 (35.9) | |
| Cardiac or pulmonary disease | 474 (10.9) | 283 (8.2) | 309 (7.9) | 170 (6.5) | <0.001 |

† High-volume hospitals conducted at least 40 colorectal cancer resections for a minimum of 8 years over the study period.

‡ Statistical significance for variation over the four time periods determined using log-likelihood ratio.

**Table 2:** Baselines characteristics patients having resection for rectal cancer by four time periods.

| | 1999/00 – 2002/03 (4) | 2003/04 – 2005/06 (3) | 2006/07 – 2008/09 (3) | 2009/10 – 2010/11 (2) | P-value‡ |
|---|---|---|---|---|---|
| N | 1852 | 1539 | 1806 | 1205 | |
| Age group | | | | | 0.771 |
| ≤50 | 179 (9.7) | 165 (10.7) | 178 (9.9) | 157 (13.0) | |
| 51-75 | 1257 (67.9) | 1043 (67.8) | 1291 (71.5) | 822 (68.2) | |
| ≥76 | 416 (22.5) | 331 (21.5) | 337 (18.7) | 226 (18.8) | |
| Sex | | | | | 0.681 |
| Male | 1197 (64.6) | 971 (63.1) | 1163 (64.4) | 787 (65.3) | |
| Female | 655 (35.4) | 568 (36.9) | 643 (35.6) | 418 (34.7) | |
| ARIA | | | | | 0.348 |
| Major city | 888 (48.0) | 731 (47.5) | 843 (46.7) | 542 (45.0) | |
| Inner regional | 535 (28.9) | 441 (28.7) | 565 (31.3) | 361 (30.0) | |
| Outer regional/remote | 429 (23.2) | 367 (23.9) | 398 (22.0) | 302 (25.1) | |
| SEIFA | | | | | 0.030 |
| 3 (most adv.) | 617 (34.7) | 517 (34.9) | 585 (33.5) | 346 (29.8) | |
| 2 | 612 (34.4) | 503 (34.0) | 565 (32.3) | 409 (35.3) | |
| 1 (least adv.) | 549 (30.9) | 461 (31.1) | 598 (34.2) | 405 (34.9) | |
| Hospital type† | | | | | <0.001 |
| High-volume private | 855 (46.2) | 733 (47.6) | 892 (49.4) | 541 (44.9) | |
| Low-volume private | 198 (10.7) | 106 (6.9) | 123 (6.8) | 119 (9.9) | |
| High-volume public | 636 (34.3) | 587 (38.1) | 691 (38.3) | 485 (40.3) | |
| Low-volume public | 163 (8.8) | 113 (7.3) | 100 (5.5) | 60 (5.0) | |
| Procedure | | | | | 0.018 |
| Restorative proctectomy | 1485 (80.2) | 1253 (81.4) | 1514 (83.8) | 1004 (83.3) | |
| APR | 367 (19.8) | 286 (18.6) | 292 (16.2) | 201 (16.7) | |
| Extent of disease | | | | | 0.031 |
| Local | 1223 (66.0) | 978 (63.6) | 1194 (66.0) | 834 (69.2) | |
| Regional | 438 (23.7) | 372 (24.2) | 413 (22.9) | 267 (22.2) | |
| Distant | 191 (10.3) | 189 (12.3) | 199 (11.0) | 104 (8.6) | |
| Charlson score | | | | | <0.001 |
| 0 | 914 (49.4) | 790 (51.3) | 993 (55.0) | 723 (60.0) | |
| 1 | 206 (11.1) | 132 (8.6) | 144 (8.0) | 76 (6.3) | |
| 2+ | 732 (39.5) | 617 (40.1) | 669 (37.0) | 406 (33.7) | |
| Cardiac or pulmonary disease | 199 (10.8) | 85 (5.5) | 92 (5.1) | 62 (5.2) | <0.001 |

† High-volume hospitals conducted at least 40 colorectal cancer resections for a minimum of 8 years over the study period.

‡ Statistical significance for variation over the four time periods determined using log-likelihood ratio.

**Figure 1:** Laparoscopic resections as a percentage of all elective segmental resections of the colon and resection of the rectum for colorectal cancer, Queensland, 1999/2000 – 2010/2011

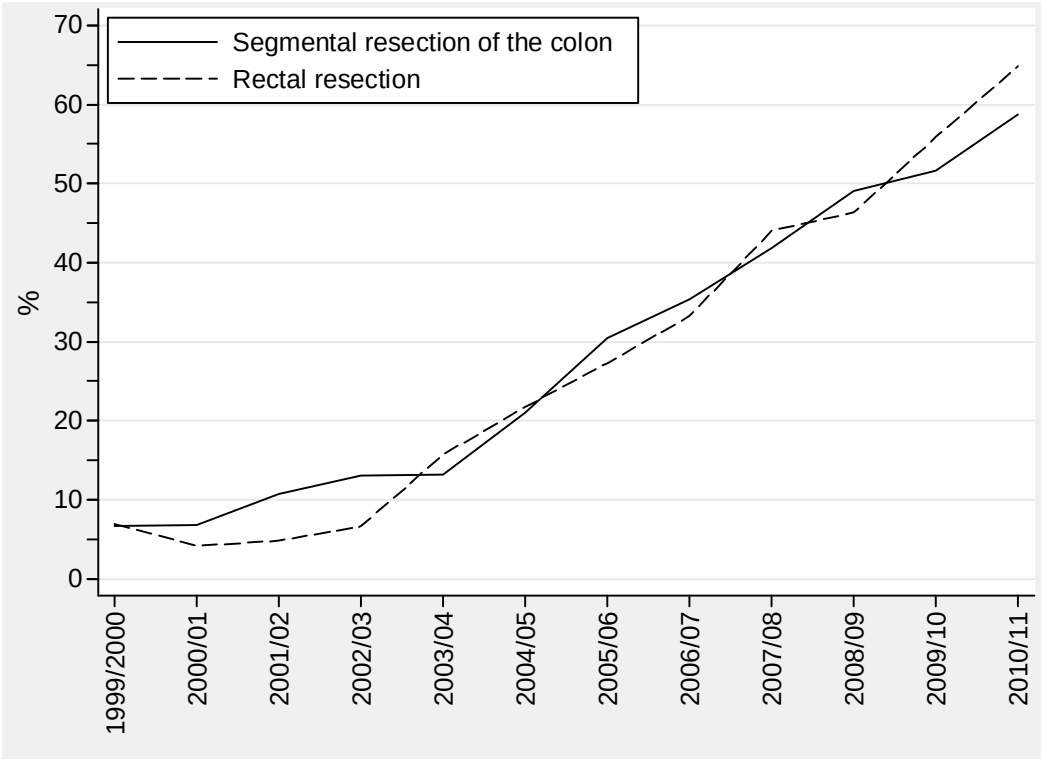

**Figure 2:** Percentage laparoscopic resections by procedure type over four time periods.

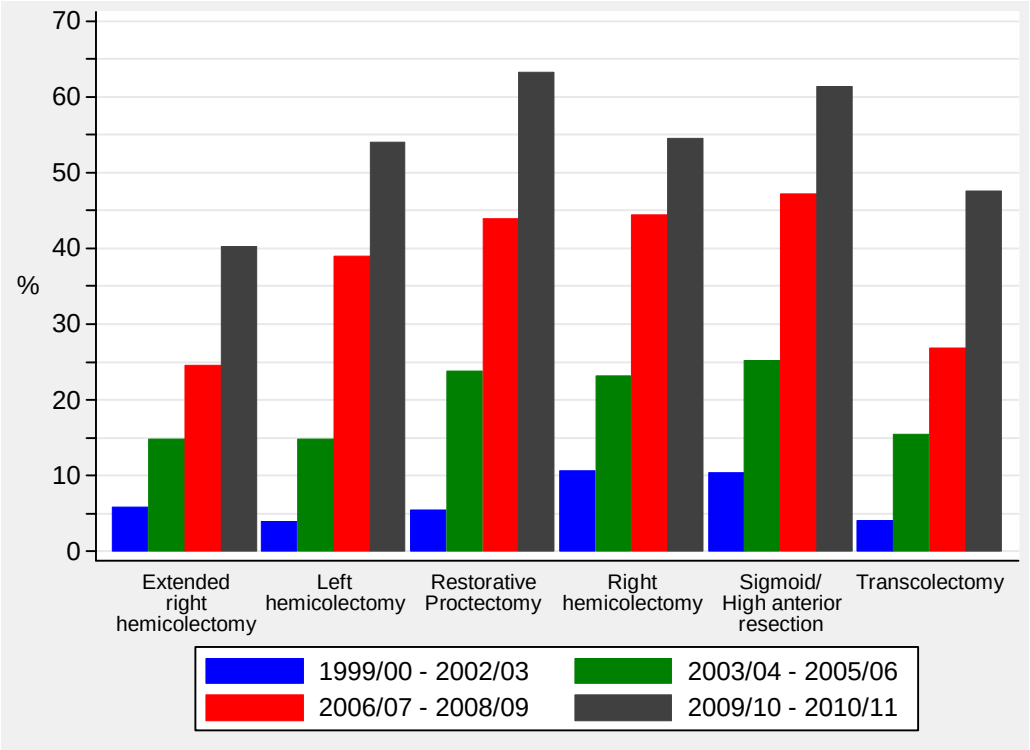

Table 6-1 and Table 6-2 were submitted for publication as online supplementary tables.

Table 6-1 Characteristics of patients having laparoscopic segmental resection for cancer of the colon by four time periods.

| | 1999/00 – 2002/03 (4) | 2003/04 – 2005/06 (3) | 2006/07 – 2008/09 (3) | 2009/10 – 2010/11 (2) | Percentage increase[1] (%) (95%CI) |
|---|---|---|---|---|---|
| N | 4362 | 3435 | 3911 | 2635 | |
| Laparoscopic n (%) | 407 (9.3) | 755 (22.0) | 1651 (42.2) | 1453 (55.1) | 45.8 (43.7, 47.9) |
| Age (median) | 70 (28-91) | 70 (17-94) | 70 (16-97) | 70 (22-102) | |
| Age category | | | | | |
| ≤50 | 29/286 (10.1) | 57/239 (23.9) | 107/256 (41.8) | 118/202 (58.4) | 48.3 (40.6, 55.9) |
| 51-75 | 250/2724 (9.2) | 466/2100 (22.2) | 1022/2354 (43.4) | 854/1517 (56.3) | 47.1 (44.4, 49.8) |
| ≥76 | 128/1352 (9.5) | 232/1096 (21.2) | 522/1301 (40.1) | 481/916 (52.5) | 43.0 (39.5, 46.6) |
| Sex | | | | | |
| Male | 207/2237 (9.3) | 384/1783 (21.5) | 856/2026 (42.3) | 750/1335 (56.2) | 46.9(44.0, 49.8) |
| Female | 200/2125 (9.4) | 371/1652 (22.5) | 795/1885 (42.2) | 703/1300 (54.1) | 44.7 (41.7, 47.6) |
| ARIA[2] | | | | | |
| Major city | 269/2169 (12.4) | 450/1691 (26.6) | 967/1934 (50) | 792/1239 (63.9) | 51.5 (48.5, 54.5) |
| Inner regional | 58/1355(4.3) | 177/1119 (15.8) | 456/1230 (37.1) | 433/863 (50.2) | 45.9 (42.4, 49.4) |
| Outer regional/remote | 83/838 (9.6) | 128/625 (20.5) | 228/747 (30.5) | 228/533 (42.8) | 39.0 (34.5, 43.5) |
| SEIFA[3] | | | | | |
| 3 (most adv.) | 188/1448 (13.0) | 316/1163 (27.2) | 611/1260 (48.5) | 488/764 (63.9) | 50.9 (47.1, 54.7) |
| 2 | 116/1457 (8.0) | 240/1090 (22.0) | 575/1307 (44.0) | 487/929 (52.4) | 44.4 (41.0, 48.0) |
| 1 (least adv.) | 83/1365 (6.1) | 154/1088 (14.2) | 401/1233 (32.5) | 415/439 (48.6) | 42.5 (38.9, 46.1) |
| Hospital type[4] | | | | | |
| High-volume private | 297/1840 (16.1) | 532/1643 (32.4) | 984/1896 (51.9) | 776/1254 (61.9) | 45.7 (42.6, 48.9) |
| Low-volume private | 17/692 (2.5) | 54/398 (13.6) | 180/461 (39.1) | 161/324 (49.7) | 47.2 (41.7, 52.8) |
| High-volume public | 82/1340 (6.1) | 161/1054 (15.3) | 373/1105 (33.8) | 363/748 (48.5) | 42.4 (38.6, 46.2) |
| Low-volume public | 11/490 (2.2) | 8/340 (2.4) | 114/449 (25.4) | 153/309 (49.5) | 47.3 (41.5, 53.0) |
| Procedure | | | | | |
| Right hemicolectomy | 217/2032 (10.7) | 353/1523 (23.2) | 802/1808 (44.4) | 675/1239 (54.5) | 43.8 (40.7, 46.9) |
| Transverse colectomy | 14/340 (4.1) | 25/148 (15.5) | 49/183 (26.8) | 49/103 (47.6) | 43.5 (33.6, 53.3) |
| Extended right hemicolectomy | 5/86 (5.8) | 40/270 (14.8) | 76/309 (24.6) | 81/201 (40.3) | 34.5 (26.0, 42.9) |
| Left hemicolectomy | 17/423 (4.0) | 54/364 (14.8) | 171/439 (39.0) | 164/304 (54.0) | 49.9 (44.0, 55.8) |
| Sigmoid colectomy / high anterior resection of rectum | 154/1481 (10.4) | 285/1130 (25.2) | 553/1172 (47.2) | 484/788 (61.4) | 51.0 (47.3, 54.8) |
| Extent of disease | | | | | |
| Local | 252/2789 (9.0) | 515/2198 (23.4) | 1127/2555 (44.1) | 989/1783 (55.5) | 46.4 (43.9, 49.0) |
| Regional | 99/1038 (9.5) | 160/834 (19.2) | 385/952 (40.4) | 345/605 (57.0) | 47.5 (43.2, 51.8) |
| Distant | 56/535 (10.5) | 80/403 (19.9) | 139/404 (34.4) | 119/247 (48.2) | 37.7 (31.0, 44.5) |
| Charlson score | | | | | |
| 0 | 196/2081 (9.4) | 412/1665 (24.7) | 916/1991 (46.0) | 871/1503 (58.0) | 48.5 (45.7, 51.3) |
| 1 | 39//499 (7.8) | 82/373 (22.0) | 135/382 (35.3) | 77/185 (41.6) | 33.8 (26.3, 41.3) |
| 2+ | 172/1782 (9.7) | 261/1397 (18.7) | 600/1538 (39.0) | 505/947 (53.3) | 43.7 (40.2, 47.1) |
| Cardiac or pulmonary disease | | | | | |
| No | 372/3516 (9.6) | 706/3152 (22.4) | 1543/3602 (42.8) | 1379/2465 (55.9) | 45.4 (43.2, 47.6) |
| Yes | 35/474 (7.4) | 49/283 (17.3) | 108/309 (35.0) | 74/170 (43.5) | 36.1 (28.3, 44.0) |

N.B. Footnotes for Table 6-1 are the same as for Table 6-2

Table 6-2 Characteristics of patients having laparoscopic resection for cancer of the rectum by four time periods.

| | 1999/00 – 2002/03 (4) | 2003/04 – 2005/06 (3) | 2006/07 – 2008/09 (3) | 2009/10 – 2010/11 (2) | Percentage increase[1] (%) (95%CI) |
|---|---|---|---|---|---|
| N | 1852 | 1539 | 1806 | 1205 | |
| Laparoscopic n (%) | 104/1852 (5.6) | 336/1539 (21.8) | 745/1806 (41.3) | 729/1205 (60.5) | 54.9 (51.9, 57.8) |
| Age (median) | 69 (19-91) | 64 (20-96) | 65 (25-93) | 65 (25-91) | |
| Age category | | | | | |
| ≤50 | 8/179 (4.5) | 43/165 (26.1) | 73/178 (41.0) | 94/157 (59.9) | 55.4 (47.2, 63.6) |
| 51-75 | 71/1257 (5.7) | 227/1043 (21.8) | 546/1291 (42.3) | 504/822 (61.3) | 55.7 (52.1, 59.2) |
| ≥76 | 25/416 (6.0) | 66/331 (19.9) | 126/337 (37.4) | 131/226 (58.0) | 52.0 (45.1, 58.8) |
| Sex | | | | | |
| Male | 56/1197 (4.7) | 199/971 (20.5) | 487/1163 (41.9) | 471/787 (59.8) | 55.2 (51.5, 58.8) |
| Female | 48/655 (7.3) | 137/568 (24.1) | 258/643 (40.1) | 258/418 (61.7) | 54.4 (49.3, 59.5) |
| ARIA[2] | | | | | |
| Major city | 60/888 (6.8) | 149/731 (20.4) | 393/843 (46.6) | 342/542 (63.1) | 56.3 (52.0, 60.7) |
| Inner regional | 17/535 (3.2) | 79/441 (17.9) | 199/565 (35.2) | 211/361 (58.4) | 55.3 (50.0, 60.6) |
| Outer regional/remote | 27/429 (6.3) | 108/367 (29.4) | 153/398 (38.4) | 176/302 (58.3) | 52.0 (46.0, 58.0) |
| SEIFA[3] | | | | | |
| 3 (most adv.) | 39/617 (6.3) | 133/517 (25.7) | 276/585 (47.2) | 228/346 (65.9) | 59.6 (54.2, 64.9) |
| 2 | 35/612 (5.7) | 99/503 (19.7) | 214/565 (37.9) | 235/409 (57.5) | 51.7 (46.6, 56.9) |
| 1 (least adv.) | 20/549 (3.6) | 84/463 (18.1) | 224/598 (37.5) | 234/405 (57.8) | 54.1 (49.1, 59.2) |
| Hospital type[4] | | | | | |
| High-volume private | 82/855 (9.6) | 236/733 (32.2) | 474/892 (53.1) | 379/541 (70.1) | 60.4 (56.1, 64.8) |
| Low-volume private | 3/198 (1.5) | 13/106 (12.3) | 32/123 (26.0) | 63/119 (52.9) | 51.4 (42.3, 60.6) |
| High-volume public | 18/636 (2.8) | 86/587 (14.7) | 221/691 (32.0) | 265/485 (54.6) | 51.8 (47.2, 56.4) |
| Low-volume public | 1/163 (0.6) | 1/113 (0.9) | 18/100 (18.0) | 22/60 (36.7) | 36.1 (23.8, 48.3) |
| Procedure | | | | | |
| Restorative proctectomy | 82/1485 (5.5) | 298/1253 (23.8) | 665/1514 (43.9) | 635/1004 (63.2) | 57.7 (54.5, 60.9) |
| Abdomino-perineal resection | 22/367 (6.0) | 38/286 (13.3) | 80/292 (27.4) | 94/201 (46.8) | 40.8 (33.5, 48.1) |
| Extent of disease | | | | | |
| Local | 70/1223 (5.7) | 218/978 (22.3) | 494/1194 (41.4) | 508/834 (60.9) | 55.2 (51.6, 58.7) |
| Regional | 21/438 (4.8) | 73/372 (19.6) | 185/413 (44.8) | 172/267 (64.4) | 59.6 (53.5, 65.7) |
| Distant | 13/191 (6.8) | 45/189 (23.8) | 66/199 (33.2) | 49/104 (47.1) | 40.3 (30.1, 50.5) |
| Charlson score | | | | | |
| 0 | 48/914 (5.3) | 182/790 (23.0) | 421/993 (42.4) | 450/723 (62.2) | 57.0 (53.2, 60.8) |
| 1 | 14/206 (6.8) | 26/132 (19.7) | 52/144 (36.1) | 39/76 (51.3) | 44.5 (32.8, 56.3) |
| 2+ | 42/732 (5.7) | 128/617 (20.8) | 272/669 (40.7) | 240/406 (59.1) | 53.4 (48.3, 58.4) |
| Cardiac or pulmonary disease | | | | | |
| No | 91/1653 (5.5) | 317/1454 (21.8) | 715/1714 (41.7) | 696/1143 (60.9) | 55.4 (52.4, 58.4) |
| Yes | 13/199 (6.5) | 19/85 (22.4) | 30/92 (32.6) | 33/62 (53.2) | 46.7 (33.8, 59.6) |

[1] Percentage increase is the difference between the first time period (1999/00 – 2002/03) and the last time period (2009/10 – 2010/11)

[2] Accessibility/Remoteness Index Australia(91)

[3] Socio-Economic Indexes for Areas(92)

[4] High-volume hospitals conducted at least 40 CRC resections for a minimum of 8 years over the study period.

