THE UNIVERSITY OF QUEENSLAND

AUSTRALIA

THE EMERGENCY DEPARTMENT (ED)-INPATIENT INTERFACE: IMPROVING THE CARE OF PATIENTS REQUIRING EMERGENCY ADMISSION TO HOSPITAL

Andrew Nathan Staib

MBBS, FACEM, FACHI

A thesis submitted for the degree of Doctor of Philosophy at

The University of Queensland in 2019

Faculty of Medicine

Abstract

Background

Access to emergency hospital care is a key element of any health system and the focus of considerable media and political attention. Emergency Department (ED) overcrowding is a common topic of public debate.

Patients who require admission to the inpatient ward from the ED are a vulnerable group. Optimising the care of these patients requires a "whole of hospital response" involving ED and inpatient clinical processes. Digital transformation of these processes of care is intended to assist in this optimisation.

Despite major health policy interventions in the area of emergency access and ED overcrowding, the Emergency Department-Inpatient interface (EDii) is poorly defined and characterised in the literature. Many major interventions have been undertaken to improve the EDii with a limited evidence base, and without robust methods of assessing the impact on patient outcomes.

Hypotheses and Aims

The working hypotheses tested and developed were that:

a. the EDii is an important, but as yet poorly characterised aspect of the healthcare system
b. the EDii is consequential because impaired EDii function is associated with impaired patient outcomes and improving the function of the EDii is associated with better patient outcomes.
c. the digitisation of the EDii via the introduction of an integrated electronic medical record (ieMR) would initially slow EDii time-based performance due to the effort of clinicians adapting to a new system, but that patient clinical outcomes may improve due to greater availability to all teams of integrated clinical information.

The work was divided into three study areas with the below aims:

1. Study Area 1- Characterisation and Definition of EDii
    - To develop a sound conceptual understanding of the EDii through review and synthesis of the existing literature. An accurate definition of EDii, its size, scope and function will assist to inform further research and evidence-based clinical redesign of this important interface to improve outcomes for patients.
2. Study Area 2- Linking of Process and Outcome Measures at the EDii
    - To demonstrate that improving a process measure of EDii function (compliance with the National Emergency Access Target (NEAT)) is associated with improved patient outcomes as measured by mortality.
    - Use an understanding of the EDii to develop a clinically useful tool to link relevant EDii process and patient outcome measures.
3. Study Area 3- The Digitisation of EDii
    - To characterise the impact of digital transformation of the EDii on hospital process measures and clinically sensitive outcome measures for patients requiring emergency admission to hospital.

Methodology

Study Area 1:

A characterisation and definition of the EDii was developed from a systematic literature review and narrative synthesis.

Study Area 2:

An analysis of the association between EDii efficiency (as measured by NEAT) and patient outcomes (as measured by risk-adjusted in-hospital mortality) was undertaken using a retrospective observational study covering the 4-year period from 1 July 2010 to 30 June 2014. This

period is highly relevant because it spanned the introduction and subsequent focus on the NEAT by the Australian government. This study analysed over 11 million ED episodes of care and 12 million inpatient episodes of care.

The links between improved EDii processes and inpatient outcomes were emphasised by the development of a clinical and quality dashboard tool to display the clinically important measures in a way that was relevant for clinical and organisational decision making.

Study Area 3:

Research into the impacts of digital transformation on the EDii involved a pre-post intervention study using administrative and clinical data involving all patients presenting to the ED between 28/11/2014 and 28/2/2017. For the purposes of comparative analysis and to minimise the impact of seasonal effects, two twelve-month periods were compared. In addition, longitudinal monthly data for ED 4-hour rule compliance was obtained over the study period.

Results

Study Area 1:

The EDii is a critical operating system for acute hospitals. ***The EDii can be defined as the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.***

The literature to date has included information which has been synthesised here to define and characterise this interface. It involves the sickest and most vulnerable patients in the hospital system, and improvements in EDii function have the ability to improve efficiency for hospitals and outcomes for patients on a large scale.

The EDii is important for individual patients, hospital function and the healthcare system as a whole.

Study Area 2:

A significant correlation between process measures of EDii function and an important patient outcome (risk-adjusted in-hospital mortality rate) was demonstrated using a large Australian dataset. This relationship was not maintained at the very high levels of compliance which were prescribed by the health policy at the time.

A clinically useful dashboard was developed using an understanding of this relationship. This dashboard was adopted by sites to monitor EDii function and patient outcomes and to encourage confidence in clinical redesign at the EDii.

Study Area 3:

Digital transformation of the EDii had a transient negative impact on process measures of the EDii, but without any evidence of worsening of patient outcomes. The safe introduction of an integrated digital platform provided potential for integrated, improved care of the individual patient, a more reliable system and transformation of patient care at the EDii.

Implications

With a clearer definition of the EDii in hand, research on how to improve the EDii to improve patient care and hospital performance will be able to proceed more systematically. The exploration of important problematics and explanations provided in this work will be used to put forth formal hypotheses that can be tested in future research. Health policy in this area is now increasingly evidence-based, and the principles learned in the development of this work are now applied in other high-risk clinical areas and interfaces.

The EDii is a critical operating system for acute hospitals. Demonstrating the association between 4-hour rule compliance and in-hospital mortality for patients who traversed the EDii provided increased focus on patient outcomes and enabled evidence-based policy re-alignment in many states of Australia.

Development of the EDii Dashboard was followed by rapid uptake in many EDs and the published principles and lessons learned applied to other areas of clinical streaming analytics in Queensland Hospitals.

The understanding that during digital transformation, digital deceleration will occur, but that worsening of key patient outcomes is not likely to occur now holds a key place in planning for digital transformation of the EDii.

Building further on this knowledge by using the wealth of integrated clinical data provided by digital transformation will enable even greater improvements in outcomes and efficiency through clinical redesign of the EDii.

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, financial support 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 higher degree by research 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.

I acknowledge that an electronic copy of my thesis must be lodged with the University Library and, subject to the policy and procedures of The University of Queensland, the thesis be made available for research and study in accordance with the Copyright Act 1968 unless a period of embargo has been approved by the Dean of the Graduate School.

I acknowledge that copyright of all material contained in my thesis resides with the copyright holder(s) of that material. Where appropriate I have obtained copyright permission from the copyright holder to reproduce material in this thesis and have sought permission from co-authors for any jointly authored works included in the thesis.

Publications included in this thesis

1. Staib, A., Sullivan, C., Jones, M., Griffin, B., Bell, A., & Scott, I. (2016). The ED-inpatient dashboard: uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emergency Medicine Australasia*. doi: 10.1111/1742-6723.12661
2. Sullivan, C., Staib, A., Khanna, S., Good, NM., Boyle, J., Cattell, R., Heiniger, L., Griffin, BR., Bell, A., Lind, J., & Scott, IA. (2016). The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *Medical Journal of Australia* 2016 May 16: 204(9), 354e1-5. doi: 10.5694/mja15.01177
3. Staib, A., Sullivan, C., Prins, J., Burton-Jones, A., Fitzgerald, G., & Scott, I. (2017). Uniting emergency and inpatient clinicians across the ED-inpatient interface: the last frontier? *Emergency Medicine Australasia*. doi: 10.1111/1742-6723.12883

Chapter 2 of this thesis was subsequently condensed, modified and published as

1. Staib, A., Sullivan, C., Prins, J., Burton-Jones, A., Fitzgerald, G., & Scott, I. (2017). Uniting emergency and inpatient clinicians across the ED-inpatient interface: the last frontier? *Emergency Medicine Australasia*. 2017 Dec:29(6):740-745 doi: 10.1111/1742-6723.12883

Contributor	Statement of contribution
Andrew Staib (Candidate) (‡*co-first author)*	Conception and design (40%) Analysis and interpretation (40%) Drafting and production (40%)
Clair Sullivan (‡*co-first author)*	Conception and design (35%) Analysis and interpretation (40 %) Drafting and production (40%)
John Prins	Conception and design (5%) Analysis and interpretation (5%) Drafting and production (5%)
Andrew Burton Jones	Conception and design (10%) Analysis and interpretation (5 %) Drafting and production (5%)

Gerry Fitzgerald	Conception and design (5%) Analysis and interpretation (5 %) Drafting and production (5%)
Ian Scott	Conception and design (5%) Analysis and interpretation (5 %) Drafting and production (5%)

2. Sullivan, C., Staib, A., Khanna, S., Good, NM., Boyle, J., Cattell, R., Heiniger, L., Griffin, BR., Bell, A., Lind, J., & Scott, IA. (2016). The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *Medical Journal of Australia.* 2016 May 16:204(9), 354e1-5. doi: 10.5694/mja15.01177

Incorporated as Chapter 3 of this thesis.

Contributor	Statement of contribution
‡Dr Andrew Staib MBBS FACEM (‡*co-first author)* (Candidate)	Conception and design (30%) Analysis and interpretation (25%) Drafting and production (30%)
Dr Clair Sullivan MBBS (Hons) MD FRACP *(‡ co-first author)*	Conception and design (30%) Analysis and interpretation (25%) Drafting and production (30%)
Dr Sankalp Khanna	Conception and design (7%) Analysis and interpretation (10%) Drafting and production (5%)
Mr Norm M Good	Conception and design (7%) Analysis and interpretation (10%) Drafting and production (5%)
Dr Justin Boyle	Conception and design (7%) Analysis and interpretation (10%) Drafting and production (5%)
Dr Rohan Cattell	Conception and design (7%) Analysis and interpretation (5%)

	Drafting and production (5%)
Mr Liam Heiniger	Conception and design (1%) Analysis and interpretation (5%) Drafting and production (2.5%)
Dr Bronwyn Griffin	Conception and design (2%) Analysis and interpretation (2%) Drafting and production (2.5%)
Associate Professor Anthony Bell	Conception and design (3%) Analysis and interpretation (2%) Drafting and production (2.5%)
Dr James Lind	Conception and design (3%) Analysis and interpretation (2%) Drafting and production (2.5%)
Associate Professor Ian Scott	Conception and design (3%) Analysis and interpretation (4%) Drafting and production (10%)

3. Staib, A., Sullivan, C., Jones, M., Griffin, B., Bell, A., & Scott, I. (2016). The ED-inpatient dashboard: uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emergency Medicine Australasia*. 2017 Jun; 29(3):363-366 .doi: 10.1111/1742-6723.12661

Incorporated as Chapter 4 of this thesis.

Contributor	Statement of contribution
Dr Andrew Staib MBBS FACEM (‡*co-first author)* (Candidate)	Conception and design (40%) Analysis and interpretation (35%) Drafting and production (35%)
Dr Clair Sullivan MBBS (Hons) MD FRACP *(‡ co-first author)*	Conception and design (40%) Analysis and interpretation (35 %) Drafting and production (35%)
Mr Matt Jones	Conception and design (5%) Analysis and interpretation (15%)

	Drafting and production (5%)
Dr Bronwyn Griffin	Conception and design (5%) Analysis and interpretation (5%) Drafting and production (5%)
Associate Professor Anthony Bell	Conception and design (5%) Analysis and interpretation (5%) Drafting and production (5%)
Associate Professor Ian Scott	Conception and design (5%) Analysis and interpretation (5%) Drafting and production (15%)

Submitted manuscripts included in this thesis

Staib, A., Sullivan, C., Cabilan, CJ., Cattell, R., Eley, R. (2018). Digital transformation of the emergency department-inpatient interface (EDii): integration for future innovation. *Australian Health Review* accepted for publication subject to minor revisions

Chapter 5 was subsequently modified and submitted for publication to Australian Health Review.

Contributor	Statement of contribution
Andrew Staib (Candidate)	Conception and design (55%) Analysis and interpretation (50%) Drafting and production (50%)
Clair Sullivan	Conception and design (25%) Analysis and interpretation (25 %) Drafting and production (35%)
Rob Eley	Conception and design (5%) Analysis and interpretation (5%) Drafting and production (10%)
Cara-Joyce Cabilan	Conception and design (10%) Analysis and interpretation (15 %)

	Drafting and production (5%)
Rohan Cattell	Conception and design (5%) Analysis and interpretation (5 %) Drafting and production (0%)

Publications during candidature

Peer Reviewed Publications:

1. Eden, R. Anghapur, S.,Burton-Jones A, **Staib, A** and Sullivan, C (2017) Unpacking the Complexity of Consistency: Insights from a Grounded Theory Study of the Effective Use of Electronic Medical Records *Procs HICCS* Jan (1-10)
2. Scott, I., Sullivan, C., Staib, A., & Bell, A. (2017). Deconstructing the 4-h rule for access to emergency care and putting patients first. *Australian Health Review*. doi: 10.1071/AH17083
3. Scott, I., Sullivan, C., and Staib, A. (2018) Going digital: a checklist in preparing for hospital-wide electronic medical record implementation and digital transformation, *Australian Health Review* in press online early epub 23/05/2018. Doi: 10.1071/AH17153
4. Eden, R., Burton-Jones, A., Scott, I., Staib, A., & Sullivan, CM. (2017). The impacts of eHealth upon hospital practice: synthesis of the current literature. *Deeble Institue Evidence Briefs, 16.* Retrieved from https://ahha.asn.au/system/files/docs/publications/impacts_of_ehealth_2017.pdf
5. Lawley, M., Truran, D., Hansen, D., Good, N., Staib, A., & Sullivan, C. (2017). SnoMAP: Pioneering the Path for Clinical Coding to Improve Patient Care *Studies in health technology and informatics*[IOS Press edition]. doi: 10.3233/978-1-61499-783-2-55
6. Staib, A., Sullivan, C., Prins, J., Burton-Jones, A., Fitzgerald, G., & Scott, I. (2017). Uniting emergency and inpatient clinicians across the ED-inpatient interface: the last frontier? *Emergency Medicine Australasia*. 2017;29(6):740-5. doi: 10.1111/1742-6723.12883
7. Sullivan, C., & Staib, A. (2017). Digital disruption 'syndromes' in a hospital: important considerations for the quality and safety of patient care during rapid digital transformation. *Australian Health Review*. 2018;42(3):294-8 doi:10.1071/AH16294
8. Keasberry, J., Scott, IA., Sullivan, C., Staib, A., & Ashby, R. (2017). Going digital: a narrative overview of the clinical and organisational impacts of eHealth technologies in hospital practice. *Australian Health Review*.2017;41(6):646-64 doi: 10.1071/AH16233
9. Hughes, JA., Cabilan, CJ., Young, C., & Staib, A. (2017). Effect of the 4-h target on time-to-ECG. *Australian Health Review*. 2018;42(2):196-202 doi 10.1071/AH16263
10. Sullivan, C., Staib, A., Ayre, S., Daly, M., Collins, R., Draheim, M., & Ashby, R. (2016). Pioneering digital disruption: Australia's first integrated digital tertiary hospital. *Medical Journal of Australia, 205*(9), 386-389. doi: 10.5694/mja16.00476
11. Sullivan, C., Staib, A., Khanna, S., Good, NM., Boyle, J., Cattell, R., Heiniger, L., Griffin, BR., Bell, A., Lind, J., & Scott, IA. (2016). The

National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *Medical Journal of Australia, 204*(9), 354e1-5. doi: 10.5694/mja15.01177
12. Staib, A., Sullivan, C., Jones, M., Griffin, B., Bell, A., & Scott, I. (2017). The ED-inpatient dashboard: uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emergency Medicine Australasia*. 2017;29(3):363-6 doi: 10.1111/1742-6723.12661

Conference Presentations:

1. "Digital transformation of the ED-inpatient interface (EDii): integration for innovation" Australasian College for Emergency Medicine Annual Scientific Meeting. 2018, November 20; Perth, Australia.

2. "Whole of Hospital Response to Access Block: Making the EDii work" Australasian College for Emergency Medicine Annual Scientific Meeting. 2018, November 20; Perth, Australia.

3. "Digital Transformation of the ED-Inpatient Interface (EDii): integration for future innovation" International Hospital Federation World Hospital Congress 10-12 October 2018: Brisbane, Australia.
4. "Evaluating Digital Transformation in Healthcare: An Institutional Theory Perspective." Invited Speaker. Research Impact and Creation of Knowledge Meeting. Judge Business School, Cambridge University. 10-11 June 2018: Cambridge United Kingdom.
5. "Integrated Emergency Medicine, the next frontier: beyond process improvement towards a patient-focussed future". Invited Speaker. 34th ACEM Annual Scientific Meeting. 19-23 November 2017; Sydney, Australia.
6. "Digital Disruption preparing and smoothing the path to large scale digital transformation". Invited Speaker. 34th ACEM Annual Scientific Meeting. 19-23 November 2017; Sydney, Australia.
7. "Digital Transformation of Clinical Care". Invited Speaker, 41st World Hospital Congress. International Hospital Federation. 7 November 2017; Taipei, Taiwan
8. "Digital Transformation of Healthcare". Invited Speaker. Australian Medical Association Private Practice and Medico-legal Conference. 6 October 2017; Brisbane, Australia.
9. "The Benefit of Collaborative Research on Service Delivery". Invited Speaker .EMF 10-year Research Symposium. 25 August 2017; Brisbane, Australia.

10. “SnoMAP: Pioneering the Path for Clinical Coding to improve patient care” and “The CXIO experience of an EMR implementation”. HIC 2017. 6-9 August 2017; Brisbane, Australia.
11. “Digital changes in trauma management”. Invited Speaker. Princess Alexandra Hospital Health Symposium. 1-4 August 2017; Brisbane, Australia.
12. “Realising the promise of digital hospitals – lower harm, improved reliability and efficiency”. 2017 Clinical Excellence Showcase. Panel discussion. 1-2 June 2017; Brisbane, Australia.
13. “Digital Device Integration”. Australian Regional User Group Conference. 17-19 May 2017; Brisbane, Australia.
14. “The Digital Hospital: The daw of Big data in Emergency Care”. Invited Speaker. 13th ACEM Queensland Autumn Symposium. 25-26 May 2017; Brisbane, Australia.
15. “Digital Hospital – Implementation, impact on patient safety and lessons learned”. Statewide Anaesthesia and Periop Care Clinical Network (SWAPNET). 20 April 2017; Brisbane, Australia.

Contributions by others to the thesis

Significant contributions to the individual chapters are detailed above.
I am grateful to my advisory team of Dr Clair Sullivan, Prof Andrew Burton Jones and Prof John Prins for their guidance and assistance with conception, design and drafting of this thesis.

Statement of parts of the thesis submitted to qualify for the award of another degree

No works submitted towards another degree have been included in this thesis

Research Involving Human or Animal Subjects

All research involving human or animal subjects requires prior ethical review and approval by an independent review committee. At UQ, the relevant committee for research involving human subjects is the Human Ethics Unit

and the relevant committee for research involving animal subjects is the relevant Animal Ethics Committee.

Copies of ethics approvals and exemption letters are included as appendix F.

Chapter 2: EDii Literature review

No animal or human subjects were involved in this research.

Chapter 3: Linking Process Measures and Outcomes

An ethics approval exemption was provided by the Metro South Health Human Research Ethics Committee (reference, HREC/15/QPAH/233).

Chapter 4: Development of a Dashboard

No animal or human subjects were involved in this research

Chapter 5: Digital Transformation of the EDii

This project was considered exempt from requiring formal ethical review by the Metro South Human Research Ethics Committee (HREC/17/QPAH/107).

Acknowledgements

In addition to the listed co-authors of the resultant publications I would like to acknowledge the valuable contributions of:

Mr Michael Zanco, Executive Director Healthcare Improvement Unit, Clinical Excellence Division, Queensland Department of Health.

Dr Richard Ashby, CEO Metro South Health, and CIO and Chief Executive eHealth Queensland

Dr Susan O'Dwyer, Executive Director Medical Services, Metro South Health

Linda McCormack and Julie-Anne Jaques Health Innovation Unit, Queensland Department of Health

Mr Michael Draheim, Stephen Canaris and Mr Cameron Ballantine Princess Alexandra Hospital

Mr Rob Eley, Cara Joyce Cabilan, Bernadette McKenna and Chantelle Judge Princess Alexandra Hospital(PAH) Emergency Department

Michelle Winning and the Clinical Service Excellence Team (CSET) PAH

Amanda Vaux, Lisa Tewhatu and David Moore and the PAH ICU outreach team.

I would also like to acknowledge the support and sponsorship of the Chair (Dr David Rosengren) and the membership of the Queensland Clinical Senate

Financial support

Aspects of this research were supported by funding provided by the Healthcare Improvement unit, Clinical Excellence Division, Queensland Health

Keywords

emergency department-inpatient interface, emergency admission, dashboard, digital disruption, digital transformation, clinical informatics

Australian and New Zealand Standard Research Classifications (ANZSRC)

ANZSRC code: 080702 Library and Information Studies (Health Informatics), 25%

ANZSRC code: 110305 Emergency Medicine, 50%

ANZSRC code: 111709 Health and Community Services Research, 25%

Fields of Research (FoR) Classification

0807 Library and Information Studies (Health Informatics), 25%

1103 Medical and Health Sciences (Emergency Medicine) 50%

1605 Public and Health Services, 25%

Table of Contents

List of Figures and Tables

Figures

Tables

List of Abbreviations

CSIRO: Commonwealth Scientific and Industrial Research Organisation

ED: Emergency Department

EDii: Emergency Department-Inpatient Interface

EDIS: Emergency Department Information System

eHSMR: The standardised mortality ratio as calculated by the Health Roundtable using validated methodology for patients admitted into hospital via the ED

HRT: The Health Roundtable Ltd

HSMR: The standardised mortality ratio as calculated by the Health Roundtable using validated methodology for all patients admitted into hospital

ICU: Intensive Care Unit

NEAT: National Emergency Access Target

PAH: Princess Alexandra Hospital

RRT: Rapid Response Team

Chapter 1

Introduction

Access to emergency hospital care is a key element of any health system and is the focus of considerable media and political attention. Emergency Department (ED) overcrowding and ambulance access to emergency departments (ramping or diversion) are common public topics of debate.[1,2]

A primary reason for this interest is that public expectations for the timeliness of emergency care are often not met.[3] Understandably, this public dissatisfaction results in bureaucratic and political pressure on hospitals to improve the timeliness of emergency care. This is a difficult task for hospitals in an environment of resource constraint and increasing demand for care.

There are two main cohorts of patients who present for emergency care: those who can be discharged home from the ED and those who require emergency admission to an inpatient ward. Improving the timeliness of care of patients who can be discharged home from the ED can be achieved by predominantly ED-based interventions with limited whole-of-hospital involvement and is well-described in the literature.[4,5]

However, optimising the care of emergency patients who require inpatient admission to hospital involves ED and inpatient clinicians, is more complex, less well-described and arguably, more important to patient outcomes.[4-10] During emergency admission to an inpatient ward, patients have to negotiate the ED-inpatient interface (EDii). There has been significant research into several specific aspects of the EDii such as access block[4] and ED performance against time targets[5] however the interface itself between the ED and the hospital inpatient wards and the factors that impact on it remain poorly understood.

This thesis has three related areas of study developed with the overall aim of improving the care delivered to patients requiring emergency admission to hospital.

Hypothesis Development

The working hypotheses for exploration and development were that

a. the EDii is an important, but as yet poorly characterised aspect of the healthcare system
b. the EDii is consequential because impaired EDii function is associated with impaired patient outcomes and improving the function of the EDii is associated with better patient outcomes.
c. the digitisation of the EDii via the introduction of an integrated electronic medical record (ieMR) would initially slow EDii time-based performance due to the effort of clinicians adapting to a new system, but that patient clinical outcomes may improve due to greater availability to all teams of integrated clinical information.

Aims

The aims of this work are summarised below:

Study Area 1- Characterisation and Definition of EDii

To develop a sound conceptual understanding of the EDii through review and synthesis of the existing literature.

An accurate definition of EDii, its size, scope and function will assist to inform further research and evidence-based clinical redesign of this important interface to improve outcomes for patients. The development of the characterisation and definition of the EDii is detailed in Chapter Two. This definition and characterisation formed the framework for subsequent areas of study.