## 6.2 Discussion and implications of findings

The findings from this study indicate that the ability to access surgeons with adequate skills and experience such as those in private hospitals and high-volume public hospitals, are stronger determinants of laparoscopic resection for CRC than characteristics of the cancer (site and stage) and patient characteristics (comorbidities and age). The total numbers of resections for rectal cancer in the low-volume public hospitals are small, indicating that these patients are probably referred to the more experienced surgeons in the high-volume public hospitals. These results suggest that in Queensland, the more complex cases are referred to surgeons with experience appropriate for the complexity of the presenting clinical circumstances and condition.

**Conclusion**

The objective of this study was to understand the types of patients and procedures performed in a large sample of patients who underwent surgery for CRC. This study is the first to describe which procedures and patients are being selected for laparoscopic resection for CRC. The results indicate that over time there has been equitable access to Queensland patients with CRC regardless of the complexity of the procedure and the clinical presentation of the patient. This is an important finding because it suggests that, since 1999/2000, there were strong referral pathways in Queensland whereby the more complex cases being treated by the most experienced surgeons; which, in turn, has ensured equitable access to laparoscopic resection. These findings are now extended in Chapter 7, which the economic cost implication of laparoscopic resection for CRC in Queensland will be discussed.

# Chapter 7 In-hospital costs of laparoscopic resection compared with open resection for colorectal cancer

## 7.1 Introduction

This chapter reports on the cost of the index admission for laparoscopic compared with open resection for CRC. Hospital costing data were sourced for all public hospital admissions in Queensland for which the primary procedure was a resection of the colon or rectum for CRC. Data were sourced for the period between June 2009 and June 2011 when more than half of resections for patients with CRC were laparoscopic. Differences in costs, length of stay, duration of surgery and duration of intensive care units (ICU) admission were determined using multivariable least-squares regression to adjust for potential confounding.

Each of the authors contributed to this study and the resulting manuscript as follows. Each author, including Michael Coory, John Lumley, Louisa Gordon and I were responsible for the conception and design of the study. I was responsible for the data acquisition, analysis and interpretation of the results. Michael Coory and Louisa Gordon provided guidance on the data analysis and interpretation of the results. Michael Coory, John Lumley and Louisa Gordon provided guidance and feedback on the first and subsequent drafts of the manuscript, while I was the primary author.

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# Cost savings for elective laparoscopic resection compared with open resection for colorectal cancer in a region of high uptake

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**Abstract**
*Background* Previous cost analyses of laparoscopic resection for colorectal cancer (CRC) reported slightly higher or similar costs to those of open resection. These analyses were based on randomised controlled trials when the laparoscopic approach was newly adopted. This study compared costs for laparoscopic versus open resection in a region of high uptake where adoption is mature.
*Methods* Hospital cost data were obtained for elective resections for CRC that occurred between June 2009 and June 2011 in public hospitals in Queensland, Australia. The primary outcome was total cost and secondary outcomes were length-of-stay, operating time, and ICU admission. Multivariate least-squares regression was used to adjust for potential confounders: age, sex, comorbidities, procedure, and hospital volume.
*Results* The crude mean cost for laparoscopic resection was €20,036 compared with that for open resection of €22,780 (difference = €2,744). Patients who underwent laparoscopic resection (744/1,397; 53 %) were slightly younger and had fewer comorbidities (decreasing costs) but more had rectal surgery (increasing costs). The adjusted mean cost for laparoscopic resection was €20,396 compared with €22,442 for open resection (difference = €2,054). Compared with open resection, when adjusted for potential confounders, laparoscopic resection resulted in similar operating time (216 vs. 214 min), shorter length-of-stay (difference = −1.1 days, 95 % CI −1.9, −0.3), and shorter admission to ICU (difference = −7.3 h, 95 % CI −11.9, −2.7).
*Conclusions* This non-randomised study in a region of high uptake found a similar operating time and lower cost for laparoscopic resection for CRC compared with those of open resection due to a shorter length-of-stay and shorter time in ICU. Laparoscopic resection for CRC saves money when the procedure is widely adopted and surgeons are experienced in the technique.

**Keywords** Colorectal cancer · Laparoscopic resection · Cost comparison · Population-based data

High-quality evidence from randomised controlled trials (RCTs) shows that when compared with open resection, laparoscopic resection for colorectal cancer (CRC) results in less intraoperative blood loss, less postoperative pain, faster return of bowel function, shorter length-of-stay [1, 2], and lower risk of thromboembolism [2]. Clinical effectiveness is essential for the adoption of new technology in healthcare; however, healthcare administrators must consider the economic value of new technologies. Published analyses have reported that the cost of laparoscopic resection for CRC is similar or slightly greater than the costs for open resection [3–7]. While fewer complications and shorter length of hospital stay result in reduced costs, previous studies have

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reported increased costs associated with the specialised equipment required for laparoscopic resection and increased costs associated with longer operating times [8]. For example, the Australasian Laparoscopic Colon Cancer Study (ALCCaS) reported an increased cost of disposable equipment in the operating theatre of $AUD274 [7]. Similar additional costs have been reported in the US [9] and UK [4]. Franks et al. [4] reported longer operating times for laparoscopic resections of CRC leading to increased costs for theatre staff of £114 per operation in the UK.

Cost analyses of laparoscopic resection for CRC, to date, were based predominantly on RCTs performed when the procedures were in the early stage of adoption of laparoscopic resection for CRC. As the level of experience, patient selection, techniques, and equipment for surgical procedures change over time, so too do the associated costs. For example, patients excluded from the RCTs in the early 1990s are now routinely considered for laparoscopic resection, specifically for resection of rectal cancer which is known to be more expensive than that for colon cancer [10]. Also, with experience, the operating time for laparoscopic resection can be similar to that for open resection [11]. It is therefore possible that as uptake of laparoscopic resection moves from the innovators to the early adopters and on to an early/late majority [12], the increased cost associated with the longer operating time for laparoscopic resection of CRC will decrease and may even result in cost savings compared with open resection.

Queensland is the third largest state of Australia with a population of 4.6 million. Surgeons in Queensland adopted laparoscopic resection for CRC early [13], and adoption has been faster than in any other state in Australia [14] and faster than in most other places around the world [15–17]. Training courses in laparoscopic resection of the colon and rectum were conducted by a group of colorectal surgeons in Queensland during the early 2000s, providing experience in this technique to surgeons in the early period of adoption. Currently, more than 50 % of resections for CRC in public hospitals in Queensland are laparoscopic. This study includes all CRC patients admitted to public hospitals for an elective resection of the colon or rectum and provides a "real world" cost assessment done on unselected patients. The specific research question is: What are the differences in total and component (e.g., theatre, ICU) costs for laparoscopic versus open resection for CRC in a region with high uptake?

## Methods

### Data

This study was based on data drawn from the statewide Transition II Clinical Costing database with standardised feeder systems and processing. The database's main role is to support activity-based funding and it is also regularly used by researchers to undertake cost studies [18]. It is a comprehensive collation of cost information associated with the provision of services to individual patients treated in public hospitals, including resource utilisation in the operating theatre such as anaesthetics, pharmacy, pathology, clinical imaging, and other allied health resources, as well as general resources associated with hospital admission and stay on the hospital ward and associated with hospital administration. It does not include costs associated with surgical training outside of the operating theatre.

Transition II collects information for public hospitals, where patients receive treatment without any out-of-pocket costs. Resections performed in private hospitals, where the cost of treatment is covered by a combination of government subsidy, private health insurance, and patient payments, were excluded. About 60 % of CRC patients in Queensland are treated in private hospitals; this paper focuses on the 40 % treated in public hospitals.

Total cost of the index admission for resection was obtained from Transition II for 1,273 of the 1,391 patients treated for CRC in public hospitals (92 %). Component costs of interest included theatre, anaesthetics, pharmacy, clinical imaging, and pathology; these costs were obtained for 1,315 of the 1,391 patients (95 %).

Patient level cost data in Transition II is a collation of costs specific to the care of an individual patient, average cost of resources associated with admission, and standard daily costs. For instance, the cost of the staff in the operating theatre for an individual patient is calculated as [cost allocated for each clinician (surgeons and nurses) multiplied by the number of minutes spent in the operating theatre]. The costs specific to the care of a patient also includes the costs associated with anaesthesia and disposable surgical equipment (single use such as the harmonic scalpel). The cost of clinical consumables is based on the average cost specific to the surgical procedure. Costs associated with stays in the hospital ward are set at a per diem or per shift rate and include the cost for items such as laundry and meals. Admissions to the ICU are allocated at a standard cost per minute per patient.

The de-identified, unit-record data from Transition II was for the period from June 2009 to June 2011. Data extraction was limited to patients with CRC who had an elective surgical resection. Patients who had undergone an emergency resection (e.g., for bowel obstruction, bleeding, or perforation secondary to CRC) or a Hartmann procedure were excluded because these are not routinely considered for the laparoscopic approach.

### Statistical analysis

Costs are presented in €2012 after inflating Australian dollars to 2012 using the Australian consumer price index [19] and converting to euros [20] (AUD1 = €0.81354).

**Table 1** Patient characteristics ($N = 1,391$)

| | Open ($N = 647$) | Laparoscopic ($N = 744$) | Difference % (95 % CI) |
|---|---|---|---|
| Age group | | | |
| <65 | 236 (36.5) | 282 (37.9) | 1.4 (−3.7, 6.5) |
| 65–74 | 205 (31.7) | 261 (35.1) | 3.4 (−1.6, 8.4) |
| 75+ | 206 (31.8) | 201 (27.0) | −4.8 (−9.6, 0.1) |
| Hospital volume | | | |
| High | 455 (70.3) | 576 (77.4) | 7.1 (2.5, 11.7) |
| Sex | | | |
| Male | 370 (57.2) | 425 (57.1) | 0.1 (−5.3, 5.2) |
| Dukes stage | | | |
| A/B | 438 (67.7) | 504 (67.7) | 0.0 (−4.9, 5.0) |
| C | 133 (20.6) | 169 (22.7) | 2.2 (−2.2, 6.5) |
| D | 76 (11.8) | 71 (9.5) | −2.2 (−5.5, 1.0) |
| Charlson Index | | | |
| 0 | 516 (79.8) | 645 (86.7) | 6.9 (3.0, 10.9) |
| 1 | 70 (10.8) | 54 (7.3) | −3.6 (−6.6, −0.5) |
| 2+ | 61 (9.4) | 45 (6.1) | −3.2 (−6.1, −0.4) |
| Procedure group | | | |
| Colon | | | |
| Right hemicolectomy | 205 (31.7) | 201 (27.0) | −4.7 (−9.5, 0.1) |
| Transcolectomy | 18 (2.8) | 10 (1.3) | −1.4 (−3.0, 0.1) |
| Extended right hemicolectomy/ total colectomy | 52 (8.0) | 60 (8.1) | 0.1 (−2.8, 2.9) |
| Left hemicolectomy | 59 (9.1) | 56 (7.5) | −1.6 (−4.5, 1.3) |
| Sigmoidectomy | 52 (8.0) | 30 (4.0) | −4.0 (−6.5, -1.5) |
| High anterior resection | 42 (6.5) | 101 (13.6) | 7.1 (4.0, 10.2) |
| Rectal | | | |
| Abdominoperineal resection | 56 (8.7) | 47 (6.3) | −2.3 (−5.1, 0.4) |
| Anterior resection of the rectum | 158 (24.4) | 233 (31.3) | 6.9 (2.2, 11.6) |
| Ultralow anterior resection | 5 (0.8) | 6 (0.8) | 0.0 (−0.9, 1.0) |

Values are *n* (%)

Hospitals were categorised as high volume if they performed at least 80 resections for CRC over the 2-year study period. Procedures were grouped according to their relative technical difficulty (see Tables 1 and 2). The intention-to-treat principle was applied throughout the analyses.

The *t* test was used to compare the unadjusted mean cost of laparoscopic resection with that of open resection, and multivariate, ordinary-least-squares regression analysis was used to compare the adjusted mean cost after accounting for differences in age, sex, Dukes stage, Charlson comorbidity index (excluding diagnosis codes for CRC and metastatic cancer), hospital volume (high/low), and type of procedure (e.g., right hemicolectomy, anterior resection). The robust variance method of Huber and White was used to account for any heteroscedasticity [21].

Cost data are known to be right-skewed (i.e., a few patients have very high costs) [22]. For a small sample size, right-skewed data can invalidate statistical inferences based on multivariate, ordinary-least-squares regression. However, for the large sample available for this study, simulation studies have shown that statistical inferences based on multivariate ordinary-least-squares regression are valid [22]. Also, mean costs are preferred by service planners and budget holders [22]. Nevertheless, to confirm the robustness of our conclusions, we also provide adjusted median costs using absolute residuals regression [23]. Marginal analysis was used to determine the adjusted means from the ordinary-least-squares regression model. All analyses were performed using STATA ver. 11 (StataCorp, College Station, TX, USA).

Ethical approval for this study was granted by the Queensland Health Human Research Ethics Committee and the University of Queensland School of Population Health Human Research Ethics Committee.

## Results

Over the 2 years of the study, 1,391 patients had elective resection for CRC in 18 public hospitals. Eight hospitals were high volume (>80 major resections during the 2 years) and accounted for 1,031 (74 %) of the resections. The mean age of the patients was 67 years, 800/1,397 (57 %) were men, and 670/1,391 (48 %) had rectal surgery.

Slightly more than half of the patients (744/1,391; 53 %) had a laparoscopic resection, which was more common in younger patients with no comorbidities and those who were treated in high-volume hospitals (Table 1). Laparoscopic resection was performed more often for anterior (and high anterior) resections of the rectum (Table 1), reflecting the centralisation of rectal surgery to high-volume hospitals. Open surgery was more common for resections of the sigmoid, transverse, and right colon (Table 1).

Of the 1,391 patients, 17 (1.2 %) died while in hospital for resection (open: 13 deaths; laparoscopic: 4 deaths). Exclusion of the deaths did not affect the cost results; all cost analyses include the costs for those who died.

The unadjusted mean cost was €20,036 for laparoscopic resection and €22,780 for open resection (difference = €2,744). The unadjusted median cost was €17,008 for laparoscopic resection and €18,094 for open resection (difference = €1,086).