Study Area 2- Linking of Process and Outcome Measures at EDii

To demonstrate that improved EDii process measures as defined by improved National Emergency Access Target (NEAT) compliance, are associated with improved patient outcomes as measured by in-hospital mortality.

This was explored by developing a clinically useful tool to link relevant EDii process and patient outcome measures.

Study area two is presented in Chapters 3 and 4.

Study Area 3-The Digitisation of EDii

To characterise the impact of digital transformation of the EDii on hospital process measures and clinically sensitive outcome measures for patients requiring emergency admission to hospital.

Study area three is presented in Chapter 5.

Research Approach

Specific research methods for each aim are detailed in the methods section for each chapter. The nature and setting of the subjects studied suited a broadly quantitative, observational research approach. My operational clinical roles and previous experience enabled an engaged, participatory approach to many aspects of the research. Working from within the system being studied enabled me to contribute to the outcomes of the interventions studied and translate findings into sustained practice change.

Overall, this thesis defines and characterises the EDii, proposes measures of its performance and explores the impacts of large-scale healthcare policy and clinical redesign in this area.

This work has already led to health policy change in Queensland and is common everyday use in Australian hospitals. The conclusions presented in Chapter 6 describe the progress of implementation of this research to date as well as outline potential directions for further research and translation.

References

1. *Commonwealth Government of Australia. Expert Panel:Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hopsital Services.* 2011 2011. 978-1-74241-535-2.
2. FitzGerald G. Uncomfortable truth about emergency care. *MJA InSight* 2016; https://www.mja.com.au/insight/2016/8/uncomfortable-truth-about-emergency-care. Accessed 23 April, 2016.
3. Secretary of State for Health. The NHS Plan: A plan for Investment, A plan for reform. 2000; http://www.nhshistory.net/nhsplan.pdf. Accessed 27 February, 2016.
4. Forero R, Hillman KM, McCarthy S, Fatovich DM, Joseph AP, Richardson DB. Access block and ED overcrowding. *Emerg Med Australas.* 2010;22(2):119-135.
5. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2015.
6. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *The Medical journal of Australia.* 2006;184(5):213-216.
7. Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *The Medical journal of Australia.* 2006;184(5):208-212.
8. Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.
9. Lowthian J, Curtis A, Straney L, McKimm A, Keogh M, Stripp A. Redesigning emergency patient flow with timely quality care at the Alfred. *Emerg Med Australas.* 2015;27(1):35-41.
10. Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *The Medical journal of Australia.* 2012;196:122-126.

Chapter 2

Characterisation and Definition

The Emergency Department Inpatient-Interface (EDii): Defining a clinically important system

Preamble

This chapter was subsequently condensed and published in *Emergency Medicine Australasia*[1] and is attached as Appendix A. Relative contributions by each author to that paper are included in the preliminary pages.

Introduction

Emergency Departments care for some of the sickest patients in the healthcare system at a critical time in their journey. Emergency Department (ED) overcrowding and ambulance access to emergency departments are common public topics of debate.[2,3]

A primary reason for the intense interest is because public expectations for the timeliness of emergency care are often not met.[4] This is a difficult task for hospitals given limited resources and increasing demand for care.

The majority of patients attending the ED can be discharged home. Improving the timeliness of care of these patients can be achieved by predominantly ED-based interventions with limited whole-of-hospital involvement and is well-described in the literature.[5,6]

However, optimising the care of emergency patients who require inpatient admission to hospital involves ED and inpatient clinicians, is more complex, less well-described and arguably, more important to patient outcomes.[5-11] During emergency admission to an inpatient ward, patients have to negotiate the ED-inpatient interface (EDii). There has been significant research into several specific aspects of the EDii such as ED overcrowding[5] and the 4-hour rule[6], however the interface between the ED and the hospital inpatient wards remains poorly defined and this apparent gap in the literature prompted this review.

It was hypothesised that the EDii is an important, but as yet poorly understood aspect of the healthcare system. The aim of this chapter was to review existing literature on the EDii and to synthesise this existing literature and the author's clinical and system-wide experience in the area into a characterisation of this critical operating system. An accurate definition of the EDii, its size, scope and function will assist to inform further research and evidence-based clinical redesign of this important interface to improve outcomes for patients.

Methods

Due to the complex and highly context-sensitive interventions contributing to the evidence base in this area, a meta-narrative review was undertaken.[12,13]

Search Strategy

In collaboration with a University of Queensland medical librarian, an applied search strategy to PubMed and Medline databases was developed in an effort to identify relevant scientific articles in the peer reviewed literature that were published between January 2006 and January 2016. Additional studies were identified by searching the reference lists of retrieved papers. Relevant media sources were also searched to provide relevant contemporaneous political context which was not documented in peer reviewed literature. Relevant "grey" literature was also included. Search terms included "emergency medicine" and synonyms, "inpatient" and synonyms and "interface" or "handover" and synonyms.

The full search string is included in Table 2.1.

Table 2.1- Full Search String

(((((((Emergency Physician[Title/Abstract]) OR Emergency Room[Title/Abstract]) OR Emergency Department[Title/Abstract]) OR Emergency Medicine[Title/Abstract])) AND (((((Inpatient Ward[Title/Abstract]) OR Inpatient Admission[Title/Abstract]) OR Inpatient[Title/Abstract]) OR Hospital Ward[Title/Abstract]) OR Hospital admission[Title/Abstract])) AND ((((((Interface[Title/Abstract]) OR Relationship[Title/Abstract]) OR Handover[Title/Abstract]) OR Junction[Title/Abstract]) OR Transition[Title/Abstract]) OR handoff[Title/Abstract]) AND ("last 10 years"[PDat] AND Humans[Mesh] AND English[lang])

Study Selection Criteria

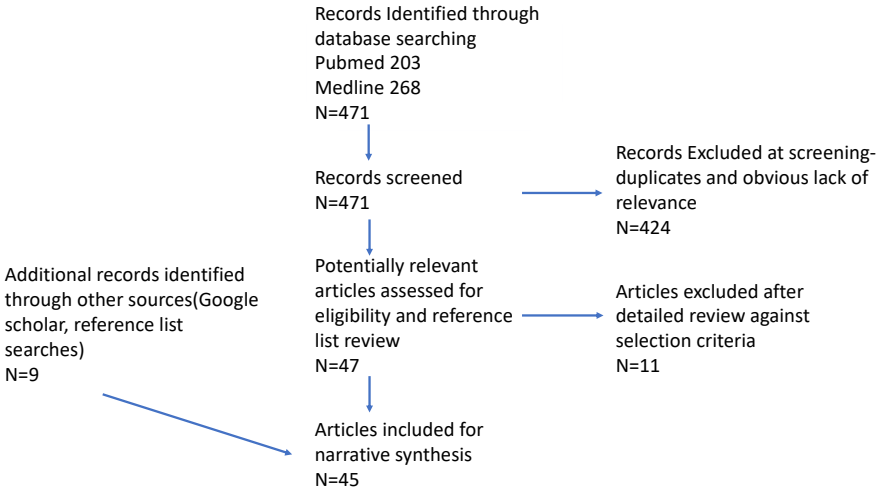
In keeping with a mixed studies review, both qualitative and quantitative studies were eligible for inclusion.[13] Studies were included if they provided data or evidence that addressed the transition of care of emergency patients to the hospital inpatient space. Papers about isolated emergency department or inpatient processes and outcomes were excluded.

Titles and abstracts of all retrieved articles were screened for relevance by a single author (AS) and final assessment of studies for inclusion were made by consensus between AS and CS as per the principles of a theoretical review.[12,14]

Data Synthesis

After the screening and exclusion process (Figure 2.1), 45 studies were included for review.

Figure 2.1 Schematic Representation of Systematic Review Process



Papers were sorted into EDii concepts based on their stated aims or outcome measures:

1. definition
2. scale and cost
3. political context
4. importance to patient outcomes
5. handover
6. monitoring the performance of EDii

Single papers could be categorised into multiple categories. The existing literature was reviewed and where gaps occurred, the authors' combined clinical experience was utilised for the synthesis.

Results and EDii Characterisation

A summary of the relevant literature is included in Table 2.2

Definition of EDii

Results

Partial definitions of the ED-inpatient interface have been described in the literature. The physical and clinical process of admission of patients from the ED to the inpatient setting has variously been referred to as the "Gray Zone", "ED to inpatient transition" and "interunit handoff".[15,16] I have previously used the term ED-inpatient interface (EDii) when discussing the process of emergency admission to hospital.[17,18] Considine used the term ED-ward interface when referring to the last hour of ED care and first hour of ward care.[19] Selected previous definitions are illustrated in Table 2.3 below.

Table 2.3 Selected Previous Definitions of the Emergency Department-inpatient interface from the literature

Term	Author, year	Definition	Context
Gray Zone	Apker 2007	"Physicians perceived handoff communication as a gray zone"	Handoff between ED and inpatient clinicians
Door to floor (D2F)	Quinn 2014	"the time required to move an ill patient through the ED to an appropriate inpatient bed"	Analysis of failed attempts to reduce the time. Hospital is a complex adaptive system.
Emergency Department-Ward interface	Considine 2010, 2014	Interface between ED and general wards	Analysis of abnormal physiological observations (in last hour of ED care and first hour of ward care) and early deterioration following admission via ED.

Emergency Department-inpatient interface (EDii)	Sullivan and Staib 2015, 2016	Interface between ED and inpatient teams	Discussing the influence of EDii processes on patient outcomes

Common themes throughout the relevant literature were the lack of specific research into the area, the importance to patient safety, confusion about the transitioning clinical responsibility during the emergency admission process and the multifactorial, complicated nature of the system at this point.[15,20-22] None of the retrieved papers specifically define or characterise the interface.

Synthesis and Characterisation

The EDii is poorly defined in the literature. It is an important, yet little described component in the concept of "whole of hospital" approaches to ED overcrowding and timely access to quality emergency care.

Through examination of the literature, the author's operational experience and consultation and testing with high profile stakeholders, a definition was synthesised, peer-reviewed and published.[1] **It is proposed that the definition of the EDii is: the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services.**

A patient is transitioning the EDii from the time the decision is made that they are likely to be admitted to hospital, until they are completely under the care of an inpatient team and physically located in an inpatient space. (Figure 2.2). Patients admitted to an ED short stay ward are generally not considered subject to the EDii.

Scale and Cost of EDii

The scale of the EDii worldwide is significant with approximately half of all admissions to hospital occurring via the EDii.[21,23,24] There were 17.5 million emergency admissions to hospital in 2010 in the USA.[23,25] In England in 2012-13, there were 5.3 million emergency admissions to hospital.[26] In

Australia, there were in excess of 2.5 million admissions to hospital via the EDii in the 2013-14 financial year.[24]

The number of patients negotiating the EDii is growing. In Australia, the growth in ED attendances over the past 5 years was 4.8% per year compared to an overall population growth rate of 1.8%.[24] The growth in emergency admissions in England was 47% over the past 15 years, compared to a 10% increase in the overall population for the same time period.[26]

Growth in emergency admissions and the subsequent issues with accessing inpatient care appear to be worse in larger hospitals looking after more complex and sicker patients.[27] Mullins reported that 2.1% of all patients admitted to hospital via the ED are admitted directly to intensive care units. This rate of high acuity emergency admission is also growing in excess of ED attendance growth.[28]

The cost of emergency care can influence outcomes with one US study reported differing admission and inpatient practices for the mentally ill depending on hospital funding models.[29] In Australia, the average cost of an admission to hospital is approximately $5000AUD.[24] Emergency admissions tend to be more complicated and therefore expensive than elective admissions.[24]

One US study of paediatric patients admitted via the ED quoted a mean cost of $9893 USD per patient[30]. Another paper by Moore estimated that $377.5 billion was spent on inpatient care in the USA in 2012.[31] The NHS England estimated 12.5 billion pounds was spent on care of emergency admissions in 2013.[26]

Synthesis and Characterisation

The literature indicates that more than $12 billion annually is spent on patients who negotiate the EDii in Australia. In the United States, this figure is

approximately $200 billion. These costs are growing at a disproportionate rate to the population and other areas of the healthcare system.

The large scale and cost of EDii mean that even small interventions and alterations in the quality, efficiency and cost of care at the EDii can have a significant clinical and financial impacts.

Political context

Results

Several nations have introduced measures and policies aimed at reducing ED overcrowding and improving emergency access to hospitals.

In the USA, ED accreditation and reimbursement is affected by nationally reportable data on median ED boarding time.[27] In the United Kingdom, the National Health Service (NHS) introduced the Four Rule for Emergency Departments in 2000.[4] I, with others, have previously published a report into introduction of, and the evidence for, the Australian National Emergency Access Target (NEAT).[6]

Many of the papers retrieved in this review include reference to calls by political and statutory bodies to address the significant patient safety risks of a dysfunctional EDii with research and patient-focussed interventions. In the UK, the report into excessive deaths in the Mid Staffordshire Trust focussed political and public attention on need to monitor the quality as well as the timeliness of the care provided in this area.[32]

Recent examples of EDii issues in the Australian mainstream media include overt disagreement between ED and inpatient physicians over hyperacute stroke management[33], difficulties with access to acute mental health care in Tasmania[34], ambulance access to hospitals in Victoria[35], debate over emergency access targets in New South Wales [36] and controversy over the timeliness and quality of care provided at Royal Darwin Hospital.[37]

Synthesis and Characterisation

Despite the lack of robust, peer reviewed research in this area or even a clear definition, the EDii is one of the very few areas where politicians have imposed time targets for clinical care. However as shown in the Mid-Staffordshire report,[32] the successful safe negotiation of the EDii requires more than compliance with time based targets such as NEAT. A focus on the quality of care provided and patient outcomes is required, and the EDii can extend beyond the points measured by traditional time-based targets. That is, a patient may still be negotiating the EDii many hours after physically leaving the ED if still on an ED- generated interim management plan (Figure 2.2). Given the scale, cost, and clinical importance of the interface, political interest and health policy intervention in the area is likely to increase. It is important that we have sound, evidence-based and patient focussed principles to inform future policy.

Importance of EDii to patient outcomes

Patients requiring emergency admission to hospital are in general sicker and at approximately 6-fold higher risk of death in hospital than patients undertaking elective admission**.** Quoted in-hospital mortality rates for patients admitted to hospital via the ED are between 1.8 and 3.9% [9,38-40] compared to 0.3-0.6% for admissions for elective surgical procedures.[40]

Several papers provided data linking measures such as ED length of stay, measures of ED crowding, and specific ED to inpatient management processes to patient outcomes such as mortality, hospital length of stay or early deterioration.[9,19,22,28,30,38,39,41-48]

ED Length of stay and overcrowding

Boarding time is defined as the length of time waiting for hospital admission from time of bed request to time of actual departure from the ED.[27] Extended

boarding times are associated with worse outcomes including length of stay and inpatient complications.[27,48]

We have previously published a significant association between ED 4-hour rule performance for admitted patients and in-hospital mortality.[17] The main beneficiaries of improved efficiency in this cohort were elderly patients and those with cardiac and respiratory disease.[44]

McCusker published data showing an increased likelihood of in-hospital mortality for very ill patients was associated with ED crowding by non-ambulant (stretcher) patients. Interestingly, this relationship did not extend to waiting room crowding by ambulant patients.[38]

Specific Patient Factors and Hospital Processes

Several studies identified patient factors in present in ED which predict early deterioration or the need for increased level of care in the inpatient space.[19,42,43,45,47] This relationship is particularly notable for abnormal vital signs such as blood pressure and respiratory rate, but less so for other patient factors such as age.[19,42] However, the clinical application of this information is complicated by the knowledge that up to 37% of patients admitted to hospital from ED have abnormal vital signs, yet only 1-2% have early deterioration.[19]

Kocher demonstrated that hospitals with higher caseloads of emergency admissions have improved in-hospital mortality outcomes when compared to lower volume systems.[39] One potential contributing factor to this result may be the more highly qualified ED and inpatient clinical workforces that such institutions tend to attract. Powell also demonstrated this relationship in the emergency admissions of patients with sepsis.[47] Specific early intervention in ED, such as early recognition and antibiotic administration, has been shown to have improved inpatient outcomes in sepsis. [39,46,47]

Despite the abundance of literature addressing discrete ED or inpatient clinical processes, only five papers described specific clinical processes

relating to the EDii. [9,46,49-51] Each paper supported the concept that improving efficiency measures at the EDii such as streamlined ED admission processes[46] and facilitated integration of inpatient management into the ED workflow[9,49,51 50] provided benefit to inpatient process or outcome measures.

Quality and efficiency improvement processes may involve early specific therapeutic interventions such as antibiotics in sepsis[46], early integration of inpatient clinicians into ED management of patients[49,51], dedicated inpatient bed allocation and management for emergency patients[50], or a combination of these.[9]

Synthesis and Characterisation

Important patient outcomes are closely associated with the quality of the EDii function (in-hospital mortality, acute in-hospital deterioration, ED representations). There is evidence that improving the quality and efficiency of EDii can improve outcomes for patients.

Research into specific clinical processes across the EDii is limited. This is a consequence of the fact that clinical responsibility and data governance for the ED and inpatient components of care have traditionally been very separate. Lack of integration between these organisational silos has made quality improvement and clinical redesign across the interface difficult. It is proposed that definition and characterisation of the EDii will facilitate evidence-based clinical redesign in this area.

The studies linking EDii processes to patient outcomes have some common limitations. They tend to be relatively small scale, retrospective or observational studies that demonstrate a statistically significant association. They are commonly designed without specific consideration of the entirety of the EDii and are subject to confounding by other factors influencing such a complex clinical system. Very large studies and studies linking specific interventions at the EDii with important patient outcomes are lacking at this time.

Handover

Results

Twelve papers primarily related to the processes of handover or handoff from the ED to inpatient environment.[15,16,20,21,52-59] In keeping with the highest volume of ED to inpatient admissions, the majority of papers analysed the handover interactions between the ED and internal medicine services.

Significant deficiencies in the handover process are perceived by clinicians on both sides of the interface, with ED physicians supplying more of the information, feeling more satisfied with the interaction, but having less control over the handover than their inpatient colleagues, who in turn tend to feel less satisfied with the interaction. Tools such as standardised handover templates have been developed in an attempt to address some of these issues, however demonstration of benefit to important patient outcomes is lacking. [16,53]

The majority of the handover literature explores handovers within the ED or within the inpatient unit, with handover studies crossing clinical boundaries such as EDii in the minority.[15,16] In a review by Hilligoss, only 9 out of 640 handover studies were related to ED-inpatient handovers [21] It is clear that ED to inpatient handovers are difficult due to their unscheduled nature interrupting scheduled inpatient activities such as clinics, surgery and ward rounds, clinical uncertainty, delays of uncertain duration, confusion over clinical ownership and a high risk of adverse clinical outcomes. These factors increase the tension related to interactions in this situation.[15,21,55]

Whitt found that a patient admitted to hospital via the ED had contact with between 17 and 28 health professionals, making the accurate and timely transfer of clinical information all the more critical.[60]

Some authors emphasised the need for more research and the importance of assessing patient outcomes in response to any handover interventions [20].

Several papers discussed the emerging importance of digital technology in providing more information to inform the handover discussion and particularly assist the receiving clinician make better decisions in response to the handover information [54,56,58].

Synthesis and Characterisation

Although handover was a major area of research relevant to the EDii, it is clear that the type and effectiveness of the handover process is very dependent on the clinical context. The communication and handover of clinical information between ED and inpatient teams is a critical component to the optimal functioning of the EDii. The mismatch between the unscheduled care needs in the ED and the scheduled nature of inpatient workflow can result in tension and lack of patient focus in EDii handover communications. Better understanding of factors which impact on this communication can facilitate effective clinical redesign in this important area.

Monitoring the Performance of EDii

Results

Because the EDii has not previously been defined or well characterised in the literature, very little specific EDii function or efficiency measurement literature exists, despite the time targets for performance in some components of the EDii set at a national level.

The common process measures relating to EDii performance in the existing literature are:

- Access Block: the proportion of patients who were admitted or planned for admission whose total ED time exceeded 8 hours [5]

- The 4-hour rule (or NEAT): the proportion of patients who are admitted, discharged or transferred from the Emergency Department within 4 hours [6]
- Boarding Time: the length of time waiting for hospital admission from time of bed request to time of actual departure from the ED. [27]

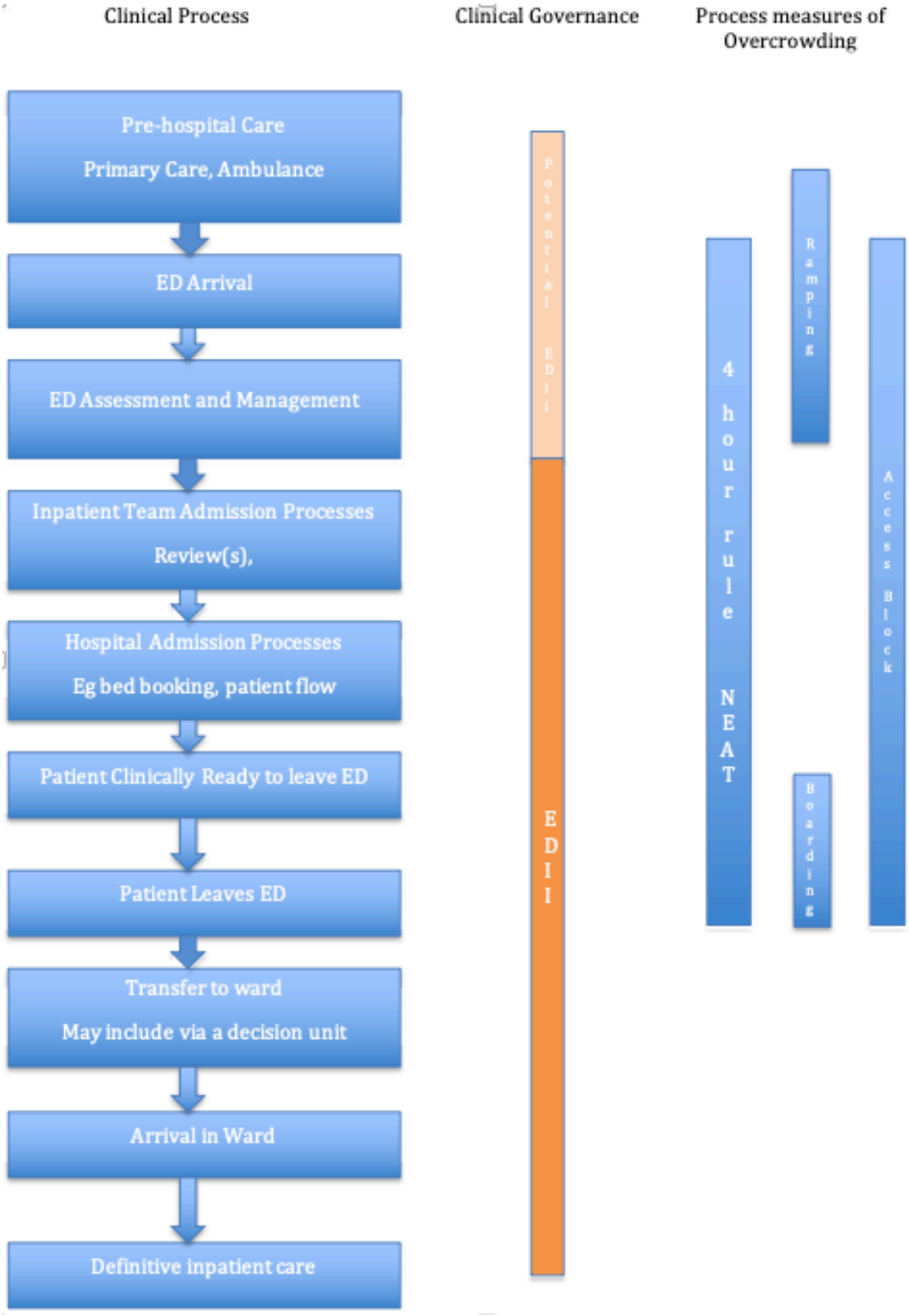
The relationship of these measures to EDii is depicted in figure 2.2.