**Table 2** In-hospital resource utilization surgery access/type, patient characteristics, and hospital volume

| | Total cost (€2,012) ($N = 1,273$) | Length-of-stay (days) ($N = 1,391$) | Operating time (min) ($N = 1,040$) | Time in ICU (h) ($N = 1,391$) |
|---|---|---|---|---|
| Surgical access | $P = 0.010$ | $P = 0.008$ | $P = 0.687$ | $P = 0.002$ |
| Open | Reference | Reference | Reference | Reference |
| Laparoscopic | −2,054 (−3,609, −498) | −1.1 (−1.9, −0.3) | 2.6 (−10.2, 15.5) | −7.3 (−11.9, −2.7) |
| Age group | $P = 0.203$ | $P < 0.001$ | $P = 0.375$ | $P = 0.909$ |
| <65 | Reference | Reference | Reference | Reference |
| 65−74 | 1,467 (−780, 3,715) | 1.2 (0.4, 2.1) | −1.1 (−14.2, 12.0) | 3.1 (−3.2, 9.5) |
| 75+ | 1,748 (−647, 4,143) | 3.0 (2.0, 4.1) | −0.6 (−16.4, 15.2) | 0.6 (−6.0, 7.2) |
| Sex | $P = 0.066$ | $P = 0.022$ | $P = 0.008$ | $P = 0.369$ |
| Female | Reference | Reference | Reference | Reference |
| Male | 1,385 (−94, 2,863) | 0.9 (0.1, 1.6) | 17.4 (4.5, 30.2) | 2.0 (−2.4, 6.5) |
| Dukes stage | $P = 0.180$ | $P = 0.037$ | $P = 0.509$ | $P = 0.984$ |
| A/B | Reference | Reference | Reference | Reference |
| C | −241 (−1,803, 1,321) | 0.6 (−0.3, 1.6) | −3.0 (−15.3, 9.4) | −5.2 (−9.2, −1.2) |
| D | 2,513 (−449, 5,475) | 1.1 (−0.3, 2.5) | 15.8 (−10.1, 41.8) | 3.9 (−4.4, 12.3) |
| Charlson comorbidity index | $P < 0.001$ | $P < 0.001$ | $P = 0.070$ | $P < 0.001$ |
| 0 | Reference | Reference | Reference | Reference |
| 1 | 5,902 (2,629, 9,175) | 2.6 (1.0, 4.2) | 6.6 (−16.0, 29.3) | 13.3 (1.3, 25.3) |
| 2+ | 16,404 (9,576, 23,232) | 7.4 (4.8, 10.0) | 31.8 (−0.9, 64.6) | 42.1 (21.6, 62.6) |
| Procedure type | $P < 0.001$ | $P < 0.001$ | $P < 0.001$ | $P = 0.315$ |
| Right hemicolectomy | Reference | Reference | Reference | Reference |
| Transcolectomy | 3,788 (−854, 8,429) | −0.2 (−1.8, 1.4) | 84.0 (17.0, 151.1) | 1.6 (−16.1, 19.3) |
| Sigmoidectomy | 2,001 (−2,214, 6,216) | 0.6 (−0.7, 1.8) | 35.0 (5.2, 64.9) | 2.3 (−11.3, 15.9) |
| Extended right hemicolectomy/total colectomy | 1,914 (−337, 4,166) | 1.5 (0.1, 2.8) | 16.5 (−10.2, 43.2) | −4.3 (−10.5, 1.9) |
| Left hemicolectomy | 3,997 (−1,012, 9,007) | 0.7 (−0.8, 2.3) | 25.6 (7.5, 43.7) | 6.3 (−7.6, 20.1) |
| High anterior resection | 2,437 (181, 4,693) | −0.2 (−1.2, 0.7) | 44.0 (22.7, 65.2) | 2.5 (−5.3, 10.2) |
| Abdominoperineal resection | 10,543 (7,347, 13,740) | 6.8 (5.0, 8.6) | 69.9 (43.7, 96.0) | 6.6 (−2.4, 15.6) |
| Anterior resection | 6,908 (4,772, 9,043) | 3.2 (2.0, 4.4) | 76.1 (59.6, 92.6) | 1.4 (−5.0, 7.7) |
| Ultralow anterior resection | 5,908 (473, 11,343) | 2.5 (−1.4, 6.5) | 82.8 (29.5, 136.1) | −9.2 (−20.5, 2.1) |
| Hospital volume | $P = 0.041$ | $P = 0.014$ | $P = 0.112$ | $P < 0.001$ |
| Low | Reference | Reference | Reference | Reference |
| High | −2,124 (−4,158, −91) | −1.1 (−1.9, −0.2) | −15.3 (−34.1, 3.6) | −14.0 (−20.6, −7.4) |

The association between each variable and the outcome of interest was controlled for all other variables included in this table

Factors influencing total cost, length of hospital stay, surgery duration, and time spent in the ICU are listed in Table 2. Older patients, those with comorbidities, those with metastases, and those who had rectal surgery incurred greater costs. Patients treated in high-volume hospitals incurred lower costs. Increased costs for the rectal procedures (abdominoperineal resection, anterior resection, and ultralow anterior resection) coincide with increased length-of-stay and operating time (Table 2).

After accounting for any differences in age, sex, comorbidities, stage, type of procedure, and hospital volume, the adjusted mean cost for laparoscopic resection was €20,369 compared with €22,442 for open resection (difference = €2,053) (Table 3). The adjusted median cost was €808 (95 % CI €33, €1,584) less for laparoscopic resection.

Most of the difference in cost (mean or median) was accounted for by a shorter length-of-stay and fewer and shorter ICU admissions. Including length-of-stay in the adjusted model decreased the mean difference in cost to €314 (95 % CI −€1,215, €587), while including admission to ICU reduced the mean difference in cost to €841 (95 % CI −€2,290, €608).

To further check the robustness of the finding that laparoscopic surgery is associated with substantially lower costs

**Table 3** Adjusted cost components (€2,012), length-of-stay, duration of surgery and anaesthesia, and admission to ICU

| | Open [mean (95 % CI)] | Laparoscopic [mean (95 % CI)] | Difference (95 % CI) | *P* value |
|---|---|---|---|---|
| Total cost (€2,012) | 22,442 (21,125, 23,719) | 2,368 (19,451, 21,286) | −2,054 (−3,609, −498) | 0.010 |
| Anaesthesia cost (€2,012) | 2,155 (2,028, 2,273) | 2,424 (2,323, 2,525) | 268 (112, 424) | 0.001 |
| Imaging cost (€2,012) | 134 (108, 161) | 168 (130, 208) | 34 (−15, 83) | 0.174 |
| Pathology cost (€2,012) | 818 (768, 867) | 789 (748, 830) | −29 (−94, 37) | 0.389 |
| Pharmacy cost (€2,012) | 229 (164, 295) | 154 (122, 187) | −75 (−152, 2) | 0.058 |
| Theatre cost (€2,012) | 5,584 (5,386, 5,783) | 5,28 (5,445, 5,810) | 43 (−231, 318) | 0.757 |
| Length-of-stay (days) | 10.3 (9.7, 11.0) | 9.2 (8.7, 9.7) | −1.1 (−1.9, −0.3) | 0.008 |
| Operating time (min) | 214 (204, 224) | 216 (209, 224) | 2.6 (−10.2, 15.5) | 0.687 |
| Anaesthesia duration (min) | 261 (251, 272) | 260 (252, 269) | −0.6 (−14.4, 13.3) | 0.937 |
| ICU admission (h) | 14.7 (10.8, 18.7) | 7.4 (4.8, 10.0) | −7.3 (−11.9, −2.7) | 0.002 |

Adjusted for age, sex, stage, Charlson Comorbidity Index, type of procedure, and hospital volume

than open surgery, we conducted an analysis on a homogeneous subgroup, similar to patients recruited to RCTs for laparoscopic surgery (<80 years of age, no metastasis, no preplanned ICU admission, no chronic pulmonary disease, and no pre-existing heart failure). After adjusting for age, sex, stage, comorbidities, type of surgery, and hospital volume within this subgroup, the results were similar to those for the entire study population. Specifically, the adjusted mean cost was €18,917 for laparoscopic resection and €20,986 for open resection (difference = €2 068; 95 % CI €379, €3,758). Similarly, a separate analysis restricted to high-volume hospitals found that the difference in adjusted mean cost was €2,107 (95 % CI €458, €3,756).

ICU admission (224 patients) was more frequent for open versus laparoscopic resection patients (22.6 % vs. 10.5 %, $P < 0.001$). Preplanned ICU admissions were more common among patients who had open resection (70/647; 10.8 %) than those who had laparoscopic resection (43/744; 5.8 %). Patients who had a prebooked ICU admission were older and more likely to have had comorbidities; these factors, along with procedure type and hospital volume, were included in the multivariate analysis, i.e., the analysis adjusted for these differences. To further assess the possible effect of prebooked ICU admissions, we conducted analyses excluding these patients. The adjusted mean costs decreased to €19,754 for laparoscopic resection and €21,350 for open resection (difference = €1,595; 95 % CI €18, €3,173), and the difference in time in ICU decreased to −5.4 h (from −7.3 h; Table 2). In short, the results were robust to the effect of preplanned ICU admissions.

## Discussion

This study of a region where uptake of laparoscopic resection for CRC is mature found that it is significantly less expensive than open resection for CRC. This coincides with laparoscopic patients having a shorter length of hospital stay, fewer and shorter admissions to the ICU, and equivalent operating time compared with open resection patients.

In 2006, the National Institute of Health and Clinical Excellence (NICE) in the UK found that laparoscopic surgery for CRC was slightly more expensive (£265) compared with open resection [24]. Franks et al. [4] reported similar results based on patients recruited into the MRC CLASICC trial (UK) between 1996 and 2002. However, the mean cost (inflated to 2013 from 1999) [25] reported by NICE was about half that found in our study; €10,833 (£9,186) for the laparoscopic group compared with €10,415 (£8,829) for the open group [24]. Similarly, Norwood et al. [7], who compared costs using a cohort from the ALCCaS RCT, reported total costs of admission that were less than half that found in this study [7]. As their results were based on patients recruited into RCTs, the cost comparisons by NICE and Norwood et al. [7] exclude patients who needed more complex care and thus have the associated higher costs.

The ALCCaS RCT reports an operating time for laparoscopic resection 60 min longer than that for open resection, resulting in statistically significant increased costs for the operating surgeon, anaesthetist, and operating room staff [7]. In our study, there was no difference in the operating times of the two approaches, indicating that the difference in theatre costs was due to equipment use rather than time-dependent resources such as staffing. The ALCCaS RCT reported an increased cost in disposable surgical equipment used in the operating theatre of €215 ($AUD274) for the laparoscopic group [7], which is slightly more than the unadjusted mean increase in theatre cost of €120 found in the current study. This slightly lower cost associated with disposable surgical equipment is due probably in part to the more experienced surgeons who

have developed efficient techniques including a reduction in the use of staples.

Like all observational (nonrandomised) studies, the present study could be subject to confounding, i.e., the lower cost for laparoscopic versus open surgery could be due to differences in the types of patients rather than the laparoscopic approach, per se. Laparoscopic patients were slightly less likely to have some characteristics that tend to increase costs, e.g., age $> 75$ years, metastases, comorbidities, and treatment in a low-volume hospital. On the other hand, they were more likely to have a rectal procedure, which tends to increase cost. The results of our study were adjusted for these potential confounders. This is also the case for factors that may have contributed to preplanned admission to ICU (i.e., age and comorbidities). In addition, we defined a more homogeneous subgroup (<80 years of age, no metastasis, no preplanned ICU admission, no chronic pulmonary disease, no pre-existing heart failure) and still found a difference in cost of about €2,000. Also, a separate analysis of just high-volume hospitals similarly found that the adjusted mean total cost was about €2,100 lower for laparoscopic resection than for open resection.

In conclusion, the results of this study are different from those of earlier studies, which have reported similar or slightly higher costs for laparoscopic versus open resection for CRC. Laparoscopic resection has a lower cost than open resection probably because Queensland is further along the adoption curve of laparoscopic resection and the majority of surgeons are very experienced with the procedure. For instance, previous studies have reported longer operating times for laparoscopic resection [8], while this study found no difference in operating time, even after adjusting for potential confounders such as procedure type and comorbidities.

The findings of this study indicate that in regions where the procedure is widely adopted and surgical teams are experienced in the technique, there will be cost savings associated with laparoscopic resection for colorectal cancer because of fewer admissions to ICU and decreases in operating time and length-of-stay. Specific inferences regarding the degree of cost benefit in other settings will depend on the relative cost of these determinants. For instance, it may be inferred that healthcare systems where hospital bed days are more expensive than in this study will see a greater cost benefit.

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The findings below are included to provide further detail about tests performed for multivariable analysis. These were not included in the publication.

No statistically significant 2-way interactions were found between hospital volume and the other explanatory or predictor variables, as outlined in Table 7-1. Because there were no statistically significant 2-way interactions, 3-way interactions were not considered.

Table 7-1 Outcomes of testing for interaction terms in the final models

| Dependent variable | Interaction term | P-value for interaction term |
|---|---|---|
| Total cost | Procedure*Hospital volume | 0.186 |
| | Charlson comorbidity score*Hospital volume | 0.465 |
| | Age group*Hospital volume | 0.824 |
| Length of stay | Procedure*Hospital volume | 0.168 |
| | Charlson comorbidity score*Hospital volume | 0.984 |
| | Age group*Hospital volume | 0.777 |
| Duration of surgery | Procedure*Hospital volume | 0.200 |
| | Charlson comorbidity score*Hospital volume | 0.950 |
| | Age group*Hospital volume | 0.117 |
| Duration in ICU | Procedure*Hospital volume | 0.133 |
| | Charlson comorbidity score*Hospital volume | 0.179 |
| | Age group*Hospital volume | 0.901 |

* All explanatory variables included in the models as follows: age group, sex, stage, Charlson comorbidity score, type of procedure and hospital volume.

The tables of results in the published manuscript include reported costs converted to Euro (€). The tables below present the same results in Australian dollars (AU).

Table 7-2 In-hospital resource utilisation surgery access/type, patient characteristics and hospitals volume

| | Total cost (AU$2012)<br><br>*N* = 1 273 | Length of stay (days)<br><br>*N* = 1 391 | Surgery duration (mins)<br><br>*N* = 1 040 | ICU duration (hours)<br>*N* = 1 391 |
|---|---|---|---|---|
| Surgical access | *P* = 0.010 | *P* = 0.008 | *P* = 0.687 | *P* = 0.002 |
| Open | Reference | Reference | Reference | Reference |
| Laparoscopic | -2 524 (-4 436, -613) | -1.1 (-1.9, -0.3) | 2.6 (-10.2, 15.5) | -7.3 (-11.9, -2.7) |
| Age group | *P* = 0.203 | *P* <0.001 | *P* =0.375 | *P* =0.909 |
| <65 | Reference | Reference | Reference | Reference |
| 65-74 | 1 804 (-959, 4 566) | 1.2 (0.4, 2.1) | -1.1 (-14.2, 12.0) | 3.1 (-3.2, 9.5) |
| 75+ | 2 148 (-795, 5 093) | 3.0 (2.0, 4.1) | -0.6 (-16.4, 15.2) | 0.6 (-6.0, 7.2) |
| Sex | *P* = 0.041 | *P* = 0.022 | *P* = 0.008 | *P* = 0.369 |
| Female | Reference | Reference | Reference | Reference |
| Male | 1 702 (-115, 3 519) | 0.9 (0.1, 1.6) | 17.4 (4.5, 30.2) | 2.0 (-2.4, 6.5) |
| Dukes Stage | *P* = 0.180 | *P* = 0.037 | *P* = 0.509 | *P* =0.984 |
| A/B | Reference | Reference | Reference | Reference |
| C | -297 (-2 217, 1 623) | 0.6 (-0.3, 1.6) | -3.0 (-15.3, 9.4) | -5.2 (-9.2, -1.2) |
| D | 3 089 (-552, 6 729) | 1.1 (-0.3, 2.5) | 15.8 (-10.1, 41.8) | 3.9 (-4.4, 12.3) |
| Charlson co-morbidity index | *P* <0.001 | *P* <0.001 | *P* = 0.070 | *P* <0.001 |
| 0 | Reference | Reference | Reference | Reference |
| 1 | 7255 (3 232, 11 278) | 2.6 (1.0, 4.2) | 6.6 (-16.0, 29.3) | 13.3 (1.3, 25.3) |
| 2+ | 20 164 (11 771, 28 557) | 7.4 (4.8, 10.0) | 31.8 (-0.9, 64.6) | 42.1 (21.6, 62.6) |

| | Total cost (AU$2012)<br><br>*N* = 1 273 | Length of stay (days)<br><br>*N* = 1 391 | Surgery duration (mins)<br><br>*N* = 1 040 | ICU duration (hours)<br>*N* = 1 391 |
|---|---|---|---|---|
| Procedure type | *P* <0.001 | *P* <0.001 | *P* <0.001 | *P* = 0.315 |
| Right hemicolectomy | Reference | Reference | Reference | Reference |
| Transcolectomy | 4 656 (-1 050, 10 361) | -0.2 (-1.8, 1.4) | 84.0 (17.0, 151.1) | 1.6 (-16.1, 19.3) |
| Sigmoidectomy | 2 460 (-2 721, 7 641) | 0.6 (-0.7, 1.8) | 35.0 (5.2, 64.9) | 2.3 (-11.3, 15.9) |
| Extended right hemicolectomy/ total colectomy | 2 353 (-414, 5 120) | 1.5 (0.1, 2.8) | 16.5 (-10.2, 43.2) | -4.3 (-10.5, 1.9) |
| Left hemicolectomy | 4 194 (-1 245, 11 072) | 0.7 (-0.8, 2.3) | 25.6 (7.5, 43.7) | 6.3 (-7.6, 20.1) |
| High anterior resection | 2 995 (223, 5 768) | -0.2 (-1.2, 0.7) | 44.0 (22.7, 65.2) | 2.5 (-5.3, 10.2) |
| Abdomino-perineal resection | 12 960 (9 031, 16 889) | 6.8 (5.0, 8.6) | 69.9 (43.7, 96.0) | 6.6 (-2.4, 15.6) |
| Anterior resection | 8 491 (5 866, 11 116) | 3.2 (2.0, 4.4) | 76.1 (59.6, 92.6) | 1.4 (-5.0, 7.7) |
| Ultra low anterior resection | 7 262 (581, 13 943) | 2.5 (-1.4, 6.5) | 82.8 (29.5, 136.1) | -9.2 (-20.5, 2.1) |
| Hospital volume | *P* = 0.041 | *P* = 0.014 | *P* = 0.112 | *P* <0.001 |
| Low | Reference | Reference | Reference | Reference |
| High | -2 611 (-5 110, -112) | -1.1 (-1.9, -0.2) | -15.3 (-34.1, 3.6) | -14.0 (-20.6, -7.4) |

The association between each variable and the outcome of interest was controlled for all other variables included in this table.