I, with others, have previously published work on some novel ED measures which are associated with performance against these process measures.[17] As well as the negative impacts on inpatient outcomes as outlined above, boarding and overcrowding also have deleterious effects on the ED's ability to manage less acute patients who are ultimately discharged.[17,27,61-65] Strategies to assist inpatient bed management and patient flow may reduce the time patients spend at the EDii.[62,64,66] However, as seen in the Mid Staffordshire Trust in the NHS, focussing only on the speed of transit of the EDii without a focus on other important aspects of the interface can lead to poorer outcomes.[32]

Synthesis and Characterisation

Given the EDii's significance to the operation of the acute hospital system, it is important to have effective ways of measuring the function and performance the EDii. Most hospitals simply monitor process measures such as those outlined above or time to specific clinical actions such as antibiotic or administration or ECG. Such time measures are of little interest to patient-focussed clinicians, and pursuit of these types of measures in isolation from clinical outcomes has previously been associated with patient harm. True clinically important indicators of EDii function such as patient mortality and morbidity (such as acute deterioration) are rarely measured in a systematic manner. EDii dysfunction may manifest as suboptimal process outcomes, patient outcomes, or a combination of both.

Figure 2.2- Relationship of EDii to clinical processes and measures of overcrowding



Discussion

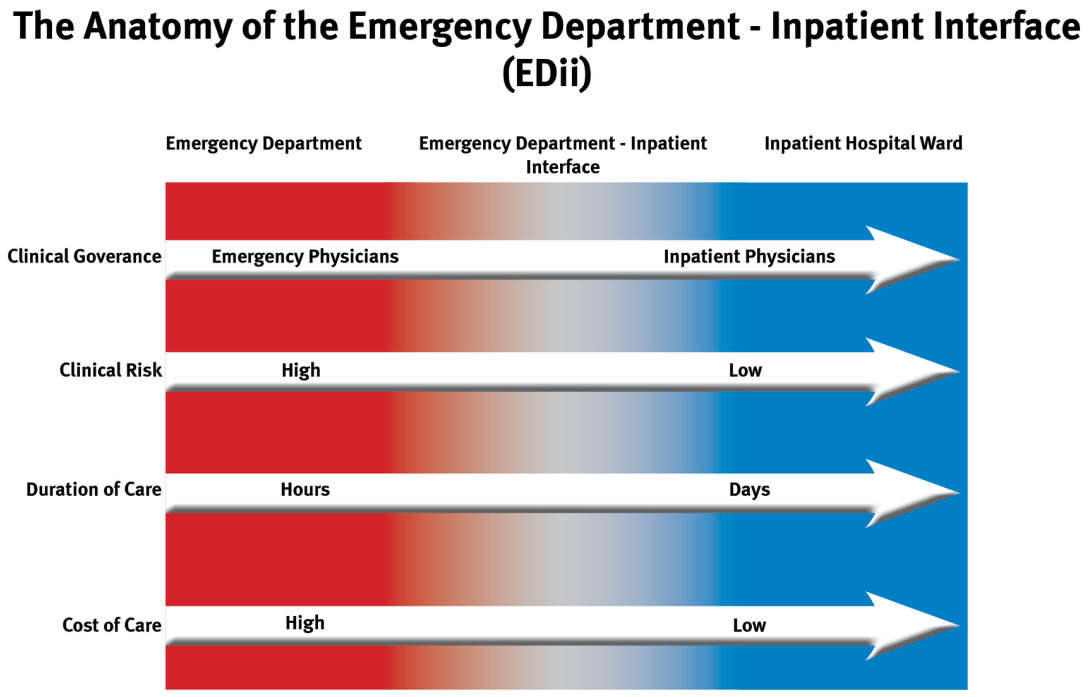
EDii definition and characterisation

The EDii is the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services.

The EDii is characterised by a complex interplay of patient, hospital and system factors.

A patient is transitioning across the EDii from the time the decision is made that they are likely to be admitted to hospital, until they are completely under the care of an inpatient team and physically located in an inpatient space; usually a ward.
Figure 2.3 illustrates the transition of functions or anatomy of the EDii.

Figure 2.3



The EDii is a critical operating system to all acute hospitals because of its

- Large scale
- High cost
- Public and political importance
- Impact on the care of the sickest and most vulnerable patients in the healthcare system
- Strong influence on important patient outcomes such as in-hospital mortality

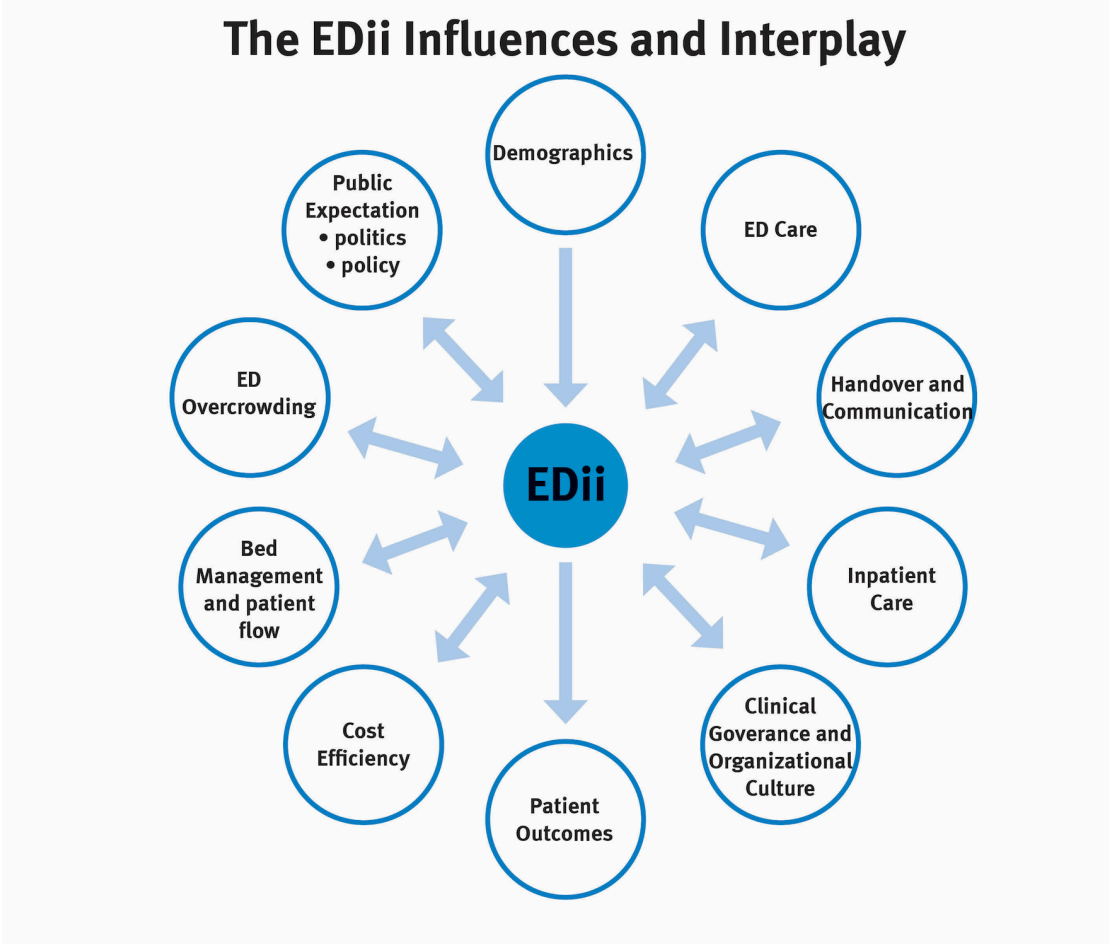
For such an important component of the acute healthcare system, understanding of, and research into, the EDii is limited. Although many of the features of the EDii are partially included in the existing literature, the focus of previous work has tended to be on the symptoms of EDii dysfunction (such as ED overcrowding) or the process measures of components of EDii function (such as NEAT, or handover) as opposed to the ED-inpatient interface itself.

Influences and Interplay

The EDii interacts with almost all components of the acute hospital system. Figure 2.4 illustrates the complex interplay between factors which can facilitate or inhibit EDii function, and in turn, the influence that EDii function can have on these systems and outcomes.

The EDii can be influenced directly or indirectly by many system factors. As such, changes in the system seemingly unrelated or distant to the EDii can lead to changes in EDii function, and potentially changes in important outcomes for this patient group.

Figure 2.4 Influences and Interplay of Factors impacting the EDii



Signs of EDii dysfunction

EDii dysfunction can manifest in many different ways. Limited access to inpatient beds can result in prolonged stays in ED, resulting in ED overcrowding and less than optimal patient outcomes.[27] Boarders are a vulnerable patient group who are nominally under the care of inpatient physicians but experience a prolonged period of time "stuck" in the ED. They undergo a period of mixed care, where their post-admission inpatient care is delivered in the emergency department setting, creating difficulties for the emergency department (in terms of overcrowding and delivery of ongoing care), the inpatient teams (in terms of visibility, communication and clinical

responsibility) and most importantly for the patient (prolonged length of stay, worse outcomes).[17,27,48]

Just as delivery of inpatient care in the ED (boarding) is sign of EDii dysfunction, so is the overly rapid transfer of patients into an inpatient space while still requiring emergency care. Unexpected rapid transfer of patients to an inpatient area prior to review by the inpatient team may inadvertently prolong the time at the EDii. Focussing only on the speed of transit to an inpatient space without a focus on other important aspects of the interface can lead to poorer outcomes.[32]

The differing cultures and priorities that exist within the ED and inpatient clinical silos can lead to disagreement over patient management on a local or global scale. The recent debate between ED and inpatient physicians over the management of hyperacute stroke is an example where differences in interpretation of the available data, perception of risk, and clinical priorities has resulted in a quite public and at times heated disagreement about management of this patient group at the EDii.[33]

Improvements in EDii function can deliver improvements in important patient outcomes. We have previously shown that process improvements at the EDii which led to a halving of Emergency Department Length of Stay (EDLOS) were associated with a near halving of in-hospital mortality for this patient group.[9] The subset of patients who are most likely to benefit from the improved EDii function appear to be the elderly, with cardiac and respiratory conditions - the same group who were most subject to poorer outcomes in the Mid Staffordshire report.[32,44]

Importance

The importance of the EDii can be considered at three levels.

Firstly, the EDii is important to the individual patient. The outcomes for this group of the sickest and most at-risk patients in the system are impacted by the function of the EDii.

Secondly, the EDii is important to overall hospital function. The function of the EDii impacts the quality and efficiency of care in many areas of the hospital, and dysfunction and poor communication can increase professional tensions. Dysfunction at the EDii can contribute to reduced scheduled hospital functions such as outpatients and elective surgery when EDii patients are seen as competing for the same scarce resources or treated as a “surprise” over and above scheduled activities.

Thirdly, the EDii is important for the healthcare system. With over half of all patients entering the hospital via the EDii, and the high cost of care for this patient group, an understanding of the EDii and optimising its function has significant potential to influence the quality and efficiency of care provided by the whole healthcare system.

Limitations

Because the EDii is such an integral part of the operation of acute hospital systems, no literature review can fully capture every paper which addresses concepts applicable to the EDii. One of the limitations of this review is the exclusion of the many papers which primarily address ED overcrowding. This work has been previously reviewed [5], and the aim of this piece was to better characterise the interface between the ED and the inpatient care of patients requiring emergency access to hospital. Another limitation is that the nature of the subject meant that much of the work reviewed was observational, and the concepts relevant to the EDii, not necessarily the primary subject of the papers. As such, methodological quality the work reviewed is difficult to interpret. Important concepts relevant to the EDii may be derived from papers of low methodological quality. These limitations are in part the reason why this characterisation and further research into this critical operating system are required.

Future

With a clearer definition of the EDii in hand, research on how to improve the EDii to improve patient care and hospital performance will be able to proceed more systematically.

The widespread implementation of electronic medical records and digitisation of the EDii will provide opportunities to create unprecedented insights into this operating system. Integrated clinical information systems with sophisticated analytic capability will allow the development of new, more sensitive patient outcome measures and ultimately evidence-based lead indicators which can be used to supplement or replace the relatively unsophisticated process measures on which we currently rely. When coupled with good clinical leadership, the breaking down of data silos that integrated digital systems can provide can lead to the breaking down of traditional clinical silos and improved care for patients.

Potential future areas of research will include developing a better understanding of the EDii factors which most influence patient outcomes; for example, are improved patient outcomes due to a less crowded ED, more rapid definitive ward care, or an integrated system that functions well at the interface?

Another area where further information is required is in the type of EDii. The widespread development of clinical decision units is changing the nature of the EDii in many areas. Currently, little is understood about the impact of these units on EDii patient outcomes, and cost efficiency. Despite being designed to reduce EDLOS, it is possible that for some patients, the use of clinical decision units may increase the time taken to negotiate the EDii, by delaying their disposition to the appropriate inpatient setting and definitive care.[67,68]

Changing models of care may potentially extend the EDii into the pre-hospital arena. A patient may already be under the care of an inpatient team, and thus transitioning the EDii before they even arrive at the ED with an acute exacerbation of a chronic condition. An example of this potential extension of the EDii would be a patient under the shared care of an inpatient team and a community or primary care team who experiences a clinical deterioration requiring emergent admission to hospital.

As we develop a greater understanding of EDii, the management of EDii within the hospital system may require modification. Tools such as dashboards which display the progress of patients across the EDii will become more common, and the current mixed system of clinical governance during this vulnerable period may require refinement with more dedicated interventions and attention. Perhaps the evidence will evolve to support the need for a dedicated EDii service.

Greater focus on the intended and unintended consequences of clinical redesign activities on the EDii will allow for more evidence based, patient centred health system reform.

Conclusion

The EDii is a critical operating system for acute hospitals. The EDii can be defined as the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.

It involves the sickest and most vulnerable patients in the hospital system, and improvements in EDii function have the ability to improve efficiency for hospitals and outcomes for patients on a large scale. The literature to date has included information which has been synthesised here to define and characterise this interface.

Future research into the EDii utilising digital technologies and enhanced insights will allow for more patient focussed, evidence based clinical redesign for emergency access to acute hospitals.

Table 2.2 Summary of the relevant literature

Author, Year, Country	Aim	Sample and Design	Findings	Relevance to EDii	Reason	Category
AIHW, 2015, Australia	Quantifies ED attendances and admissions in Australia 2013-2014		8 million ED attendances, >2.5 million admissions	High	Scale	Scale
Apker, 2007 USA	Identify EP and hospitalist perceptions regarding handoff communication in the ED to Inpatient setting	Comparative thematic analysis of 12 interviews	Grey Zone at the interface. Poor communication leading to conflicting expectations, incomplete data. Perception that this leads to more boarding	High	Process of transfer of care	Handover Process
Beach, 2012, USA	Focus on gaps in interspecialty communication	Concept article, consensus opinion	Proposed content and style of handoffs and suggested process and outcome measures to measure improvement are also proposed.	High	Process of transfer of care, proposed outcome monitoring	Handover
Bekmezian, 2012, USA	Assess relationship between boarding of admitted children in the ED	Retrospective observational, 1792 patients	$9893 /admission, EDLOS 9 hours, boarding time 5 hours. Boarding time associated with increased cost, and LOS,	High	Patient and economic consequences of EDII dysfunction, cost, mortality.	Outcomes, cost

	and cost, inpatient LOS mortality and read mission		but not mortality or readmissions.			
Caterino, 2013, USA	Determine predictors for need for admission from an ED observation unit	Prospective, observational cohort study, 300 patients	Age of 65 years or more is not associated with need for admission. Older adults can successfully be discharged from these units. Systolic pressure 180 mm Hg or greater was the only predictive vital sign.	Mod	Outcomes	Outcomes
Considine, 2014, Australia	Assess if vital sign abnormalities detected in the emergency department (ED) can be used to forecast clinical deterioration occurring within 24 hours of hospital admission.	Retrospective case-control study performed after implementation of a hospital wide rapid response team (RRT) system. 74 patients and 224 controls	One-quarter of emergency responses after admission via the ED occurred within 24 hours. Further research is needed to understand the predictors of deterioration in patients needing emergency admission.	High	Outcomes	Outcomes

Considine, 2016, Australia	Examine the relationship between physiological status at the ED-ward interface, and MET calls during the first 72 hours of admission	Descriptive, exploratory, 1980 patients	Median time to call 18.8 hours, 34.9% had at least 1 abnormal physiological parameter in the last hour of ED care. 47.1% had abnormal obs in first hour of ward care. Abnormal heart rate and conscious state in ED most predictive. 55% afferent limb (RRT activation rate). Could be used to prime responses in these patient groups.	High	Process and outcomes	Outcomes
Farley, 2010,USA	Assess relationship between abnormal vital signs in the emergency department and clinical deterioration within 24 hours of admission.	Retrospective case-control study	Abnormal respiratory rate in the ED had significant relationship to the need for ICU in first 24 hours.	High	Processes in ED and inpatient outcomes	Outcomes
Fischer, 2012, USA	Explore perceptions about effectiveness of communication in handovers	Survey of EM residents (50) and IM residents (74)	25% perceived as suboptimal and led to admission to inappropriate level of care, 10% led to harm or	High	Process of transfer of care	Handover

			delay. EM rated quality higher than IM.			
Gonzalo, 2014, UK	Evaluate effect of electronic handover tool	Prospective mixed methods analysis of submitted data (1131 handovers)	e-sign out more popular, no change in reported adverse events	High	Process of transfer of care	Handover
Hillier, 2009, USA	Examine the relationship between hospital occupancy and ED throughput	Cross sectional analysis, paediatric population	Increased hospital occupancy associated with increased EDLOS, DNW	Mod	Primary end points were EDLOS for all patients and did not wait rates and not ED-inpatient end points. Brief mention of admitted patient LOS.	ED overcrowding
Hilligoss, 2013, USA	To examine how clinicians on the receiving end of admission handoffs use EHRs in preparation for those handoffs	Ethnographic study, iterative analysis of qualitative data from 48 interviews, 349 observed handoffs, and 48 recorded conversations	EHR's enable pre-handoff "chart biopsy" by receiving team to get an overview, prepare for handoff and defend against potential biases. Particularly useful for receiving IM residents. May help efficiency and safety by allowing earlier planning of inpatient care	High	Process of transfer of care	Handover and digitisation

Hilligoss, 2014, USA	Analyse language used in ED-Inpatient handovers	Discourse analysis of 48 interviews, 349 observed handoffs, and 48 recorded conversations	Described 4 interpretive frames for handoff-persuasion, competition, expectation matching, collaboration. Complex interaction requiring more research and practice improvement	High	Process of transfer of care	Handover
Hilligoss, 2015, USA	Describe a conceptual framework for ED admission Handoffs	Forum discussion paper	Elaborated on a previous paper about the framework for handoff negotiations. Discussed importance of context of handoff activities> Suggests framework can help intervene and improve contexts in which handoffs occur	High	Process of transfer of care	Handover
Horwitz,2009, USA	Identify vulnerabilities in ED to IM patient transfers	Qualitative survey analysis. 139 respondents	29% reported adverse events or near miss. Issues- incomplete information, difficulty accessing key information especially vital signs, crowding, workload, professional conflicts. Systems based interventions could ameliorate many of these	High	Discusses many EDii issues and calls for systems research in this area. Identifies EDii as a source of risk for patients. highlights boarders at particular risk as unclear governance and	Risk, Outcomes

			and improve patient safety		they accumulate in ED when resources at their most stretched.	
Jalili, 2013, Iran	Investigate the effect of door-to-antibiotic time in sepsis patients with various degrees of severity.	Longitudinal prospective cohort study 145 patients	Early antibiotic initiation for patients in sepsis phase with higher severity scores was associated with significant improvement in survival rate.	Low	Looks at outcomes for a specific condition	Outcome, condition specific process
Jensen, 2012, Australia	Description of a tool to visualise hospital patient flow activities	Description and demonstration of modelling from routinely collected data	Visualisation may allow bed managers to aid in bed management decisions	Mod	Hospital patient flow measures and interaction with general ED and hospital function, Not EDii specific	Patient Flow, ED overcrowding, measurement
Johnson, 2012, Australia, USA, Europe	Demonstrate how process mapping can illustrate handover practices between ambulatory and	Descriptive. Focus group interviews with users and creation of a process map	Identified communication barriers, regional differences in processes	Mod	Process of transfer of care, not ED-inpatient specific, but included	Handover Process

	inpatient care setting and identify potential areas for improvement					
Josephson, 2008, USA	Describe a hospitalist model for management of acute neurological admissions	Case Study	More frequent and timely neurology consultations in ED and the hospital, and improved education	Mod	A process case study involving EDii	Specific Processes
Kessler, 2014, USA	Describe current state of ED-inpatient handoffs, and assess best practices	Survey of 1799 Physicians (ED and Inpatient). Descriptive and quantitative analysis	Low use of standardised tools, low rates of formal training, Importance of uninterrupted time and handoff at the bedside.	High	Process of transfer of care	Handover
Kocher, 2014, USA	Examine the association between ED hospitalisation volume and mortality for common high risk conditions	Retrospective national data set regression analysis of 17.5 million admissions	Mortality decreased as volume increased for all conditions, but influence of volume varied for some conditions. Overall raw(in hospital) mortality 3.1%, Early mortality(2 days) 1.2% (all EDii admissions)	High	Outcomes of EDii	Outcomes

Krall, 2014, USA	Analyse correlation between ED treatment metrics and wait times	Correlation between ED treatment interval metrics. Looking at intervals directly impacted by EP and their correlation with door to room times.	Factors beyond EP control more strongly correlate to wait times.	Mod	ED specific wait times, brief mention of bed wait times	Measurement
Levin, 2011, USA	To determine how increases in surgical patient volume will affect emergency department (ED) access to inpatient cardiac services.	Stochastic discrete event simulation	Increasing elective activity increased boarding time for emergency patients. Both simulated increased capacity and reduced inpatient LOS reduced boarding time	Mod	Simulated competition modelling	Impact of external factors
Lucas, 2009, USA	Evaluate the association between hospital census variables and emergency department length of stay (EDLOS)	Multicentre cohort study, 27325 Patients	ED LOS is correlated with the number of admissions and census of the higher acuity nursing units, more so than the number of ED patients each day	Mod	Measurement, impact of external factors	Measurement

McCusker, 2014, Canada	Examine the associations of changes over time in ED occupancy with patient outcomes in a sample of EDs that vary by size and location	Retrospective cohort study 677475 patents	10% Increased relative ED occupancy was associated with 3% increase in death and readmission for ED patients- ED bed overcrowding more important than waiting room overcrowding, Associations stronger in large ED's	Mod	Implied hospital occupancy by ED occupancy.	Outcomes
Moore, 2014, USA	Quantify hospital inpatient costs	Multiple source costing exercise	$377.5 billion on inpatient care. Half of which is emergency	High	Cost	Cost
Morse, 2013, UK	Examine number of emergency admissions to hospital, and how well they are managed.	Retrospective national database report	5.3 million admissions, 67% of bed days, 12.5 billion pounds. 47 % increase over 15 years.	High	Size and cost	Size and cost
Mullins, 2013, USA	Describe trends in ED-ICU admissions	Observational Study 4267 patients from National Database (NHAMCS)	ICU admissions growing at a greater rate than population or ED visit growth	Mod	Calls for better understanding of ED-ICU interface	Scale, outcomes
NHAMCS, 2010, USA	Quantify ED attendances	National Database	130 Million attendances, 13 % admission rate	High	Scale	Scale