Table 7-3 Adjusted* cost components (AU$2012), length of stay, duration of surgery and anaesthesia, and admission to intensive care units

| | Mean (95% CI) | | Difference (95%CI) | *P*-value |
|---|---|---|---|---|
| | Open | Laparoscopic | | |
| Total cost | 27 561 (25 966, 29 156) | 25 036 (23 909, 26 165) | -2 524 (-4 436, -613) | 0.010 |
| Anaesthesia cost | 2 650 (2 505, 2 794) | 2 980 (2 855, 3 104) | 330 (138, 522) | 0.001 |
| Imaging cost | 165 (132, 198) | 207 (159, 255) | 42 (-19, 103) | 0.174 |
| Pathology cost | 1 005 (944, 1 066) | 970 (919, 1 020) | -35 (-115, 45) | 0.389 |
| Pharmacy cost | 282 (201, 362) | 189 (149, 230) | -92 (-187, 3) | 0.058 |
| Theatre cost | 6 864 (6 620, 7 108) | 6 917 (6 693, 7 142) | 53 (-284, 391) | 0.757 |
| Length of stay (days) | 10.3 (9.7, 11.0) | 9.2 (8.7, 9.7) | -1.1 (-1.9, -0.3) | 0.008 |
| Surgery duration (mins) | 214 (204, 224) | 216 (209, 224) | 2.6 (-10.2, 15.5) | 0.687 |
| Anaesthesia duration (mins) | 261 (251, 272) | 260 (252, 269) | -0.6 (-14.4, 13.3) | 0.937 |
| ICU admission (hours) | 14.7 (10.8, 18.7) | 7.4 (4.8, 10.0) | -7.3 (-11.9, -2.7) | 0.002 |

* Adjusted for age, sex, stage, Charlson Co-morbidity Index, type of procedure and hospital-volume

## 7.2 Discussion and implications of findings

This is the first study to demonstrate cost savings for laparoscopic resection for CRC. Among the existing cost analysis literature, most studies have used RCT data, which means that the most complicated cases are excluded. Despite laparoscopic procedures being performed on patients with comorbid conditions and those requiring complex procedures (e.g., rectal resection), this study found cost savings to the Queensland Government associated with laparoscopic resection compared with open resection for CRC.(93)

**Conclusion**

The objective of this study was to determine whether laparoscopic resection was associated with cost savings in this jurisdiction, where surgical teams are experienced in the technique. Where surgeons are now experienced in performing laparoscopic resection for CRC, surgical duration is equivalent to open resection. This, combined with reduced length of hospital stay and shorter and fewer admissions to ICU, results in considerable cost savings for patients who have laparoscopic resection compared with open resection for CRC. It is important that jurisdictions where adoption is delayed realise that cost savings will be attained when surgical teams have gained adequate experience in the technique. Economic cost should no longer be a barrier for uptake of laparoscopic resection for CRC. Potential barriers are considered in Chapter 8, in a study that compares uptake of laparoscopic surgery for a range of other procedures.

# Chapter 8 Differentials in the uptake of laparoscopic surgery by site and cancer and non-cancer related indications.

## 8.1 Introduction

In contrast to the other chapters in this thesis, this chapter is not in the format of a manuscript for publication but rather the format of a traditional thesis. This is a university requirement.

Surgical innovation is the foundation for continued improvements to patient outcomes and quality-of-life, and from which life-saving procedures are developed.(94) The uptake of healthcare innovations is one of the major pressures on health services.(95) To ensure effective uptake and planning of research and control of innovation in healthcare, healthcare administrators must consider factors that may affect uptake and be able to estimate the likely rate of uptake.(95) Furthermore, if these factors can be predicted, then healthcare providers can more accurately plan for increase in the use of innovative procedures.(95)

Over the past two decades, common abdominal surgical procedures have increasingly been performed using minimal-access laparoscopic technology, and have demonstrated significant improvements to patient outcomes. Since the introduction of laparoscopic surgery in the late 1980s and early 1990s, they have been associated with short-term benefits to patients compared with open resection. These include shorter hospital length of stay,(19, 96-99) reduced post-operative morbidity,(21, 97) faster return to normal activities,(96, 99-101) as well as reduced blood loss,(21, 98, 99), wound infection (59, 99) and post-operative pain (21, 99, 100, 102).

There have been considerable improvements to laparoscopic surgical equipment. First, the video imaging via the laparoscope was two-dimensional until the visual image of the surgical area was vastly enhanced through the introduction of high-definition video cameras in the early 2000s. Coming into popular use around the same time, the Harmonic scalpel uses high-frequency mechanical energy to simultaneously cut and coagulate tissue.(103) There have also been improvements to the articulation of handheld instruments, and suturing and stapling devices.(104) The availability of better techniques in imaging, such as magnetic resonance imaging (MRI), provides better pre-operative information about the tumour location, size and the extent of invasion.

When performed by a surgical team who are experienced in the techniques, there are few contraindications for laparoscopic procedures.(43, 105, 106) Compromised cardiopulmonary status is an important pre-surgery assessment due to potential complicating effects of the carbon dioxide

pneumoperitoneum required for laparoscopic surgery. However, as surgeons and anaesthetists have gained knowledge and experience, methods for managing pneumoperitoneum in patients with cardiopulmonary conditions have been developed.(107) When in the hands of an experienced minimal-access surgeon, laparoscopic cholecystectomy is considered an appropriate technique for use in all patients.(104) Severe obesity is stated as a contraindication for laparoscopic fundoplication due to obstruction from bulky structures.(104) For CRC, it has been suggested that 90% of patients are suitable for laparoscopic resection of their primary tumour; the exceptions are patients with MRI-predicted threatened margins of rectal cancer, and those with a history of complicated previous surgery suggesting extensive abdominal adhesions.(43)

The data presented in Chapter 5 show a delayed and slow uptake of laparoscopic resection for CRC in Australia. Uptake has not been slow for all laparoscopic procedures. In the US, there has been great variation in the speed of uptake between procedures. Within five years of being introduced, more than 70% of cholecystectomies were performed with laparoscopic access, while the laparoscopic percentage for nephrectomies and hysterectomies remained below 20% for over 10 years.(108) Similarly in Australia, laparoscopic cholecystectomy quickly became the standard of care. The laparoscopic percentage for cholecystectomies increased from 11% in the financial year 1990/91 to 73% in 1991/92.(109) This is far quicker than the nationwide adoption of laparoscopic segmental colon resection for cancer, which increased from 2.4% in 2000/01 to 27.5% in 2007/08.(90)

This chapter was formulated with the guidance and assistance of each of my PhD supervisors. Additional assistance was provided by Jim Nicklin, a Gynaecologist specialising in gynaecological oncology, and Sue Walker, Director of the National Centre for Health Information Research and Training. Michael Coory, John Lumley and I were each responsible for the conception and design of the study. I was responsible for the data acquisition and performed the data analysis. Sue Walker was integral in determining the Australian Classification of Health Intervention codes for each of the procedures and in clarifying the rules around coding for laparoscopic procedures. Under the guidance of Michael Coory, John Lumley, and Louisa Gordon, and with the assistance of Jim Nicklin, I interpreted the results. I was responsible for the first and subsequent drafts of the chapter under the guidance of, and with feedback from, Michael Coory, John Lumley and Louisa Gordon.

## 8.2 Aims

The aim of the analyses presented and discussed in this chapter is to:

1. Calculate the annual percentage of all procedures in Australia which have been conducted with laparoscopic access between financial years 1993/94 to 2009/10, individually for each of the procedures outlined in Table 8-3, for the purpose of:
    a. Comparing the timing of introduction of laparoscopy between procedures
    b. Comparing the rate of uptake of laparoscopic access between procedures by calculating the annual percentage increase
    c. Comparing the uptake of laparoscopic access between cancer and non-cancer related indications for surgery
    d. Discussing the procedure specific factors likely to influence the timing and rapidity of uptake of laparoscopic access

## 8.3 Background literature

Table 8-1 includes a summary of recommendations from health technology assessments, clinical practice guidelines (CPG) and consensus from specialist committees for laparoscopic hysterectomy, laparoscopic colorectal resection, laparoscopic nephrectomy, laparoscopic cholecystectomy and laparoscopic fundoplasty. Table 8-2 summarises results from the meta-analyses, reviews and individual studies. These tables provide a comprehensive but not an exhaustive list of the available recommendations or evidence for these procedures.

Hysterectomy, nephrectomy, colorectal resection, cholecystectomy and fundoplasty were specifically chosen because there are large numbers of these procedures performed and clear rules for identifying laparoscopic procedures using Australian Classification of Health Interventions classification system(ACHI) procedure codes in hospital morbidity data. Other procedures were considered unsuitable for the study; for example, laparoscopic prostatectomy was not included because robotic prostatectomy is the emerging method of interest, which is outside of the scope of this study.

Table 8-1 Recommendations for laparoscopic hysterectomy, laparoscopic colorectal resection, laparoscopic fundoplasty, laparoscopic nephrectomy and laparoscopic cholecystectomy.

| Procedure | Indication | Guideline | Not Recommended | Recommended |
|---|---|---|---|---|
| Laparoscopic Hysterectomy | Epithelial ovarian cancer | Australian Cancer Network and the National Breast Cancer Centre Clinical practice guidelines for the management of women with epithelial ovarian cancer(110) 2004 | | X |
| | Cancer and non-cancer | National Institute for Health and Clinical Excellence (United Kingdom) – Guidance(111) 2007 | X | |
| Colorectal resection | Colon cancer | Consensus of the European Association of Endoscopic Surgery(112) 2004 | | X |
| | Colon cancer | The American Society of Colon and Rectal Surgeons – Approved Statement(44) 2004 | | X |
| | Colon cancer | The Cancer Council Australia/Australian Cancer Network Clinical Practice Guidelines(8) 2005 | | X |
| | Rectal cancer | The Cancer Council Australia/Australian Cancer Network Clinical Practice Guidelines(8) 2005 | X | |
| | Colorectal cancer | National Institute for Health and Clinical Excellence (United Kingdom) – technology appraisal(18) 2006 | | X |
| | Colectomy (cancer and non-cancer) | French Authority for Health Health technology assessment(113) 2008 | | X |
| | Rectal cancer | Clinical Practice Guidelines of the European Association of Endoscopic Surgery(46) 2011 | | X |

| Procedure | Indication | Guideline | Not Recommended | Recommended |
|---|---|---|---|---|
| Laparoscopic fundoplasty | Non-cancer | Society of American Gastrointestinal and Endoscopic Surgeons - Guidelines for the clinical application of laparoscopic biliary tract surgery(114)<br>2010 (previous 2001) | X | |
| Laparoscopic nephrectomy | Cancer and non-cancer | National Institute for Health and Clinical Excellence (United Kingdom) – Guidance (115)<br>Five non-randomised comparative studies 2005 | | X |
| | Laparoscopic radical nephrectomy T1-T2 tumours | Doublet J. et al.(116)<br>Guidelines on Laparoscopy. European Association of Urology. 2006 | | X |
| | Laparoscopic nephro-urectomy for low-stage cell carcinomas | Doublet J. et al.(116)<br>Guidelines on Laparoscopy. European Association of urology. 2006 | X | |
| Laparoscopic cholecystectomy | Non-cancer | NIH consensus statement(117) 1992 | | X |
| | Non-cancer | UpToDate Review(118) 2013 | | X |

Table 8-2 Summary of findings from meta-analyses, reviews and individual studies for laparoscopic hysterectomy, nephrectomy, colorectal resection, cholecystectomy and fundoplication

| Procedure | Indication (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic hysterectomy | Not stated | 2005 | The NIHR Evaluation, Trials and Studies Coordinating Centre (United Kingdom)(119)<br>- Health technology appraisal | Compared with abdominal hysterectomy:<br>Higher rate of complications (11.1% vs 6.2%)<br>Shorter hospital stay (1 day)<br>Longer operating time (84 vs 50 minutes)<br>Sexual frequency and body image better in short-term |
| | Non-cancer gynaecological disease | 2006 | Johnson, N.(98)<br>Cochrane review<br>27 RCTs | Less blood loss (WMD 45.3 mls, 95%CI 17.9 to 72.7 mls)<br>Short hospital stay (2 days; 95%CI 1.9, 2.2)<br>Faster return to normal activities (WMD 13.6 days, 95%CI 11.8 to 15.4 days)<br>Fewer wound or abdominal wall infections (OR 0.32, 95%CI 0.12 to 0.85)<br>Longer operating time (WMD 10.6 minutes, 95%CI 7.4 to 13.8 minutes)<br>Increased urinary tract (bladder or ureter) injuries (OR 2.61, 95%CI 1.22 to 5.60) |

| Procedure | Indication (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic hysterectomy | Non-cancer gynaecological disease | 2009 | Nieboer, T. et al.(99)<br>Cochrane review<br>34 RCTs<br>4 495 patients | Laparoscopic hysterectomy recommended<br>Fewer febrile episodes or unspecified infection (OR 3.77)<br>Longer operation time (MD 20.3 minutes; 95%CI 4.0, 36.6)<br>Faster return normal activities (MD -13.6 days; -15.4, -11.8)<br>Less blood loss (MD -45.3; 95%CI -72.7, -17.9)<br>Shorter length of stay (MD -3.8; 95%CI -4.3, -3.3) |
| | Early endometrial cancer | 2012 | Galaal, K. et al.(97)<br>Cochrane review<br>8 RCTs<br>3 644 patients | Laparoscopic hysterectomy recommended<br>Overall survival HR = 1.14, 95% confidence interval (CI): 0.62 to 2.10)<br>Recurrence free survival HR = 1.13, 95% CI: 0.90 to 1.42)<br>Less blood loss (MD = -106.82 mL, 95% CI: -141.59 to -72.06)<br>Severe post-operative adverse events (RR = 0.58, 95% CI: 0.37 to 0.91)<br>Shorter length of stay |

| Procedure | Indication (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic colorectal resection | Colorectal cancer | 2007 | The NIHR Evaluation, Trials and Studies Coordinating Centre (United Kingdom)<br>- Health technology appraisal(120) | Laparoscopic resection associated with additional cost<br>- 40% chance that laparoscopic resection is the more cost effective at a willingness to pay threshold of £30 000 per QALY. A judgment is required as to whether the benefits of earlier recovery are worth the extra cost. |
| Laparoscopic fundoplasty | Cancer | 1999 | Ono, Y. et al.(121)<br>Retrospective comparative study<br>Japan<br>100 patients | Equivalent DFS (95.5% vs 97.5%)<br>Longer operating time (5.2 vs 3.3 hours; $P$<0.001)<br>Less analgesia (31 vs 68mg; $P$<0.001)<br>Faster return normal activities (23 versus 57 days, $P$ <0.001).<br>Equivalent complications<br>Reduced blood loss (255 versus 512 mL, $P$< 0.001).<br>1.7% conversions |

| Procedure | Indictation (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic nephrectomy | Cancer | 2000 | Dunn, M. et al(122) | Longer operating time (5.9 vs 2.8 hrs; *P*<0.001) |
| | | | Non-randomised comparative study | Reduced blood loss (172 versus 451 ml., *P*<0.001) |
| | | | US | Reduced analgesia (28.0 versus 78.3 mg., *P*<0.001) |
| | | | 93 patients | Shorter length stay (3.4 versus 5.2 days, *P*<0.001) |
| | | | | Faster return normal activities(3.6 versus 8.1 weeks, *P*<0.001) |
| | | | | Faster return normal activities (5.1 vs 7.6 weeks; *P* = 0.11) |
| | | | | Fewer complications |
| | Non-cancer | 2001 | Fornara, P. et al.(96) | Equivalent operating time (90 mins; *P* = 0.361) |
| | | | Retrospective comparative study | Reduced blood loss (200 vs 250 mls; *P* <0.001) |
| | | | Germany | Reduced blood transfusion (9.9% vs 18.6%; *P* <0.001) |
| | | | 249 patients | Reduced analgesia (median 32 vs 48; *P* <0.001) |
| | | | | Shorter length stay (median 4 vs 10 days; *P* <0.001) |
| | | | | Faster return normal activities (median 24 vs 36 days; *P* < 0.001) |

| Procedure | Indication (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic cholecystectomy | Non-cancer | 1997 | Eldar, S. et al.(102)<br>RCT<br>271 patients | (Data unavailable)<br>Shorter operating time and hospital stay<br>Less frequent use of nasogastric tube<br>Reduced analgesia<br>Equivalent post-operative complications |
| | Non-cancer | 1998 | Kiviluoto, T. et al.(123)<br>RCT<br>63 patients | Equivalent operating time (mean 108 vs 100 mins; *P* = 0.49)<br>Shorter length stay (median 4 [IQR 2–5] vs 6 [5–8] days; *P*=0·0063)<br>Faster return to normal activities (mean 13.9 vs 30.1 days; 95%CI 10.9-21.7)<br>Fewer post-operative complications (3% vs 19%; *P* = 0.05) |
| | Non-cancer | 2005 | Johansson, M. et al.(124)<br>RCT<br>70 patients | Equivalent post-operative pain (Visual Analogue Score) (11 vs 14; *P* = 0.771)<br>Longer operating time (median 90 vs 80; *P* = 0.04)<br>Equivalent hospital stay (2 days; *P* = 0.011)<br>Equivalent post-operative complications 2 vs 3; *P* = 0.652)<br>Faster return to normal activities (median 11 vs 14; *P* = 0.771) |

| Procedure | Indictation (cancer/non-cancer) | Year | What (CPG/review) | Outcome/recommendation |
|---|---|---|---|---|
| Laparoscopic nephrectomy | Cancer | 2004 | Hsueh, T. et al.(100)<br>Retrospective comparative study<br>Taiwan<br>145 patients | Longer operating time (mean 259 vs 230 mins; *P* = 0.006)<br>Reduced analgesia (mean 26 vs 35 mg; *P* = 0.03)<br>Reduced blood loss (mean 409 vs 747 mls; *P* < 0.001)<br>Shorter length of staylength of stay (mean 9.3 vs 12.6 days; *P* < 0.001)<br>Faster return normal activities (mean 19 vs 25 days; *P*<0.001)<br>Equivalent local recurrence (9% vs 9%; *P*= 0.23)<br>Equivalent metastasis (10% vs 8%; *P* = 0.20) |
| | Cancer | 2004 | Bariol, S. et al.(125)<br>Non-randomised comparative study<br>United Kingdom<br>64 patients | Equivalent recurrence (8% vs 15%; *P* = 0.3)<br>Equivalent DFS (87% vs 82%; *P* = 0.26) |

DFS = Disease free survival; OS = overall survival; MD = mean difference; SMD = standardised mean differences; QALY = Quality Adjusted Life Years WMD = Weighted Mean Difference, HR= Hazard Ratio

## 8.4 Methods

We obtained unit-record data for 17 financial years, 1993/1994-2009/2010, from the National Hospital Morbidity Data (NHMD), which collates administrative inpatient data from all of the Australian states and territories.(126) The extraction was restricted to elective surgical admissions for resections of the colon or rectum, nephrectomy, hysterectomy, fundoplication and cholecystectomy and included all procedure and diagnosis codes. Patients who had emergency resections (e.g., for bowel obstruction, trauma) were excluded because emergency procedures are less likely to be performed laparoscopically. No data were provided that could identify (or re-identify) an individual patient or the Australian state where the patients were treated.

Included in the analysis are additional aggregated laparoscopic cholecystectomy data for 1989/90 to 1992/93 sourced from a report from the Australian Institute of Health and Welfare.(127) The number of cholecystectomies was estimated using state level hospital morbidity data, national state level population ratios and known variations in surgical rates between states. The number of laparoscopic cholecystectomies was extrapolated from the Medicare database.(127)

NHMD uses ACHI codes which are derived from the Medicare Benefits Schedule to indicate the procedure performed. The 10 edition releases of the ACHI codes throughout the study period were reviewed to identify relevant procedure codes. To distinguish between cancer and non-cancer related conditions, all relevant editions of the International Classification of Diseases (ICD) were reviewed. The ACHI and ICD codes to classify the procedure groups and to identify laparoscopic procedures are included in 8.7 Appendix 1.

The laparoscopic percentage was calculated separately for 10 groups (Table 8-3), including six procedures; four of these were sub-grouped into cancer and non-cancer related conditions. The laparoscopic percentage was calculated as the number of laparoscopic resections divided by the total number of procedures (open + laparoscopic). These were calculated for each year of the study to give an annual percentage. The data analyses were generated using SAS software (Version 9.2; SAS Institute, Cary, NC).Graphs were produced using STATA Version 11.0 statistical software package.(128)

Ethical approval was granted by The University of Queensland's School of Population Health Human Research Ethics Committee.

Table 8-3 List of procedures and stratified sub-groups included in the analyses

| Procedure | Conditions |
|---|---|
| Cholecystectomy | Non-cancer |
| Fundoplication | Gastro-oesphageal Reflux Disease |
| Resection of the colon or rectum | Cancer |
| | Non-cancer |
| Partial nephrectomy | Cancer |
| | Non-cancer |
| Total nephrectomy | Cancer |
| | Non-cancer |
| Hysterectomy | Cancer |
| | Non-cancer |

## 8.5 Results

The total number of cases differed greatly between procedures. Cholecystectomy was the most common procedure throughout the study; 37 572 procedures were performed in 1993/94, which increased to 49 892 in 2009/10. The total annual numbers of cholecystectomy, and number and percentage performed as laparoscopic cholecystectomy are presented in Table 8-4. Abdominal hysterectomy for non-cancer related disease was also common, however, since the early 2000s the numbers of abdominal hysterectomies have decreased slightly. There were 19 932 hysterectomies for non-cancer related disease in 1993/94, which increased to almost 32 000 by 2001/02 and decreased to 26 397 by 2009/10 (Table 8-5). The total annual number of cases was less than 10 000 for colorectal resection (Table 8-7), fundoplasty (Table 8-4) and hysterectomy for cancer-related disease (Table 8-5). Nephrectomy was the least common procedure, particularly partial nephrectomy for which there were 500 in the most recent year, 2009/10 for cancer related disease, and 222 for non-cancer related disease (Table 8-8).

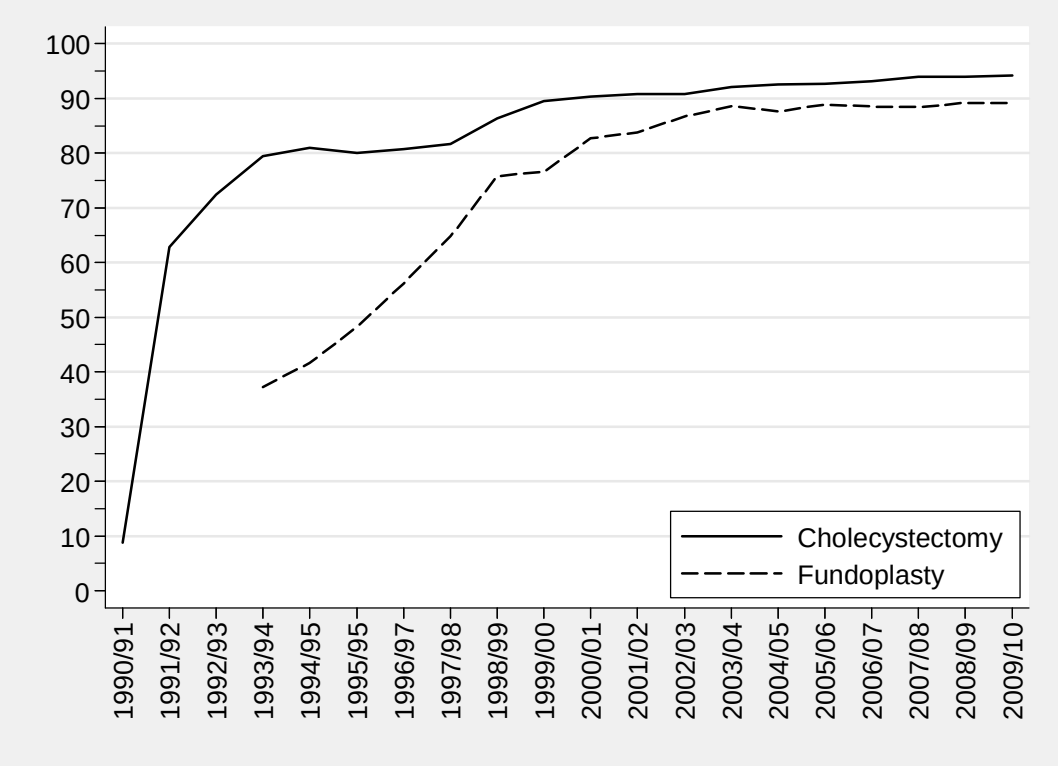
### 8.5.1 Laparoscopic procedures

*Cholecystectomy*

Cholecystectomy was the earliest and most rapidly adopted laparoscopic surgery (Figure 8-1). In 1990/01, the laparoscopic percentage for cholecystectomy was just short of 10%; by 1991/92 this increased by 55% to 63% (Table 8-4). Annual percentage increases decreased considerably

thereafter; however, the prevalence of this procedure did continue to increase until around 2000 where it has remained at just over 90% (Table 8-4 and Figure 8-1).

Figure 8-1 Annual percentage laparoscopic cholecystectomy and fundoplication, 1993/94 to 2009/10




*Fundoplasty*

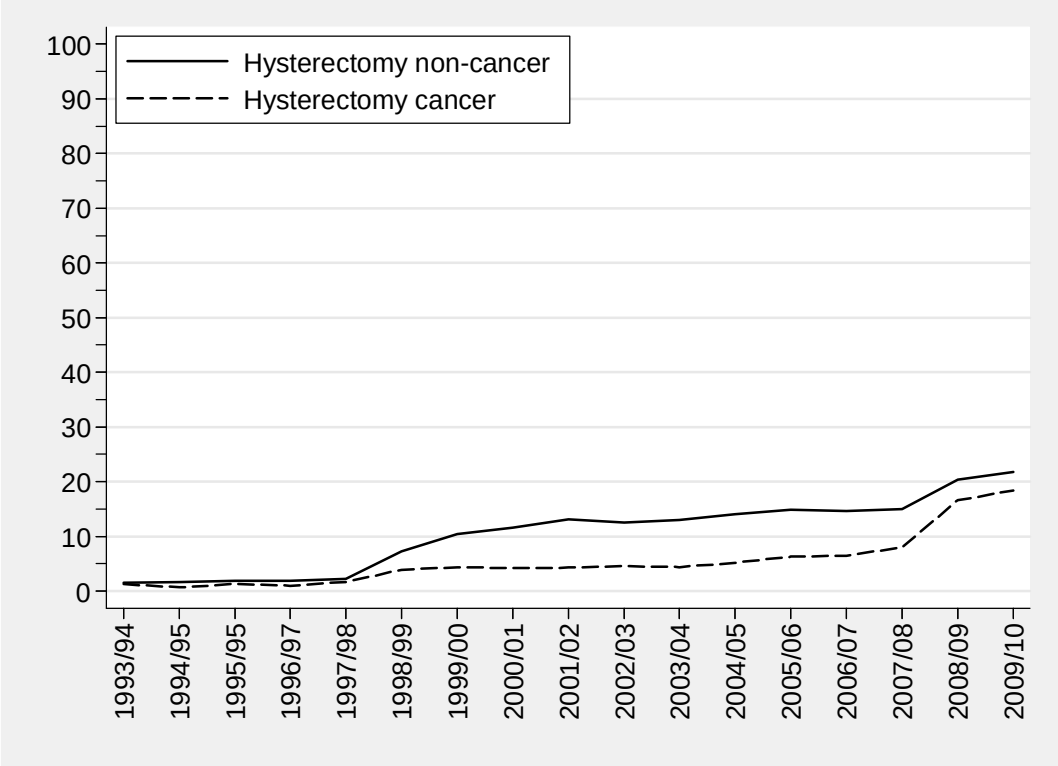
Uptake of laparoscopic fundoplasty was less rapid than cholecystectomy. The early data available indicates that the laparoscopic percentage for fundoplasty was 37% in 1993/94; annual percentage increases ranged from 5%-11% until 2000 when the laparoscopic percentage was greater than 80% and annual percentage increases decreased to around 2%. Laparoscopic fundoplasty reached its maximum just short of 90% in the early 2000s where it has since remained (Table 8-4 and Figure 8-1).

*Hysterectomy*

Increases in laparoscopic hysterectomy have been slow for cancer and non-cancer related conditions (Figure 8-2 and Table 8-5). Towards the late 1990s, the laparoscopic percentage increased to greater than 5% for non-cancer related conditions and the annual percentage increase has continued to be small at less than 5%. Annual percentage increases for cancer related conditions commenced around the same time as for non-cancer related conditions; however, the increases were smaller. For the financial year 2008/09, the annual percentage increase rose to above 5% for both cancer and non-cancer related conditions; this increase did not continue in the following year (Table 8-5). By

2009/10, the laparoscopic percentage for hysterectomy was around 20% for cancer and non-cancer related conditions (Figure 8-2 and Table 8-5). The data included in Table 8-6 includes vaginal hysterectomies for cancer and non-cancer indications. This table shows a decrease in open hysterectomies for cancer conditions, with correlating slow increases in laparoscopic hysterectomy and vaginal hysterectomy. However, the percentage of vaginal hysterectomies for non-cancer related conditions has decreased from 39% in 1993/94 to 27.1% in 2009/10, and there has been little change in the percentage of open hysterectomies over the study period.

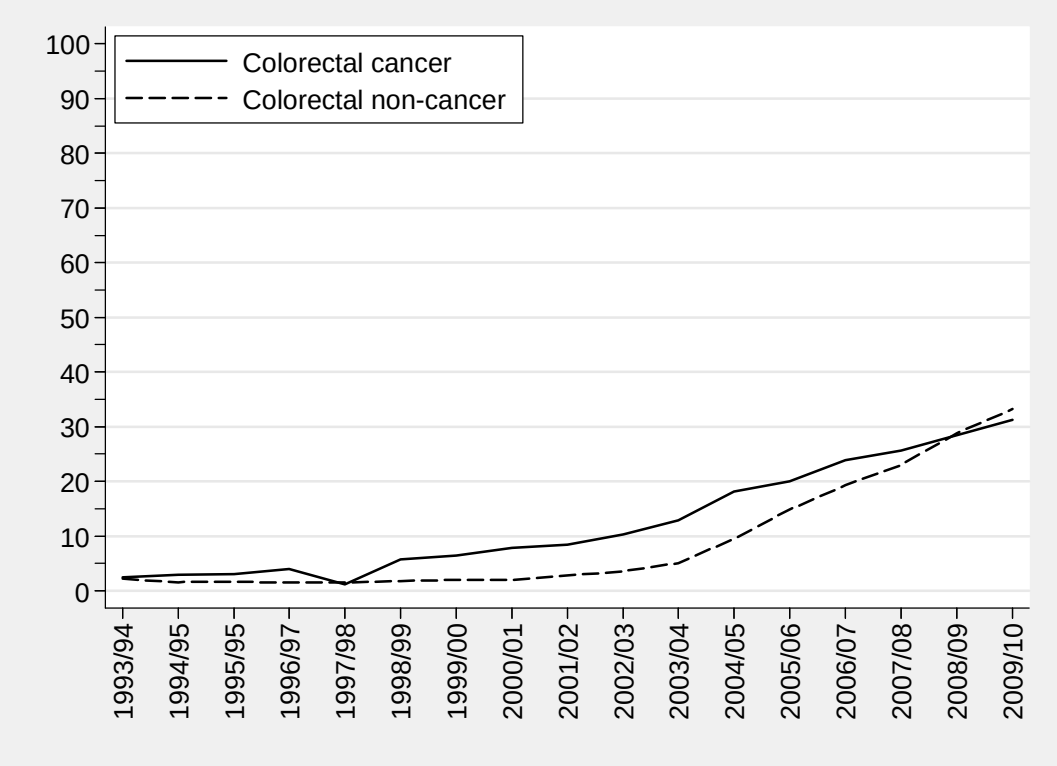
Figure 8-2 Annual percentage laparoscopic hysterectomy for cancer and non-cancer indications, 1993/94 to 2009/10



*Colorectal resection*

By the early 1990s, the laparoscopic percentage for colorectal resection for non-cancer related conditions was around 3%; from which point there were moderate annual percentage increases of less than 5% throughout the study period (Table 8-7). Increases in laparoscopic colorectal resection for cancer related conditions commenced five years later in 1998/99. Annual percentage increases were greatest for cancer related conditions from 2004/05; by 2009/10 the laparoscopic percentage was greater than for non-cancer related conditions (33% versus 31%) (Figure 8-3).

Figure 8-3 Annual laparoscopic colorectal resection, by cancer and non-cancer indication, 1993/94 to 2009/10

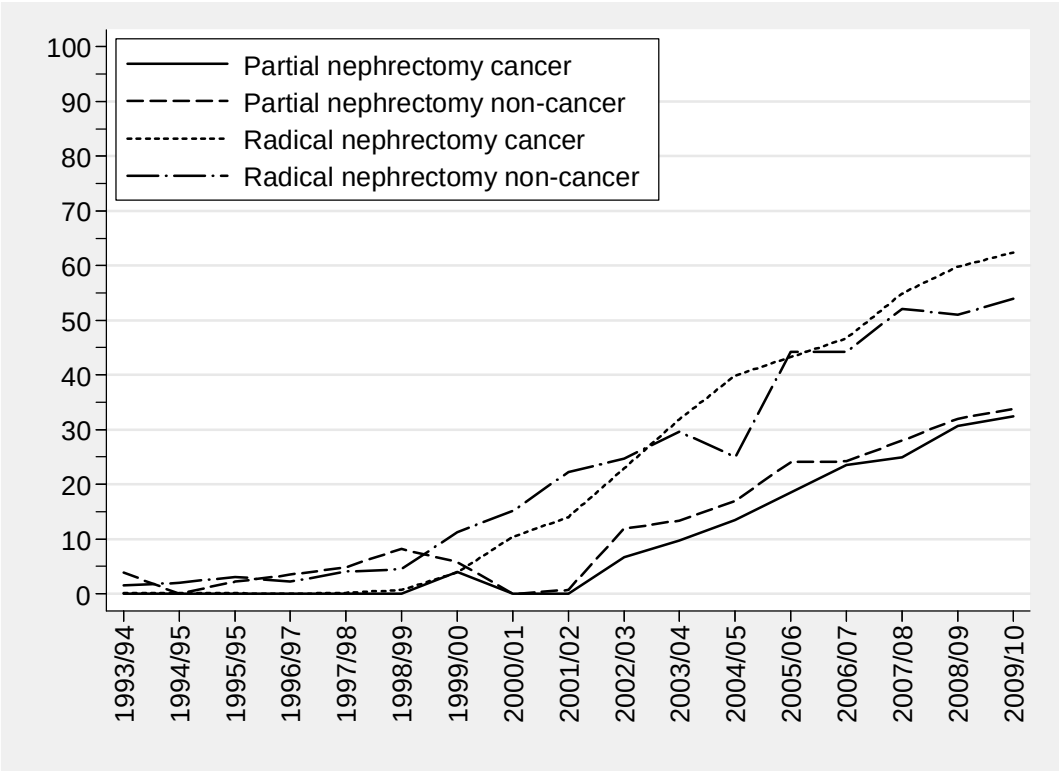



*Nephrectomy*

There were irregular trends in the laparoscopic percentages of radical and partial nephrectomies throughout the study period due to the small numbers of these procedures. For example, the small peak in the graph 1998/99 for partial nephrectomies for non-cancer related conditions is the result of 13 laparoscopic procedures out of 154 (Table 8-8). Following 2001/02 the percentage of laparoscopic partial nephrectomies increased at a moderate rate of 3%-7%; reaching 32% in 2009/10 (Table 8-8). Throughout the period, laparoscopic percentages were similar for cancer and non-cancer related conditions (Figure 8-4). Increases in laparoscopic radical nephrectomy began in the early 1990s for non-cancer related conditions and in the late 1990s for cancer related conditions (Figure 8-4). Annual percentage increases were larger and more consistent throughout the study

period for cancer related conditions resulting in a laparoscopic percentage of 62% in 2009/10, compared with 54% for non-cancer related conditions (Table 8-9).