Pitts, 2008, USA	Quantify ED attendances	National Database	119 million attendances, source of entry for half of all non-obstetric admissions	High	Scale	Scale
Pitts, 2014, USA	Study NAHMCS database to establish national baseline values	National Database retrospective analysis	Boarding disproportionally affects larger ED's	High	US measure of EDii	Scale, Measurement. Politics
Powell, 2010, USA	Examines whether there is an association between the annual volume of patients admitted via the emergency department with sepsis and inpatient mortality	Retrospective cross sectional analysis of national sample	Significant relationship between emergency department sepsis case volume and overall and early inpatient mortality among patients admitted through the emergency department with sepsis. Patients admitted to hospitals in the highest-volume quartile had 27% lower odds of inpatient mortality in this large heterogeneous sample.	Mod	Outcomes linked o process, Single condition.	Outcomes
Rathlev, 2014, USA	assess the impact of involving a patient placement manager (PPM) early in the decision to	Pre and post intervention pilot studies	Reduction in secondary patient transfers, no change in deterioration or LOS	Mod	Specific process	Specific Process

	hospitalise ED patients					
Ruiz, 2015, UK	To examine the association of mortality by day of the week for emergency and elective patients	Retrospective observational study	Elective rate 0.3-0.6% worse on weekends	Mod	Outcomes by day of week	
Ryan, 2011, Ireland	Prospectively audit the introduction of an electronic handover tool	Prospective audit	Reduction in hospital LOS	Low	All unit handovers, looked at hospital LOS	Handover
Shen, 2008, USA	Examined the relationship among hospital ownership, market forces, and admission of the SMI patient from the emergency department into the general hospital.	Cross-sectional study	Public hospitals were more likely to admit while investor-owned hospitals were less likely to admit SMI patients.	Low	About hospitals decision to admit non-paying patients. Limited EDii	External factors, economics

Sullivan, 2014, Australia (Aiming)	Implement and evaluate strategies for improving access to emergency department (ED) care in a tertiary hospital	Retrospective pre-post intervention study, single site, 2 years, 60000 admissions	Multiple reforms implemented in a poor performing tertiary hospital caused the proportion of patients exiting the ED within 4h to double within 9 months to reach levels comparable with best performing peer hospitals. This was associated with a 26% reduction in in-hospital mortality for admitted patients and no clinically significant adverse effects	High	Outcomes and processes	Outcomes and specific processes
Sullivan, 2015, Australia (Metrics)	Compare the association of NEAT with new and traditional markers of patient flow across the ED-inpatient interface	Retrospective cohort study, 120000 patients, single site	No correlation between admitted NEAT and ED attendances or hospital occupancy. Strong correlation with novel markers of ED-inpatient dysfunction	High	Measurement	measurement
Sullivan, 2015, Australia (Who is less likely to die)	Identify patient and non-patient factors associated with reduced mortality among patients admitted from the	Retrospective dataset analysis	Improved mortality associated with improved 4 hour compliance are admitted elderly with cardiac and respiratory disease.	High	EDii outcomes	Outcomes

	emergency department (ED) to in-patient wards					
Viccellio, 2009 USA	Hypothesised that transfer of admitted patients from the emergency department (ED) to inpatient hallways would be feasible and not create patient harm	Retrospective cohort study		Mod	Clinical process, outcomes	Outcomes
White, 2013, USA	Investigates the impact of boarding inpatients on the ED LOS of discharged patients	Retrospective, observational, cohort study , adult ED	Increasing boarder burden was associated with increasing LOS of patients discharged from the ED	Low	Impact on discharged patients	Measurement
Whitt, 2007, New Zealand	Assess how many health professionals are directly involved in a patient's stay when admitted through the ED	Retrospective review of 81 patient records, tertiary hospital setting	17.8 health professionals for a medical admission, 26.6 for surgical admissions	High	Complexity, specific EDii process	Complexity, handover

Wu, 2013, USA	Examined whether inpatient admissions after palliative care (PC) consultation initiated in the ED were associated with decreased length of stay (LOS)	Retrospective, observational cohort study	Early initiation of PC consultation in the ED was associated with a significantly shorter LOS for patients admitted to the hospital	Mod	Specific intervention blending inpatient and EDcare for improved process measure	Specific process
Wu, 2015, China	Investigated whether emergency department (ED) crowding was associated with poor performance and outcomes of damage control resuscitation (DCR) strategies in treating haemorrhagic shock trauma patients	Retrospective cohort study, 852 patients	Reduced DCR in times of overcrowding, more coagulopathy in ICU, no change in 30 day mortality.	Mod	Clinical process, outcomes	Outcomes
Ye , 2007, Australia	Determine problems resulting from ED handover	Prospective observational study, 914 patients	Medical information, including presenting complaints, was handed over better than	Mod	Handover, predominantly within ED but identifies issues	Handover

			communication and disposition information		with disposition and inpatient communication	

References

1. Staib A, Sullivan C, Prins JB, Burton-Jones A, Fitzgerald G, Scott I. Uniting emergency and inpatient clinicians across the ED-inpatient interface: The last frontier? *Emerg Med Australas.* 2017;29(6):740-745.
2. *Commonwealth Government of Australia. Expert Panel:Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hopsital Services.* 2011 2011. 978-1-74241-535-2.
3. FitzGerald G. Uncomfortable truth about emergency care. *MJA InSight* 2016; https://www.mja.com.au/insight/2016/8/uncomfortable-truth-about-emergency-care. Accessed 23 April, 2016.
4. Secretary of State for Health. The NHS Plan: A plan for Investment, A plan for reform. 2000; http://www.nhshistory.net/nhsplan.pdf. Accessed 27 February, 2016.
5. Forero R, Hillman KM, McCarthy S, Fatovich DM, Joseph AP, Richardson DB. Access block and ED overcrowding. *Emerg Med Australas.* 2010;22(2):119-135.
6. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2015.
7. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *The Medical journal of Australia.* 2006;184(5):213-216.
8. Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *The Medical journal of Australia.* 2006;184(5):208-212.
9. Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.
10. Lowthian J, Curtis A, Straney L, McKimm A, Keogh M, Stripp A. Redesigning emergency patient flow with timely quality care at the Alfred. *Emerg Med Australas.* 2015;27(1):35-41.
11. Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *The Medical journal of Australia.* 2012;196:122-126.
12. Greenhalgh T. Assisted dying debate: Try another approach, BMJ. *BMJ.* 2011;342:d451.
13. Pluye P, Hong QN. Combining the power of stories and the power of numbers: mixed methods research and mixed studies reviews. *Annu Rev Public Health.* 2014;35:29-45.
14. Pare G, Trudelb, M-C., Mirou, J., Kitsioud, S. Synthesizing information systems knowledge: Atypology of literatire reviews.*Information and management* 2015;52:183-199.
15. Apker J, Mallak LA, Gibson SC. Communicating in the "gray zone": perceptions about emergency physician hospitalist handoffs and patient safety. *Acad Emerg Med.* 2007;14(10):884-894.

16. Apker J, Mallak LA, Applegate EB, 3rd, et al. Exploring emergency physician-hospitalist handoff interactions: development of the Handoff Communication Assessment. *Ann Emerg Med.* 2010;55(2):161-170.
17. Sullivan C, Staib A, Eley R, Scanlon A, Flores J, Scott I. National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. *Aust Health Rev.* 2015.
18. Sullivan CS, A. Emergency Admissions:Processes and outcomes for our most vulnerable patients. 2015(33):8-9.
19. Considine J, Jones D, Pilcher D, Currey J. Patient physiological status at the emergency department-ward interface and emergency calls for clinical deterioration during early hospital admission. *Journal Of Advanced Nursing.* 2016.
20. Beach C, Cheung DS, Apker J, et al. Improving interunit transitions of care between emergency physicians and hospital medicine physicians: a conceptual approach. *Acad Emerg Med.* 2012;19(10):1188-1195.
21. Hilligoss B, Mansfield JA, Patterson ES, Moffatt-Bruce SD. Collaborating-or "Selling" Patients? A Conceptual Framework for Emergency Department-to-Inpatient Handoff Negotiations. *Joint Commission journal on quality and patient safety / Joint Commission Resources.* 2015;41(3):134-143.
22. Horwitz LI, Meredith T, Schuur JD, Shah NR, Kulkarni RG, Jenq GY. Dropping the baton: a qualitative analysis of failures during the transition from emergency department to inpatient care. *Ann Emerg Med.* 2009;53(6):701-710 e704.
23. Centres for Disease Control: National Ambulatory and Hospital Care Statistics Branch. National Ambulatory Medical Care Survey 2010 Emergency Department Summary Tables. 2010; http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf. Accessed 20 March, 2016.
24. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014.
25. Pitts SR, Niska RW, Xu J, Burt CW. National Hospital Ambulatory Medical Care Survey: 2006 emergency department summary. *Natl Health Stat Report.* 2008(7):1-38.
26. Morse A. Emergency Admissions to hospital: managing the demand. Report by the Comptroller and Auditor General. 2013; https://www.nao.org.uk/report/emergency-admissions-hospitals-managing-demand/. Accessed 29 May, 2016.
27. Pitts SR, Vaughns FL, Gautreau MA, Cogdell MW, Meisel Z. A cross-sectional study of emergency department boarding practices in the United States. *Acad Emerg Med.* 2014;21(5):497-503.
28. Mullins PM, Goyal M, Pines JM. National growth in intensive care unit admissions from emergency departments in the United States from 2002 to 2009. *Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine.* 2013;20(5):479-486.
29. Shen JJ, Cochran CR, Moseley CB. From the emergency department to the general hospital: hospital ownership and market factors in the admission of the seriously mentally ill. *Journal of healthcare management / American College of Healthcare Executives.* 2008;53(4):268-279; discussion 279-280.

30. Bekmezian A, Chung PJ. Boarding admitted children in the emergency department impacts inpatient outcomes. *Pediatr Emerg Care.* 2012;28(3):236-242.
31. Moore BL, K. Elixhauser A. Cost for Hospital Stays in the United States, 2012. HCUP Statistical Brief #181. *Healthcare Cost and Utilization Project* 2014; http://www.hcup-us.ahrq.gov/reports/statbriefs/sb181-Hospital-Costs-United-States-2012.pdf. Accessed April 23, 2016.
32. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Controller of Her Majesty's Stationery Office. 2013; http://webarchive.nationalarchives.gov.uk/20150407084003/http://www.midstaffspublicinquiry.com/report. Accessed May 18, 2015.
33. Mannix L. Emergency Room row over controversial stroke drug, Alteplase. *Sydney Morning Herald* 2016; http://www.smh.com.au/national/health/emergency-room-row-over-controversial-stroke-drug-alteplase-20160321-gnnh58.html. Accessed March 21, 2016.
34. ABC News. Mental Health patients at Royal Hobart Hospital not being given access to natural light advocates warn. 2016. Accessed March 25, 2016.
35. Medew J. Ambulance emergency: When speed is a casualty of care. 2014; http://www.smh.com.au/national/ambulance-emergency-when-speed-is-a-casualty-of-care-20141024-11b362.html. Accessed April 22, 2016.
36. Alexander H. NSW emergency departments relax four hour patient targets. 2015; http://www.smh.com.au/nsw/nsw-emergency-departments-relax-fourhour-patient-targets-20150115-12r3yh.html. Accessed April 22, 2016.
37. ABC News. Gurrumul Yunupingu: Formal Investigation into singer's treatment at Darwin hospital ruled out. 2016; http://www.abc.net.au/news/2016-04-05/no-investigation-into-gurrumul-yunupingu-hospital-treatment/7299640. Accessed April 6, 2016.
38. McCusker J, Vadeboncoeur A, Levesque JF, Ciampi A, Belzile E. Increases in emergency department occupancy are associated with adverse 30-day outcomes. *Acad Emerg Med.* 2014;21(10):1092-1100.
39. Kocher KE, Haggins AN, Sabbatini AK, Sauser K, Sharp AL. Emergency department hospitalization volume and mortality in the United States. *Ann Emerg Med.* 2014;64(5):446-457.e446.
40. Ruiz M, Bottle A, Aylin PP. The Global Comparators project: international comparison of 30-day in-hospital mortality by day of the week. *BMJ Qual Saf.* 2015;24(8):492-504.
41. Wu D, Zhou X, Ye L, Gan J, Zhang M. Emergency department crowding and the performance of damage control resuscitation in major trauma patients with hemorrhagic shock. *Acad Emerg Med.* 2015;22(8):915-921.
42. Caterino JM, Hoover EM, Moseley MG. Effect of advanced age and vital signs on admission from an ED observation unit. *Am J Emerg Med.* 2013;31(1):1-7.
43. Considine J, Charlesworth D, Currey J. Characteristics and outcomes of patients requiring rapid response system activation within hours of emergency admission. *Critical care and resuscitation : journal of the Australasian Academy of Critical Care Medicine.* 2014;16(3):184-189.
44. Sullivan C, Staib A, Eley R, et al. Who is less likely to die in association with improved National Emergency Access Target (NEAT) compliance for emergency admissions in a tertiary referral hospital? *Aust Health Rev.* 2015.