Figure 8-4 Annual percentage laparoscopic partial and radical nephrectomy, by cancer and non-cancer indication, 1993/94 to 2009/10



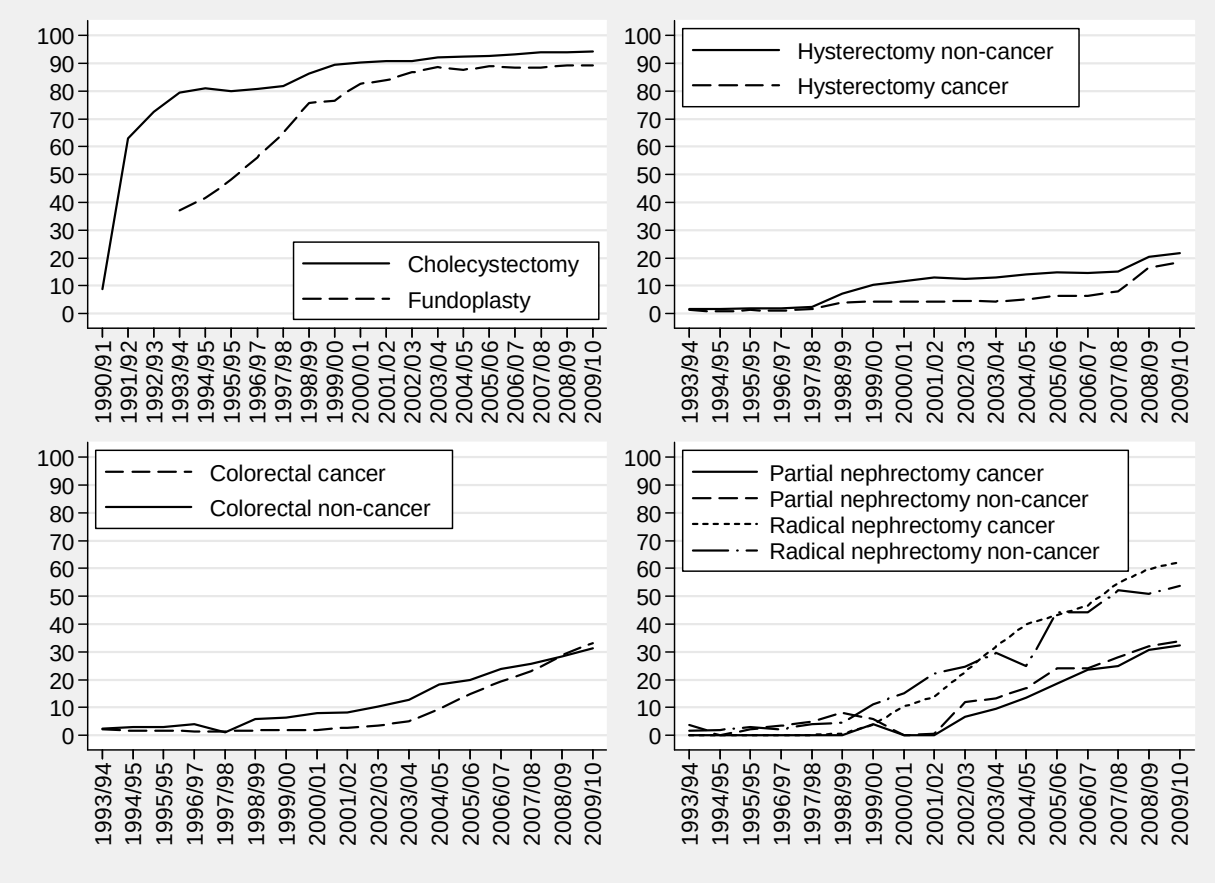

*Comparing uptake of laparoscopic percentage between procedures*

Figure 8-5 includes the individual graphs for cholecystectomy, hysterectomy, colorectal resection and nephrectomy to allow for comparison in the uptake of laparoscopic resection across these procedure types.

Increases in the laparoscopic percentage of innovative surgical techniques differ greatly between the procedures. Cholecystectomy was the most common laparoscopic procedure throughout the study period, with very rapid uptake over a couple of years at introduction. The laparoscopic percentage for fundoplasty was also high; however, uptake was more gradual throughout the 17 years of the study. Although abdominal hysterectomy was a very common procedure, the laparoscopic percentage was smallest and uptake slowest of all procedures, particularly for cancer related conditions. There was similarly slow uptake of laparoscopic colorectal resection. Although laparoscopic resections for cancer-related conditions were delayed, uptake was rapid from the early 2000s. Uptake of laparoscopic radical nephrectomy was earlier and more rapid than for hysterectomy or colorectal resection. For cancer related conditions, uptake of laparoscopic radical nephrectomy did not start until the late 1990's, when uptake was quite rapid. The uptake of

laparoscopic partial nephrectomy was delayed (early 2000s) from which time there was moderately rapid uptake.

Figure 8-5 Annual percentage laparoscopic procedures for cholecystectomy, hysterectomy, colorectal resection and nephrectomy, 1993/94 to 2009/10




## 8.6 Discussion

There were considerable differences in the uptake of laparoscopic surgery between each of the procedures presented in this chapter. Laparoscopic cholecystectomy and fundoplasty were more rapidly adopted than the other laparoscopic procedures. For colorectal resection, hysterectomy and nephrectomy, laparoscopic procedures for cancer related conditions were generally delayed by three to five years compared with non-cancer related conditions however, following the delay, uptake followed similar trends compared with the other procedures.

Laparoscopic cholecystectomy was the first laparoscopic procedure popularised around the world.(19) It was first introduced to the US in 1988 and was rapidly adopted by surgeons.(19) Similar to the uptake shown in this chapter, data from the Nationwide Inpatient Sample (NIS) in the US shows an increase in the laparoscopic percentage for cholecystectomy of about 65% in the first

few years of introduction.(108) By 2003, almost 80% of cholecystectomies in the NIS were laparoscopic,(108) which is comparable with the 90% found in this study at the same time.

Uptake of laparoscopic fundoplasty in the NIS was also similar to this current study, however, the laparoscopic percentage levelled to about 60%,(108) while increases in Australia continued up to around 90%. Studies have reported uptake of laparoscopic radical nephrectomy in the US(108, 129) and France(130) comparable to those experienced in Australia. Likewise, similar percentages for laparoscopic hysterectomies were reported in the NIS in the US,(108) while studies in the US using different data sources have found percentages of laparoscopic hysterectomy considerably higher than that found in this current study.(131, 132) Also from the NIS database in the US, 50% of colorectal resections for cancer were performed with laparoscopic access in 2008 and 2009, which is considerably greater than the laparoscopic percentage found in Australia.(70) For non-cancer related conditions, laparoscopic percentages for colon resections were also higher than in this current study; 38% in 2008 and 44% in 2011.(133)

The short-term benefits of laparoscopic access for various procedures were quickly realised in the 1990's; however, there remained limited information on the risks. For example, the slower uptake of laparoscopic fundoplasty compared with laparoscopic cholecystectomy is probably because of the relative risk of unsuccessful fundoplasty. While cholecystectomy is an ablative surgery resulting in the removal of the gall bladder, there is greater risk that fundoplasty will not be successful in achieving its functional purpose of reinforcing the lower oesophageal sphincter. It is probable that uptake was more gradual as surgeons sought assurance that outcomes were equivalent to open fundoplasty. Similarly, following colorectal resection, the bowel must be functional, as should the kidney following a partial nephrectomy.

The risks associated with adopting a new surgical technique for cancer related disease exceed the risks for non-cancer related disease. The risks are increased because the surgical requirements for achieving oncologic principles are more demanding; including removal of the primary tumour with adequate surgical margins and the assessment of any regional spread of cancer.(13) For example, there were concerns about a reduced yield of regional lymph nodes in laparoscopic colon resection.(134) In the early period of adoption, there were also concerns about port-site metastasis following laparoscopic surgery for cancer-related conditions.(134) However, experience with the technique rapidly improved adherence to oncological principles in laparoscopic surgery, largely alleviating these concerns by the early 2000s.(134)

The evidence and corresponding recommendations and CPG, and how these influence uptake of laparoscopic techniques, varies greatly between the procedures. For instance, laparoscopic resection for colon cancer is one of the few surgical procedures for which there is high-quality evidence from large multi-centre RCTs. These studies provide the evidence to assure surgeons, healthcare providers and patients that the short and long-term oncological outcomes for laparoscopic resection are equivalent to open resection for colorectal cancer.(54) The uptake of laparoscopic resection for CRC in Australia was delayed until 2003/04, partly because it was around this time that the long-term outcomes for laparoscopic resection for colon cancer became available. It is probable then, that the rate of uptake will probably increase further when long-term outcomes for laparoscopic resection for rectal cancer become available.

In contrast, there is no RCT evidence for laparoscopic nephrectomy and there are currently no CPG for the management of renal disease or cancer in Australia. In 2006, the European Association of Urology recommended laparoscopic nephrectomy and nephro-urectomy for non-cancer conditions. The guidelines stated laparoscopic radical nephrectomy was feasible in early stage (T1-T2) tumours while laparoscopic nephro-urectomy for low stage cell carconomas, was not recommended.(116) Despite the lack of formal recommendation in Australia, uptake in laparoscopic radical nephrectomy for cancer and non-cancer related conditions, has been greater than for laparoscopic colorectal resection since 1998/99.

Sub-specialised surgeons, such as urologists and colorectal surgeons, will have better knowledge of current practice of the latest technological developments in their sub-specialities. Although nephrectomies are usually always performed by a specialist urologist, it is not uncommon for colorectal resections to be performed by general surgeons. Sub-specialist surgeons are also exposed to a greater number of cases and may therefore progress through the learning curve more quickly than general surgeons who perform a wider range of procedures. Resections for CRC are likely to be referred to specialist colorectal surgeons, which may account for the more rapid uptake in laparoscopic colorectal resection for cancer than for non-cancer conditions in the later period.

Laparoscopic hysterectomy is also supported by RCT evidence for non-cancer related conditions(99) and for early endometrial cancer(97). It appears that this evidence and recommendations for laparoscopic hysterectomy from the National Institute for Health and Clinical Excellence(111) and resulting from two Cochrane reviews,(97, 99) has not influenced the uptake of laparoscopic hysterectomy in any material way. There are other factors which are likely influencing uptake of laparoscopic hysterectomy. First, the need for hysterectomy is decreasing as gynaecologists experience growing success with conservative therapeutic management. Also,

vaginal hysterectomies are the preferred minimally invasive approach.(99) Similar to the US(131), the current study found a decrease in the percentage of vaginal hysterectomies for non-cancer conditions and slow uptake in vaginal hysterectomies for cancer related conditions. Pelvic organ prolapse/incontinence is the most common indication for vaginal hysterectomy; this is decreasingly being treated with hysterectomy in favour of more conservative treatment, thus explaining a decrease on vaginal hysterectomy for non-cancer related conditions.

The National Health and Medical Research Council along with the Australian Cancer Network and The Cancer Council, release CPGs to provide healthcare professionals with evidence-based recommendations to assist with clinical decision-making and improve healthcare for patients.(135) There are currently no Australian CPGs that address laparoscopic cholecystectomy, fundoplication or nephrectomy. The CPG for epithelial ovarian cancer does not recommend laparoscopic hysterectomy.(110) For colorectal cancer, laparoscopic resection is recommended for colon cancer but not for rectal cancer.(8) The CPG for epithelial ovarian cancer and colorectal cancer were published in 2004 and 2005, respectively,(8, 110) and therefore do not incorporate recent evidence to reach the recommendation. In some cases, there are contrary recommendations in other jurisdictions; for example, in 2007 the National Institute for Health and Clinical Excellence recommended laparoscopic hysterectomy for cancer and non-cancer related conditions.(111) If these recommendations existed in Australia, there may be higher expectations for minimal-access surgery from patients, which would result in more pressure on healthcare providers to increase access to laparoscopic procedures.

The learning curve is directly associated with the complexity of the procedure; that is, the more complex the procedure, the longer it takes and the more cases are required for a surgeon to gain adequate skills and experience. Laparoscopic cholecystectomy is a very common procedure for which the risks are relatively small. General surgeons are trained to perform cholecystectomy with laparoscopic access relatively quickly. This is reflected in the very rapid uptake of this procedure from its introduction. Laparoscopic colorectal resection, laparoscopic hysterectomy and laparoscopic nephrectomy are complex procedures with long learning curves. Despite large numbers of hysterectomies offering ample opportunity for observation and trial, the uptake of laparoscopic hysterectomy has remained slow and far less than the uptake of laparoscopic nephrectomy. Difference in the opportunity for formalised training is a potential reason for this slow uptake; for example urologists probably have more training opportunities to gain skills and experience in laparoscopic nephrectomy in their surgical training, while opportunities for laparoscopic specific training for gynaecologist may be limited.

Robotics is an emerging field of surgery, particularly for hysterectomy and colorectal resection. Robotic hysterectomy results in the short-term benefits normally associated with minimal-access surgery, such as reductions in length of hospital stay, blood loss and complications.(136) There are also increased costs for robotic hysterectomy because of a longer operating time and the requirement for very expensive equipment. However, as surgical teams gain adequate experience in the technique (it has been suggested 90 cases is the necessary number of procedures before a surgeon is proficient), the increased cost of equipment is counteracted by reduced operating time and shorter length of stay.(137) In the US, over the three years since its introduction, there have been decreases in the percentage of laparoscopic, open and vaginal hysterectomies, while the percentage of robotic hysterectomy has increased to over 20%.(132) In Australia, robotic hysterectomy and colorectal resection are still in the very early days of introduction; however, in future years as surgeons focus on gaining skills in robotic surgery, laparoscopic surgery will become less common.

It is a common belief that laparoscopic surgery is more appealing treatment option for patients.(21) However, there may be a small sub-group of patients who request traditional methods of surgery and opt for open procedure, possibly because of concerns about the experience of the surgeon in the technique and the associated potential risks. Patient preference for open procedure along with medical contraindications for laparoscopic procedure means that the laparoscopic percentage for any procedure will reach maximum potential short of 100%. For cholecystectomy, the maximum potential has been reached at 94%, for fundoplasty this is 90%. It is probable that in future years, similar percentages will be reached for other laparoscopic procedures as more surgeons acquire the necessary skills and experience.

This study is based on routinely collected population-based data (NHMD) and therefore provides complete measures of laparoscopic surgery in public and private hospitals across Australia from very early in the introduction of laparoscopic procedures (2003/04) until the most recent data available (2009/10). Each of the procedures included in the analysis for this chapter is a major procedure resulting in considerable reimbursement in both the private and the public sectors; data is therefore likely to be accurate and complete. On the other hand, it has been suggested that clinical information, such as cancer diagnosis, is not subject to government reimbursement, and therefore may not be coded with the same attention given to procedure codes.(138, 139) The coding for cancer related conditions in this study is validated by the lag in uptake of laparoscopic procedures for cancer compared with non-cancer related conditions; a result which is consistent with a previously published study(108).

## Conclusion

This study has identified vast differences in the rate of uptake of laparoscopic surgical procedures. The procedures with relatively reduced risk, particularly laparoscopic cholecystectomy and laparoscopic fundoplasty, were adopted very rapidly. Procedures for cancer related conditions were delayed in their uptake compared with the same procedure for non-cancer conditions, mainly due to the increased risk but also because the learning curve for surgeons is long and experience in the technique for non-cancer conditions must be obtained prior to performing the procedure for cancer conditions. It is important that the uptake of innovative techniques is monitored, to inform healthcare administrators of past and current practices, and to predict future practice. Healthcare administrators can use this knowledge to plan for impending increases in the utilisation of innovative technologies and to improve patient access to the best available treatments. This may be achieved through ensuring that there are up-to-date recommendations for innovative techniques and that appropriate training opportunities exist for healthcare providers.

## 8.7 Appendix 1: Procedure codes

| Procedure | ICD9 | | ICD10 | |
|---|---|---|---|---|
| | Open | Laparoscopic | Open | Laparoscopic |
| Colorectal | 457, 486, 485 | Concurrent with code for open resection: 542, 545 | 3200000, 3200001, 3200300, 3200301, 3200400, 3200401, 3200500, 3202600, 3202800, 3202801, 3203900, 3203600, 3202800, 3204700, 3206000, 3209900, 3211200, 4399301, 9034100, 9220800, 3202400, 3203000 | Concurrent with code for open resection: 3039000, 3039300 |
| Fundoplasty | 446 | Concurrent with code for open resection: 542, 545 | 3052700, 3052701, 3053304, 3053305, | 3052702, 3052703, 3052704, 3052705, 3052900, 3052901, 3053000, 3053300, 3053301, 3053302, 3053303, 4395100, 4395400<br>Concurrent with code for open resection: 3039000, 3039300 |
| Cholecystectomy | 512 | Concurrent with code for open resection: 542, 545 | 3044300, 3045401, 3045500 | 3044500, 3044600, 3044800, 3044900<br>Concurrent with code for open resection: 3039000, 3039300 |

| | ICD9 | | | ICD10 | | |
|---|---|---|---|---|---|---|
| | TAH* | TLH* | Vaginal hysterectomy | TAH* | TLH* | Vaginal hysterectomy |
| Hysterectomy | 683, 684, 686 | Concurrent with code for open resection: 542, 545 | 685, 687 | 3566100, 3566700, 3567000, | 9044801, 9044802, 9044800, 3575000, 3575300, 3575301, 3575302, 3575600, 3575601, 3575602, 3575603, 3575000 Concurrent with code for open resection: 3039000, 3039300 | 3565700, 3566701, 3567300, 3567301, 3567302 |

*TAH = Total abdominal hysterectomy; TLH = Total laparoscopic hysterectomy

| | ICD9 | | | ICD10 | | |
|---|---|---|---|---|---|---|
| | Radical | Partial | Laparoscopic | Radical | Partial | Laparoscopic |
| Nephrectomy | 555 | 5539, 554 | Concurrent with code for open resection: 542, 545 | 3651601, 3651603, 3652800, 3652801, 3652900, 3653100, 3653101, 3653300, 3651902, 3651903 | 3652200, 3652201, 3652500, 3652501 | 3651600, 3651602, 3651902, 3652200, 3652500, 3652800, 3653100, 3655800 |

## 8.8 Appendix 2: Results tables

Table 8-4 Laparoscopic resections for cholecystectomy and fundoplasty

| | Cholecystectomy | | | Fundoplasty | | |
|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Annual increase (%) | Total N | Laparoscopic n (%) | Annual increase (%) |
| 1989-90* | 25 422 | 0 (0) | - | | | |
| 1990-91* | 25 002 | 2 205 (8.8) | 8.8 | - | - | - |
| 1991-92* | 33 877 | 21 295 (62.9) | 54.1 | - | - | - |
| 1992-93 | 30 428 | 22 030 (72.4) | 9.5 | - | - | - |
| 1993-94 | 37 572 | 29 828 (79.4) | 7.0 | 1 731 | 644 (37.2) | - |
| 1994-95 | 38 876 | 31 447 (81.0) | 1.6 | 1 875 | 782 (41.7) | 4.5 |
| 1995-96 | 40 131 | 32 111 (80.0) | -1.0 | 2 025 | 975 (48.2) | 6.5 |
| 1996-97 | 41 680 | 33 657 (80.8) | 0.8 | 2 182 | 1 226 (56.2) | 8.0 |
| 1997-98 | 43 034 | 35 163 (81.7) | 0.9 | 2 380 | 1 542 (64.8) | 8.6 |
| 1998-99 | 43 914 | 37 935 (86.4) | 5.6 | 2 822 | 2 112 (75.8) | 11.0 |
| 1999-00 | 44 467 | 39 807 (89.5) | 3.1 | 2 838 | 2 175 (76.6) | 0.8 |
| 2000-01 | 46 204 | 41 703 (90.3) | 0.8 | 2 995 | 2 476 (82.7) | 6.1 |
| 2001-02 | 45 919 | 41 693 (90.8) | 0.5 | 2 942 | 2 464 (83.8) | 1.1 |
| 2002-03 | 45 884 | 41 693 (90.8) | 0 | 2 854 | 2 475 (86.7) | 2.9 |
| 2003-04 | 46 318 | 42 657 (92.1) | 1.3 | 2 833 | 2 510 (88.6) | 1.9 |
| 2004-05 | 46 689 | 43 205 (92.5) | 0.4 | 2 824 | 2 474 (87.6) | 1.0 |
| 2005-06 | 46 746 | 43 333 (92.7) | 0.2 | 2 865 | 2 548 (88.9) | 1.3 |
| 2006-07 | 47 407 | 44 127 (93.1) | 0.4 | 2 866 | 2 536 (88.5) | -0.4 |
| 2007-08 | 47 376 | 44 511 (94.0) | 0.9 | 3 027 | 2 677 (88.4) | -0.1 |
| 2008-09 | 47 763 | 44 893 (94.0) | 0 | 3 223 | 2 876 (89.2) | 0.8 |
| 2009-10 | 49 892 | 46 975 (94.2) | 0.2 | 3 377 | 3 012 (89.2) | 0 |

* Data sourced from: Marshall, D. AIHW(127)

Table 8-5 Laparoscopic abdominal hysterectomy; cancer versus non-cancer

| | | | | Non-cancer | | |
|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Annual increase (%) | Total N | Laparoscopic n (%) | Annual increase (%) |
| 1993-94 | 2 042 | 27 (1.3) | - | 19 932 | 289 (1.5) | - |
| 1994-95 | 2 148 | 15 (0.7) | -0.6 | 20 017 | 345 (1.7) | 0.2 |
| 1995-96 | 1 964 | 26 (1.3) | 0.6 | 18 453 | 354 (1.9) | 0.2 |
| 1996-97 | 2 039 | 21 (1.0) | 0.7 | 18 035 | 343 (1.9) | 0 |
| 1997-98 | 2 043 | 34 (1.7) | 0.7 | 17 003 | 384 (2.3) | 0.4 |
| 1998-99 | 2 153 | 84 (3.9) | 2.2 | 25 004 | 1 824 (7.3) | 5.0 |
| 1999-00 | 2 388 | 105 (4.4) | 0.5 | 31 251 | 3 255 (10.4) | 3.1 |
| 2000-01 | 2 429 | 102 (4.2) | -0.2 | 31 766 | 3 678 (11.6) | 1.2 |
| 2001-02 | 2 409 | 104 (4.3) | 0.1 | 31 966 | 4 192 (13.1) | 1.5 |
| 2002-03 | 2 397 | 110 (4.6) | 0.3 | 30 173 | 3 760 (12.5) | -0.6 |
| 2003-04 | 2 412 | 107 (4.4) | -0.2 | 29 576 | 3 852 (13.0) | 0.5 |
| 2004-05 | 2 484 | 128 (5.2) | 0.8 | 28 844 | 4 061 (14.1) | 0.6 |
| 2005-06 | 2 482 | 157 (6.3) | 1.1 | 27 856 | 4 144 (14.9) | 0.8 |
| 2006-07 | 2 598 | 170 (6.5) | 0.2 | 27 239 | 3 988 (14.6) | -0.3 |
| 2007-08 | 2 614 | 209 (8.0) | 1.5 | 27 240 | 4 081 (15.0) | 0.4 |
| 2008-09 | 2 767 | 459 (16.6) | 8.6 | 26 166 | 5 332 (20.4) | 5.4 |
| 2009-10 | 2 875 | 529 (18.4) | 1.8 | 26 397 | 5 752 (21.8) | 1.4 |

Table 8-6 Laparoscopic hysterectomy; cancer versus non-cancer

| | Cancer | | | | Non-cancer | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Vaginal Hysterectomy | Open abdominal | Total N | Laparoscopic n (%) | Vaginal Hysterectomy | Open abdominal |
| 1993-94 | 2 153 | 27 (1.3%) | 111 (5.2%) | 2 015 (93.6%) | 32 649 | 289 (1.4%) | 12 717 (39.0%) | 19 643 (60.2%) |
| 1994-95 | 2 297 | 15 (1.7%) | 149 (6.5%) | 2 133 (92.9%) | 34 121 | 345 (1.7%) | 14 104 (41.3%) | 19 672 (57.7%) |
| 1995-96 | 2 109 | 26 (1.2%) | 145 (6.9%) | 1 938 (91.9%) | 32 907 | 354 (1.9%) | 14 454 (43.9%) | 18 099 (55.0%) |
| 1996-97 | 2 192 | 21 (1.0%) | 153 (7.0%) | 2 018 (92.1%) | 33 523 | 343 (1.9%) | 15 488 (46.2%) | 17 692 (52.8%) |
| 1997-98 | 2 231 | 34 (1.5%) | 188 (8.4%) | 2 009 (90.0%) | 32 106 | 384 (2.3%) | 15 103 (47.0%) | 16 619 (51.8%) |
| 1998-99 | 2 403 | 84 (3.5%) | 250 (10.4%) | 2 069 (86.1%) | 38 397 | 1824 (7.3%) | 13 393 (34.9%) | 23 180 (60.4%) |
| 1999-00 | 2 736 | 105 (3.8%) | 348 (12.7%) | 2 283 (83.4%) | 43 364 | 3 255 (10.4%) | 12 113 (27.9%) | 27 996 (64.6%) |
| 2000-01 | 2 755 | 102 (3.7%) | 326 (11.8%) | 2 327 (84.5%) | 43 695 | 3 678 (11.6%) | 11 929 (27.3%) | 28 088 (64.3%) |
| 2001-02 | 2 790 | 104 (3.7%) | 381 (13.7%) | 2 305 (82.6%) | 43 924 | 4 192 (13.1%) | 11 958 (27.2%) | 27 774 (63.2%) |
| 2002-03 | 2 776 | 110 (4.0%) | 379 (13.7%) | 2 287 (82.4%) | 41 911 | 3 760 (12.5%) | 11 738 (28.0%) | 26 413 (63.0%) |
| 2003-04 | 2 810 | 107 (3.8%) | 398 (14.2%) | 2 305 (82.0%) | 41 204 | 3 852 (13.0%) | 11 628 (28.2%) | 25 724 (62.4%) |
| 2004-05 | 2 908 | 128 (4.4%) | 424 (14.6%) | 2 356 (81.0%) | 40 092 | 4 061 (14.1%) | 11 248 (28.1%) | 24 783 (61.8%) |
| 2005-06 | 2 915 | 157 (5.4%) | 433 (14.9%) | 2 325 (79.8%) | 38 478 | 4 144 (14.9%) | 10 622 (27.6%) | 23 712 (61.6%) |
| 2006-07 | 3 061 | 170 (5.6%) | 463 (15.1%) | 2 428 (79.3%) | 37 399 | 3 988 (14.6%) | 10 160 (27.2%) | 23 251 (62.2%) |
| 2007-08 | 3 107 | 209 (6.7%) | 493 (15.9%) | 2 405 (77.4%) | 37 410 | 4 081 (15.0%) | 10 170 (27.2%) | 23 159 (61.9%) |
| 2008-09 | 3 323 | 459 (13.8%) | 556 (16.7%) | 2 308 (69.5%) | 36 075 | 5 332 (20.4%) | 9 909 (27.5%) | 20 834 (57.8%) |
| 2009-10 | 3 452 | 529 (15.3%) | 557 (16.7%) | 2 346 (68.0%) | 36 212 | 5 752 (21.8%) | 9 815 (27.1%) | 20 645 (57.0%) |

Table 8-7 Colorectal resection; cancer versus non-cancer

| | Cancer | | | Non-cancer | | |
|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Annual increase (%) | Total N | Laparoscopic n (%) | Annual increase (%) |
| 1993-94 | 7 398 | 161 (2.2) | - | 7 438 | 184 (2.5) | - |
| 1994-95 | 8 131 | 129 (1.6) | -0.6 | 8 079 | 233 (2.9) | 0.4 |
| 1995-96 | 8 279 | 143 (1.7) | 0.1 | 8 152 | 256 (3.1) | 0.3 |
| 1996-97 | 8 647 | 125 (1.5) | -0.2 | 8 510 | 340 (4.0) | 0.9 |
| 1997-98 | 8 875 | 137 (1.5) | 0 | 8 902 | 373 (1.2) | -2.8 |
| 1998-99 | 9 116 | 160 (7.8) | 6.3 | 7 664 | 447 (5.8) | 4.6 |
| 1999-00 | 9 380 | 187 (2.0) | 5.8 | 6 829 | 442 (6.5) | 0.7 |
| 2000-01 | 9 843 | 200 (2.0) | 0 | 6 956 | 550 (7.9) | 1.4 |
| 2001-02 | 9 972 | 279 (2.8) | 0.8 | 6 921 | 584 (8.4) | 0.5 |
| 2002-03 | 10 078 | 360 (3.6) | 0.8 | 7 207 | 737 (10.3) | 1.9 |
| 2003-04 | 9 973 | 510 (5.1) | 1.5 | 7 269 | 938 (12.9) | 2.6 |
| 2004-05 | 10 081 | 953 (9.5) | 4.4 | 7 463 | 1 358 (18.2) | 5.3 |
| 2005-06 | 10 326 | 1 539 (14.9) | 5.4 | 7 615 | 1 521 (20.0) | 1.8 |
| 2006-07 | 10 907 | 2 109 (19.3) | 4.4 | 7 753 | 1 849 (23.9) | 3.9 |
| 2007-08 | 11 303 | 2 596 (23.0) | 3.7 | 7 616 | 1 952 (25.6) | 1.7 |
| 2008-09 | 11 056 | 3 179 (28.8) | 5.8 | 7 735 | 2 200 (28.4) | 2.8 |
| 2009-10 | 10 953 | 3 639 (33.2) | 4.4 | 7 891 | 2 459 (31.2) | 2.8 |

Table 8-8 Laparoscopic partial nephrectomy; cancer versus non-cancer

| | Cancer | | | Non-cancer | | |
|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Annual increase (%) | Total N | Laparoscopic n (%) | Annual increase (%) |
| 1993-94 | 40 | 0 (0) | - | 130 | 5 (3.9) | - |
| 1994-95 | 68 | 0 (0) | - | 126 | 0 (0) | -3.9 |
| 1995-96 | 50 | 0 (0) | - | 139 | 3 (2.2) | 2.2 |
| 1996-97 | 80 | 0 (0) | - | 142 | 5 (3.5) | 1.3 |
| 1997-98 | 82 | 0 (0) | - | 143 | 7 (4.9) | 1.4 |
| 1998-99 | 92 | 0 (0) | - | 158 | 13 (8.2) | 3.3 |
| 1999-00 | 125 | 5 (4.0) | 4.0 | 154 | 9 (5.8) | -2.4 |
| 2000-01 | 117 | 0 (0) | -4.0 | 102 | 0 (0) | -5.8 |
| 2001-02 | 154 | 0 (0) | 0 | 138 | 1 (0.7) | 0.7 |
| 2002-03 | 180 | 12 (6.7) | 6.7 | 135 | 16 (11.9) | 11.2 |
| 2003-04 | 195 | 19 (9.7) | 3.0 | 149 | 20 (13.4) | 1.5 |
| 2004-05 | 252 | 34 (13.5) | 3.8 | 159 | 27 (17.0) | 3.6 |
| 2005-06 | 302 | 56 (18.5) | 5.0 | 162 | 39 (24.1) | 7.1 |
| 2006-07 | 324 | 76 (23.5) | 5.0 | 182 | 44 (24.2) | 0.1 |
| 2007-08 | 345 | 86 (24.9) | 1.4 | 157 | 44 (28.0) | 3.8 |
| 2008-09 | 401 | 123 (30.7) | 5.8 | 197 | 63 (32.0) | 4.0 |
| 2009-10 | 500 | 162 (32.4) | 1.7 | 222 | 75 (33.8) | 1.8 |

Table 8-9 Laparoscopic radical nephrectomy; cancer versus non-cancer

| | Cancer | | | Non-cancer | | |
|---|---|---|---|---|---|---|
| Year | Total N | Laparoscopic n (%) | Annual increase (%) | Total N | Laparoscopic n (%) | Annual increase (%) |
| 1993-94 | 1 296 | 3 (0.2) | - | 992 | 16 (1.6) | - |
| 1994-95 | 1 391 | 2 (0.1) | -0.1 | 1 024 | 20 (2.0) | 0.4 |
| 1995-96 | 1 426 | 1 (0.1) | 0 | 1 056 | 33 (3.1) | 1.1 |
| 1996-97 | 1 461 | 0 (0.0) | -0.1 | 1 125 | 25 (2.2) | -0.9 |
| 1997-98 | 1 613 | 3 (0.2) | 0.2 | 1 130 | 46 (4.1) | 1.9 |
| 1998-99 | 1 686 | 12 (0.7) | 0.5 | 1 019 | 46 (4.5) | 0.4 |
| 1999-00 | 1 699 | 67 (3.9) | 3.2 | 893 | 101 (11.3) | 6.8 |
| 2000-01 | 1 700 | 177 (10.4) | 6.5 | 849 | 128 (15.1) | 3.8 |
| 2001-02 | 1 668 | 234 (14.0) | 3.6 | 844 | 188 (22.3) | 7.2 |
| 2002-03 | 1 692 | 387 (22.9) | 8.9 | 873 | 216 (24.7) | 2.4 |
| 2003-04 | 1 714 | 546 (31.9) | 9.0 | 784 | 232 (29.6) | 4.9 |
| 2004-05 | 1 786 | 713 (39.9) | 8.0 | 1 077 | 269 (25.0) | -4.6 |
| 2005-06 | 1 831 | 793 (43.3) | 3.4 | 943 | 418 (44.3) | 19.3 |
| 2006-07 | 1 933 | 941 (46.7) | 3.4 | 961 | 425 (44.2) | -0.1 |
| 2007-08 | 1 994 | 1 079 (54.9) | 8.2 | 908 | 473 (52.1) | 7.9 |
| 2008-09 | 1 974 | 1 181 (59.8) | 4.9 | 1 000 | 510 (51.0) | -1.1 |
| 2009-10 | 1 972 | 1 230 (62.4) | 2.6 | 904 | 487 (53.9) | 2.9 |

# Chapter 9 Discussion

Laparoscopic resection is a safe, effective and accepted treatment for patients with CRC. Patients having laparoscopic resection have a better overall experience than those having open resection because they encounter less intraoperative blood loss, reduced pain, reduced postoperative ileus and shorter hospital stay, and improved pulmonary function and quality of life.(21) Almost all patients with CRC are suitable for laparoscopic resection provided that they are treated by appropriately trained and experienced surgeons.

The population is aging and because CRC primarily affects the older population, the number of elective colorectal resections is likely to increase. Also, increased population screening for CRC will result in the detection of tumours which might not have otherwise come to light during the patient's life time, further increasing demand for laparoscopic resection. Further, population screening will mean that fewer cases present as emergencies; requiring emergency as opposed to elective resection will result in larger number of patients who are eligible for laparoscopic resection. An increasing proportion of patients moving from emergency to elective resection will also increase demand for laparoscopic resection.

By analysing the uptake and diffusion of laparoscopic resection, the findings reported in this thesis can be used by policy-makers to ensure equitable, evidence-based access for all CRC patients. This final chapter summarises the contribution of the studies that form this thesis to the current state of knowledge in the uptake of laparoscopic resection.

## 9.1 Overview of findings

### 9.1.1 Uptake and diffusion of laparoscopic procedures

Chapter 5 describes a moderate uptake of laparoscopic resection for CRC across Australia. The annual percentages found in Australia are slightly higher than those reported in the United Kingdom by NICE.(65, 66) However, it is possible that the Australian percentages are inflated by the high annual percentages experienced in Queensland and that some Australian states and territories have annual percentages which are similar to those in the UK. Comparison was not made between the Australian states and territories because these data were not provided by AIHW.

Although laparoscopic resection is performed in all types of hospitals (public and private, low-volume and high-volume), patients treated in private hospitals were more likely to have laparoscopic resection. Disparity in the laparoscopic percentage between private and public

hospitals and between low- and high-volume hospitals reduced after 2003/2004 when there was a large increase in the percentage across all types of hospitals.

In Queensland, there has been less disparity in uptake between hospital types. Referring to the findings in Chapter 6, although patients treated in high-volume private hospitals have been the most likely to have laparoscopic resection, the uptake of laparoscopic resection has also been rapid for the other hospital types. The exception is rectal resections in low-volume public hospitals, where very few rectal resections for cancer were performed. Rectal resections are more technically difficult to perform than segmental resections of the colon, and surgeons performing these will be among the most skilled and experienced.

Reported laparoscopic percentages for CRC also vary greatly within the US. Based on data from the University Health System Consortium, the laparoscopic percentage for CRC from 2007 to 2009 was 15%,(140) which is far less than reports of 50% from the National Inpatient Sample(70).

In Queensland, where surgeons were early and rapid adopters of the technique, there was little disparity in the uptake of laparoscopic resection by procedure type and patient characteristics. That is, even the most complex procedures involving resection of the rectum or transverse colon were performed with laparoscopic access throughout the adoption of the technique. Similarly, patients presenting with complicating clinical comorbidities or advanced cancer were also selected for laparoscopic resection. The data used in Chapter 6 provides the opportunity to perform logistic regression analysis to determine predictors of laparoscopic resection over time. However, this is a different research question and outside of the scope of this thesis and may be addressed at a later date.

No literature exists describing which patients are being selected for laparoscopic resection for CRC and whether disparities exist in the uptake between procedure and patient characteristics. A single-hospital study reported an increase in the percentage of all colorectal resections for cancer which were considered suitable for laparoscopic resection from 38% in 1994-1997 to 94% in 2002-2005 of adoption.(43) The conclusion was that among experienced surgeons, the only elective procedures not suitable for laparoscopic resection for CRC are those with a history of complicated abdominal surgery and those with threatened margins in rectal cancer predicted using MRI.(43) Patients requiring emergency resection are not suitable for laparoscopic resection and are excluded from the studies presented in this thesis.

Australian trends in the uptake of laparoscopic resection for CRC are compared with other laparoscopic procedures in Chapter 8. An association was found between the rate of uptake and the

complexity and risk associated with the procedure. Laparoscopic cholecystectomy was adopted very rapidly and almost all cholecystectomies were performed with laparoscopic access within four years of introduction. Laparoscopic hysterectomy, nephrectomy and colorectal resection are more technically complex and adoption of these procedures was much slower. Also, there were substantial variations in uptake of these procedures. Relative to laparoscopic colorectal resection, the uptake of laparoscopic hysterectomy has been very slow, while uptake of laparoscopic nephrectomy has been rapid. In fact, the uptake of laparoscopic radical nephrectomy for cancer has been more rapid than laparoscopic resection for CRC in Queensland. For colorectal resection, hysterectomy, and partial and total nephrectomy, adoption of laparoscopic approach was delayed for treatment of cancer compared with non-cancer indications. However, following the initial period of adoption, annual increases were similar for cancer and non-cancer indications.

### 9.1.2 Hospital resource implications for laparoscopic resection for colorectal cancer

In the 12 years between 1999/2000 and 2010/2011, more than 6000 Queenslanders received laparoscopic resection for CRC. Surgical teams in Queensland have performed large numbers of these procedures and are experienced in the technique. Chapter 7 describes the first study to report on the resource implications of laparoscopic resection for CRC in a location where adoption of the procedure is mature.

When adoption is mature and surgeons are experienced in the technique, laparoscopic resection for CRC is associated with equivalent surgical duration to open resection. Previous studies and meta-analyses have found laparoscopic resection is associated with longer surgical duration.(18, 35, 43, 56, 59) Patients having laparoscopic resection utilise fewer hospital resources compared with patients having open resection. After adjusting for differences between the groups (age group of patient, sex, summary stage, Charlson comorbidity index, procedure type and hospital volume), patients having laparoscopic resection had a length of stay which was one day shorter, were admitted to intensive care less frequently and for shorter duration, had equivalent surgical duration and had a total cost of hospital stay which was $2 524 less. This is the first study to examine the impact that laparoscopic resection for CRC has on healthcare facilities using data from a location where the procedure is mature; and the likely reason why this is the first study to find cost savings for laparoscopic resection compared with open resection for CRC.

## 9.2 Synthesis of findings

Increases in uptake of laparoscopic resection for CRC occurred around 2003/04, which coincided with several advancements in the field of laparoscopic resection for CRC. First, there were major improvements to the available equipment, namely the ultrasonic tissue dissector, high-definition videoendoscopy and better endoscopic stapling devices. Second, in Queensland particularly, surgeons were selecting more patients with CRC for laparoscopic resection because they had acquired adequate levels of experience. Finally, in 2004, long-term outcome data became available from one of the large RCTs, providing assurance in the long-term oncological safety of the procedure.(77)

The findings in Chapter 6 indicate that whether a patient receives laparoscopic resection for CRC is determined by access to surgical teams who have the appropriate training, skills and experience, rather than the characteristics of the patient or procedure type. Laparoscopic resection for CRC is a complex procedure requiring advanced and specialised training. Training for laparoscopic resection is hierarchical because colorectal resection includes a range of procedures of varying complexity. For instance, surgeons must acquire adequate skills and experience in performing laparoscopic segmental resection of the left or right colon before progressing to the more technically difficult resections of the rectosigmoid colon, transverse colon or extraperitoneal rectum.

It is important to ensure that surgeons have the opportunity to acquire the appropriate training and adequate experience to offer patients with CRC laparoscopic resection. Although uptake across Australia has been slow, especially in low-volume public hospitals, increases in the percentage of laparoscopic resection have been seen across all types of hospitals. This finding suggests that there is successful post-fellowship education and training of surgeons. That is, surgeons in low-volume public hospitals are gaining skills in this technique.

However, the learning curve is long and there will always be surgeons in the earlier phase of training of laparoscopic resection for CRC, meaning that unless the more complex cases are referred to the more experienced surgeons, the percentage of patients selected for laparoscopic resection will continue to fall short of the previously suggested 90% of patients who are eligible.(43) Queensland has experienced high uptake in laparoscopic resection for all procedure types and all patients, regardless of complexity. We postulate that referral pathways were established early in the adoption of this technology, ensuring that most patients had the best opportunity to receive laparoscopic resection. Although this was not a result of policy, clinicians, healthcare policy-makers, planners and budget-holders from locations that are in the earlier phase of

adoption, may consider developing service capability frameworks, such as, restricting complex procedures to major hospitals with experienced surgeons.

Health technology assessments evaluate the benefits, harms and cost-effectiveness of a new technology.(141) The evidence available for health technology assessments is usually based on experiences early in the adoption or uptake of an innovative technique. For example, the health technology assessment for laparoscopic resection for CRC conducted by the National Institute for Health and Clinical Excellence (UK) in 2006, estimated a higher cost for laparoscopic resection based on two studies from the early period of adoption.(18) The cost comparison presented in Chapter 7, shows that when the procedure is widely adopted and surgical teams are experienced in the technique, laparoscopic resection for CRC is associated with cost saving compared with open resection. It is therefore important that health technology assessments are systematically updated to include the latest available evidence.

In Australia, there is no health technology assessment for laparoscopic resection for CRC and the clinical practice guidelines have not been updated since 2005.(8) Similarly for the other laparoscopic procedures; laparoscopic hysterectomy is only addressed in the clinical practice guidelines for ovarian cancer (2004). I also did not find recommendations in the form of clinical practice guidelines or health technology assessments for laparoscopic nephrectomy, laparoscopic cholecystectomy or laparoscopic fundoplasty. While laparoscopic cholecystectomy and fundoplasty are generally considered the "gold standard" in care, the uptake of laparoscopic hysterectomy continues to be very slow. It would be appropriate to update the Australian assessment of laparoscopic hysterectomy to bring recommendation in line with recent evidence.(97) For CRC, it is important that a contemporary recommendation is available, similar to those available in the UK,(18) Europe(46) and America(43, 44).

According to Roger' theories on the dynamics of diffusion, adoption acquires its own momentum at around 15-20% of adoption of an innovation, provided that there is contact between the innovators and early adopters with the early majority and late majority (Figure 2-6).(71) Marketing techniques to implement change in medical intervention include an informal setting in which an influential person imparts their local experiences to opinion leaders.(142) Within the medical community, social influence is a major driver for individual change.(72, 143) To ensure continued uptake of innovative techniques within their jurisdictions, it is important that clinicians and members of surgical teams have opportunities to attend conferences, forums and training programs.

Evidence suggests that technological advances are generally associated with increased costs.(129) Even when technical advancement decreases the cost of providing a procedure to an individual

patient, there is more capital investment in the equipment, labour and expenses associated with the spread of knowledge.(129) In addition, greater availability is associated with greater per capita use and higher spending on those services.(129) For instance, there were rapid increases in the total number of cholecystectomies following the introduction of laparoscopic cholecystectomy. In 1998 it was reported that, in New South Wales, the unit cost for laparoscopic cholecystectomy was lower because of a shorter length of stay; however, increases in the number of procedures meant that there were no net savings for the health system.(130)

In Australia, the public healthcare system is able to contain costs in surgical innovation. For example, healthcare providers may limit the availability of specialised equipment necessary to perform the procedure, therefore limiting its uptake. Costs associated with surgical innovation are less of a problem among private hospitals where additional costs are passed on to patients and private health insurers. Consequently, the percentage of cholecystectomies that were laparoscopic in 1995 was 96% among private hospitals compared with 71% among public hospitals in New South Wales.(130) However, if patients who are able to afford private healthcare are able to access the latest technology, then there is a moral obligation to ensure equal opportunities to public patients.

The adoption of laparoscopic resection for CRC is unlikely to ever reach 100% of all eligible patients. Aside from patient preference and contra-indications for laparoscopic surgery, there will always be newer surgeons who are required to learn open surgical techniques as well as laparoscopic techniques. There will also be those who choose to perform a procedure with open access because they consider themselves not to have adequate skills and experience to perform certain procedures with laparoscopic access. For example, patients in rural settings may elect not travel to metropolitan centres for their treatment, where they are more likely to have laparoscopic resection, and the local surgeon/surgical team may choose to perform an open resection because they lack adequate experience to perform laparoscopic resection.

## 9.3 Strengths and limitations

The studies included in this thesis have several strengths.

The main strength is that these studies utilise very large government databases which are likely to show the most representative and accurate account of service use in Queensland and National populations. These datasets are not usually available to researchers to conduct extensive analysis because of concerns about the privacy of individuals.

Chapter 5, Chapter 6 and Chapter 8 are observational studies based on routinely collected population-based hospital morbidity data sources. They include information for every patient admitted for the procedures of interest to public and private hospitals. Similar to hospital morbidity data, the costing data utilised in Chapter 7 is comprised of routinely collected population-based data for all public hospital patients in Queensland. Observational studies have the ability to include a broader range of patients than those selected for inclusion in RCTs.(144) Observational studies therefore usually have a larger sample size, are not subject to the same degree of selection bias and allow for assessment of clinical practice and outcomes in the "real world".(89)

However, these databases were designed for purposes other than research which pose potential methodological issues. For example, administrative databases such as hospital morbidity data were designed for billing purposes.(89) These databases usually contain primary and secondary diagnosis, information about procedures performed and demographic information.(139) However, it has been suggested that data which directly results in reimbursement are likely to be better coded than comorbidities and complications.(138) Because they lack relevance for financial reimbursement, results for laboratory tests, pathology or radiology reports, and clinical measures such as blood pressure or height and weight are not usually recorded in population-based administrative data.(138, 139) Hospital morbidity data are routinely audited by each of the Australian states and territories to ensure complete and accurate coding of procedure and diagnosis codes. Procedure codes were the most important variable throughout this thesis; these are the main source of financial reimbursement to hospitals and are the most reliably documented codes.

In the absence of some measures of potential confounders, the inclusion of surrogate measures in risk adjustment models is better than complete omission of a construct. For example, Chapter 4 identified that summary stage for colorectal cancer determined from other diagnosis codes is a suitable surrogate measure for stage. This method was employed to adjust for potential confounders in the multivariate analyses in Chapter 7.

This research program is largely based on Queensland data, a region with advanced adoption of laparoscopic resection for CRC in Queensland. Chapter 6 and Chapter 7 present the first studies to examine clinical practice and outcomes for laparoscopic resection for CRC in a location where the adoption is mature and surgeons are experienced in the technique.

The studies included in this thesis demonstrate that routinely collected hospital data sources can provide current information on practices in surgery and patient management. Hospital morbidity data from each of Australia's states and territories are collated annually to give the National Hospital Morbidity Dataset, and information on national trends and patterns of care is available for

admission prior to the past year. State level hospital morbidity datasets, such as the Queensland data used in this research program, are more current than the national data and can provide information to within one year. Data were usually attained within six months of the initial request and retrospective data dating back to 1993 could be sourced.

For CRC, there is currently no procedure code to identify planned laparoscopic colorectal resection converted to open resection. A planned laparoscopic resection converted to an open resection due to complications at the time of surgery, are coded in the hospital morbidity data as laparoscopic. This thesis therefore presents intention-to-treat analyses. Importantly, the conversion rate for patients with CRC in Queensland was identified as 7% in the early period of adoption,(64) and has probably decreased further with increasing surgical experience.

## 9.4 Further research

Lomas wrote;

> "Even with research information that, after diffusion, has been synthesized and then disseminated by a credible body, its impact is likely to go no further than the awareness, attitude, and knowledge of the physician without active and coordinated implementation efforts."(145), p.230

This study does not address methods of effective implementation of innovative surgery, ways to improve uptake, barriers to uptake, or who the key stakeholders are in improving uptake and increasing access to laparoscopic resection for CRC. However, this would be a valuable area of research that would probably require qualitative methods. For instance, it would be beneficial to discover from health service delivery providers, including clinicians and healthcare planners, policy-makers and budget-holders, their degree of understanding around laparoscopic resection for CRC, the need to improve access and to identify what is required to implement change. This process would benefit from close collaboration with clinicians through the Colorectal Surgical Society of Australia and New Zealand, and relevant state-level health policy departments.

Regular monitoring of the implementation and diffusion of innovative techniques is important for resource management, planning of resource allocation and to ensure patients have equitable access to effective innovative techniques. This thesis has demonstrated that population-based routine data are suitable data sources to perform this function. As the custodians of these data, Queensland Health and other state and territory departments of health could investigate means to maximise the potential of these data sources; not only in terms of resources to perform data analytics, but also to

include information such as stage at diagnosis, required to conduct outcomes analysis. These data sources hold the potential to be used by Departments of Health to guide policy, perform health services research, measure the safety and effectiveness of patient care, and to understand the diffusion of innovative techniques in healthcare. While laparoscopic surgery was the innovative surgical technology in the early 1990s, robotic surgery is the current innovating technique in surgery, and, in the future, other innovative technologies will emerge. The methods used throughout this thesis as well as the potential lessons learnt from conducting studies into effective implementation techniques and enhancing the utility of government managed, routinely collected, population-based data sources may be applied to emerging technologies in the future.

## 9.5 Conclusion

Laparoscopic resection for CRC is supported by evidence from large multi-centre RCTs which have shown benefits to patients in the short-term, and equivalent oncological outcomes in the long-term. Despite this, Australia has experienced a relatively slow uptake of this procedure among public hospitals in particular. In Queensland, where there was rapid uptake of laparoscopic resection for CRC, all patients received laparoscopic resection regardless of complexity of the procedure, the extent of the disease (summary stage) and comorbidities of the patient. This suggests that the more technically difficult procedures or clinically complex cases were appropriately referred to the more experienced surgical teams. Importantly, in terms of benefits to the healthcare system, this thesis has demonstrated that laparoscopic resection for colorectal CRC is less expensive than open resection.

The research questions included in this thesis are based on routinely collected population-based data sources which are government owned and managed. These studies have been effective in demonstrating the utility of these data sources for describing uptake and differentials in patient care, as well as for measuring hospital resource utilisation.

The findings from this thesis can be used by healthcare providers including clinicians, policy-makers, budget-holders and healthcare planners, to plan and manage the uptake of laparoscopic resection for CRC.

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# Appendix 1 Data obtained for this thesis

| Research Chapter | Data source | Variables/fields accessed | Years extracted | Date data obtained | Comments |
|---|---|---|---|---|---|
| Chapter 4 | QHAPDC | Variables used for linkage:<br>Facility identifier<br>Date of Birth<br>Dates of admission and discharge<br>Date of procedure<br>Sex<br>Procedure codes<br>Variables used for analysis:<br>Secondary diagnosis codes | 1st June 2001 to 30th June 2008 | 3rd June 2009 | The years extracted from QHAPDC was determined by the data available from the clinical cancer registry.<br>De-identified patient level data. |
| Chapter 5 | NHMD | Aggregated data with counts for the numerator (laparoscopic) and denominator (all resections for CRC). The counts were stratified by the following:<br>- Public hospital/private hospital<br>- Low volume/high volume (40+ resection CRC/year)<br>- Segmental resections of the colon / rectal resections<br>- Year (e.g. 1999/00, 2000/01) | 1st July 1999 to 30th June 2008 | 22nd February 2010 | This date range was determined by implementation of the ICD-10 (as opposed to ICD-9), until the most recent available data at the time of extraction.<br>Cohort:<br>All hospital admissions with a diagnosis code for CRC and a concurrent procedure code for resection of the colon or rectum. |

| Research Chapter | Data source | Variables/fields accessed | Years extracted | Date data obtained | Comments |
|---|---|---|---|---|---|
| Chapter 6 | QHAPDC | - Public hospital/private hospital<br>- High volume (Yes/No) (40+ resection CRC/year)<br>- Sex<br>- Age (years)<br>- ARIA+<br>- SEIFA<br>- Year (e.g. 1999/00, 2000/01)<br>- Length of stay (days)<br>- ICU admission (Yes/No)<br>- Elective/Emergency admission<br>- Death within 30 days of discharge (Yes/No)<br>- Death within 30 days of procedure (Yes/No)<br>- Principle Diagnosis<br>- Other diagnoses (1 to 47)<br>- Procedure (1 to 64) | 1st July 1999 to 30th June 2011 | 24th February 2012 | This date range was determined by implementation of the ICD-10 (as opposed to ICD-9), until the most recent available data at the time of extraction.<br>De-identified patient level data.<br>Cohort:<br>All hospital admissions with a diagnosis code for CRC and a concurrent procedure code for resection of the colon or rectum. |

| Research Chapter | Data source | Variables/fields accessed | Years extracted | Date data obtained | Comments |
|---|---|---|---|---|---|
| Chapter 7 | Transition II | - Sex<br>- Age (years)<br>- Procedure code (1 to 3) (resection of the colon or rectum only)<br>- Principle diagnosis (CRC only)<br>- Laparoscopic procedure code (Yes/No)<br>- LOS (days)<br>- Date of admission<br>- Date of discharge<br>- Days admitted to ICU<br>- Total cost of admission<br>- Total cost of theatre<br>- Total cost of anaesthesia<br>- Total cost of imaging<br>- Total cost of pharmacy<br>- Total cost of pathology<br>- Duration of anaesthesia (mins)<br>- Duration of surgery (mins) | 1st July 2009 to 30th June 2011 | 15th August 2011 | Two years of the most recently available data were considered appropriate as it would provide adequate sample size.<br>Cohort:<br>All public hospital admissions with a diagnosis code for CRC and a concurrent procedure code for resection of the colon or rectum. |

| Research Chapter | Data source | Variables/fields accessed | Years extracted | Date data obtained | Comments |
|---|---|---|---|---|---|
| Chapter 8 | NHMD | - Year<br>- Procedures (1 to 5)<br>- Diagnosis (1 to 3) | 1st July 1993 to 30th June 2010 | 25th January 2012 | Procedure and diagnoses were provided for a specified list only. For most procedure types. the 2nd to 4th procedure codes identified a concurrent laparoscopic code, while procedure code 1 determined the major procedure type (e.g. liver resection). |

Note: QHAPDC = Queensland Hospital Admitted Patients Data Collection, NHMD = National Hospital Morbidity data