45. Farley H, Zubrow MT, Gies J, et al. Emergency department tachypnea predicts transfer to a higher level of care in the first 24 hours after ED admission. *Acad Emerg Med.* 2010;17(7):718-722.
46. Jalili M, Barzegari H, Pourtabatabaei N, et al. Effect of door-to-antibiotic time on mortality of patients with sepsis in emergency department: a prospective cohort study. *Acta Med Iran.* 2013;51(7):454-460.
47. Powell ES, Khare RK, Courtney DM, Feinglass J. Volume of emergency department admissions for sepsis is related to inpatient mortality: results of a nationwide cross-sectional analysis. *Crit Care Med.* 2010;38(11):2161-2168.
48. Viccellio A, Santora C, Singer AJ, Thode HC, Jr., Henry MC. The association between transfer of emergency department boarders to inpatient hallways and mortality: a 4-year experience. *Ann Emerg Med.* 2009;54(4):487-491.
49. Josephson SA, Engstrom JW, Wachter RM. Neurohospitalists: an emerging model for inpatient neurological care. *Ann Neurol.* 2008;63(2):135-140.
50. Rathlev NK, Bryson C, Samra P, et al. Reducing patient placement errors in emergency department admissions: right patient, right bed. *The western journal of emergency medicine.* 2014;15(6):687-692.
51. Wu FM, Newman JM, Lasher A, Brody AA. Effects of initiating palliative care consultation in the emergency department on inpatient length of stay. *J Palliat Med.* 2013;16(11):1362-1367.
52. Ye K, Mc DTD, Knott JC, Dent A, MacBean CE. Handover in the emergency department: deficiencies and adverse effects. *Emerg Med Australas.* 2007;19(5):433-441.
53. Fischer M, Hemphill RR, Rimler E, et al. Patient communication during handovers between emergency medicine and internal medicine residents. *Journal Of Graduate Medical Education.* 2012;4(4):533-537.
54. Gonzalo JD, Yang JJ, Stuckey HL, Fischer CM, Sanchez LD, Herzig SJ. Patient care transitions from the emergency department to the medicine ward: evaluation of a standardized electronic signout tool. *International journal for quality in health care : journal of the International Society for Quality in Health Care / ISQua.* 2014;26(4):337-347.
55. Hilligoss B. Selling patients and other metaphors: a discourse analysis of the interpretive frames that shape emergency department admission handoffs. *Soc Sci Med.* 2014;102:119-128.
56. Hilligoss B, Zheng K. Chart biopsy: an emerging medical practice enabled by electronic health records and its impacts on emergency department-inpatient admission handoffs. *J Am Med Inform Assoc.* 2013;20(2):260-267.
57. Kessler C, Scott NL, Siedsma M, Jordan J, Beach C, Coletti CM. Interunit handoffs of patients and transfers of information: a survey of current practices. *Ann Emerg Med.* 2014;64(4):343-349.e345.
58. Ryan S, O'Riordan JM, Tierney S, Conlon KC, Ridgway PF. Impact of a new electronic handover system in surgery. *International Journal Of Surgery (London, England).* 2011;9(3):217-220.
59. Johnson JK, Farnan JM, Barach P, et al. Searching for the missing pieces between the hospital and primary care: mapping the patient process during care transitions. *BMJ Qual Saf.* 2012;21 Suppl 1:i97-105.
60. Whitt N, Harvey R, McLeod G, Child S. How many health professionals does a patient see during an average hospital stay? *The New Zealand Medical Journal.* 2007;120(1253):U2517-U2517.

61. White BA, Biddinger PD, Chang Y, Grabowski B, Carignan S, Brown DF. Boarding inpatients in the emergency department increases discharged patient length of stay. *J Emerg Med.* 2013;44(1):230-235.
62. Hillier DF, Parry GJ, Shannon MW, Stack AM. The effect of hospital bed occupancy on throughput in the pediatric emergency department. *Ann Emerg Med.* 2009;53(6):767-776.e763.
63. Krall SP, Cornelius AP, Addison JB. Hospital factors impact variation in emergency department length of stay more than physician factors. *The western journal of emergency medicine.* 2014;15(2):158-164.
64. Levin S, Dittus R, Aronsky D, Weinger M, France D. Evaluating the effects of increasing surgical volume on emergency department patient access. *BMJ Qual Saf.* 2011;20(2):146-152.
65. Lucas R, Farley H, Twanmoh J, et al. Emergency department patient flow: the influence of hospital census variables on emergency department length of stay. *Acad Emerg Med.* 2009;16(7):597-602.
66. Jensen A, Boyle J, Khanna S. Visualising patient flow. *Stud Health Technol Inform.* 2012;178:77-82.
67. Galipeau J, Pussegoda K, Stevens A, et al. Effectiveness and safety of short-stay units in the emergency department: a systematic review. *Acad Emerg Med.* 2015;22(8):893-907.
68. Russell PT, Hakendorf P, Thompson CH. A general medical short-stay unit is not more efficient than a traditional model of care. *The Medical journal of Australia.* 2014;200(8):482-484.

Chapter 3

Linking of process and outcome measures at the EDii to effect change:

The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target

Preamble

This chapter was published as a standalone paper in the Medical Journal of Australia[1] and is attached as Appendix B. I was co-first author on this paper and led the team for study design, implementation and manuscript preparation. Relative contributions to this work by each author are included in the preliminary pages.

Subsequent to publication, I presented this work at the Australasian College for Emergency Medicine Scientific Meeting where it was awarded the best paper by a fellow for the year.

The process and progress of translation of this work into clinical practice and National health policy is also described in this chapter.

Introduction

The National Emergency Access Target (NEAT) stipulates that a certain proportion of patients should be admitted, discharged or transferred from Australian emergency departments (EDs) within four hours of presentation. Targets that varied from state to state were set for all Australian EDs via the National Partnership Agreement in 2012[2] in response to evidence that ED overcrowding and prolonged length of stay were associated with increased in-hospital mortality.[3,4] The original aim was to increase the target incrementally to 90% across all jurisdictions by 2015, in line with the target set in the UK in 2010.

Despite the potentially major impact of the NEAT upon patient care, there was no prospective standardised framework for monitoring patient outcomes for those patients admitted to the hospital from the ED. Measuring patient outcomes is difficult and no approach is beyond criticism. The hospital standardised mortality ratio (HSMR) is an objective screening tool designed to alert clinicians to potentially avoidable harm and has been accepted as a core indicator of hospital safety.[5] The

HSMR compares the numbers of observed and expected deaths; unlike raw mortality statistics, it screens out the deaths of palliative patients and attempts to risk adjust for clinically relevant factors such as age, sex and principal diagnosis. The HSMR has been clinically useful in Australia where it has helped guide clinical redesign of ED admission processes[6,7] and in the UK where elevated HSMRs helped identify potentially avoidable adverse clinical events in Mid Staffordshire Trust hospitals.[8]

Retrospective studies in large hospitals in Melbourne[9], Perth[10] and Brisbane [6] have shown that clinical restructuring induced by the NEAT has been associated with reduced ED crowding, enhanced patient flow through ED, and reduced in-hospital mortality. In one study, a rise in NEAT compliance rates from 30% to 70% was strongly correlated with a decrease in the HSMR for patients specifically admitted from the ED (eHSMR), from 110 to 67 ($R=0.914$, $p=0.0006$).[6]

However, certain factors may have confounded these findings. Following the introduction of the NEAT more low acuity patients who are less likely to die, may have been admitted to short stay wards instead of being discharged from ED more than four hours after presenting. This would introduce a bias if the risk adjustment were to overestimate the mortality risk of these low risk patients. In addition, an increase in the coding of patients as receiving palliative care after acute admission would increase the number of expected deaths while the number of observed deaths would remain unchanged, again reducing the eHSMR.[11]

Putting these interpretive considerations to one side, no hospital in Australia, apart from small rural institutions, has consistently reached four hour targets greater than 85%.[12] Moreover, despite evidence associating ED overcrowding with increased in-hospital mortality, and reduced mortality in some jurisdictions after introducing a time-based target, uncertainty persists as to such targets consistently improve patient outcomes in most hospitals.

Overzealous pursuit of stringent time-based targets may actually compromise quality of care and endanger patient safety. This was seen in the Mid-Staffordshire

experience in the UK where elevated HSMRs suggested that avoidable patient harm may have increased after introducing time-based treatment targets[8]. A focus on NEAT must be coupled with patient-centred outcome measures to balance the dual needs for hospital efficiency and safe, effective care. [3,4,7,9,10,13,14]

The ideal NEAT compliance rate which maximises the benefits of decongesting EDs while minimising the potential harms of rushed and suboptimal management of acutely ill patients has not been determined on the basis of empirical data. A recent literature review on 4-hour targets in Australia and the UK noted that all were arbitrary and lacked validation.[15] Another review noted that the introduction of the 4-hour rule in the UK, undertaken at considerable financial cost had not resulted in consistent improvements in care with markedly varying effects between hospitals being reported.[16] In Australia, the need to determine the optimal NEAT has increased because of the opportunity costs involved in achieving high compliance rates and the loss of financial incentives following dissolution of the National Partnership Agreement in 2014.[17,18]

The aims of this study were to explore the relationship between risk-adjusted mortality for patients admitted to the hospital from the ED (eHSMR) and NEAT compliance rates using a large dataset from multiple Australian hospitals, and to assess the effects on this association of potential confounding due to the inclusion of palliative care patients and short stay patients.

Methods

Study Design, Participating Sites and Data Sources

This retrospective observational study covered the 4 year period from 1st July 2010 to 30th June 2014. This timeframe was chosen to span the introduction and subsequent focus on NEAT by Australian Governments following the signing of the National Partnership Agreement on Improving Public Hospital Services in February 2011.[2]

De-identified data on hospital admissions during the study period was sourced from The Health Roundtable Ltd (HRT) in accordance with its academic research policy. The final dataset comprised 59 Australian hospitals. All 33 New Zealand hospitals which were working towards a 6-hour target were excluded, as were 26 sites in Australia that had no general emergency departments, 2 specialist hospitals with a different mortality profile, and 48 hospitals for which ED data over the study period were incomplete. With approval from HRT, the de-identified dataset was analysed independently by investigators from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) e-Health Research Centre.

Episodes of care and patient cohorts

All patients presenting to the ED of one the study hospitals and were subsequently admitted or discharged from the ED were included in the analysis. For admitted patients, the unit of analysis was the entire hospital stay, while preserving any changes in care type during the admission. Elective patients, patients coded as dead-on-arrival with a principal diagnosis of sudden unexplained death or who died in ED, organ donation episodes, non-acute and geriatric evaluation and management episodes, and all neonates were excluded. Patients coded as palliative and short stay patients (defined an inpatient less than 24hrs) were excluded from the primary analysis.

In addition to the original cohort, three additional patient cohorts were created:

- patients coded as palliative care at the time of death;
- patients with short stays (defined as a length of hospital stay of less than 24 hours), this cohort serving as a proxy group for patients admitted to short-stay observation wards or clinical decision units, and thereby compensating for inconsistencies between hospitals in coding transfers to these wards as inpatient admissions: and
- these two cohorts combined.

NEAT compliance rates

The NEAT compliance rate was defined as the proportions of patients with ED length of stay (LOS) less than 4 hours. The rate was calculated separately for all patients (total NEAT), and patients admitted to inpatient units and designated short stay units (admitted NEAT).

Main Outcome Measure

The main outcome measure was the relationship between NEAT compliance rates and inpatient mortality for emergency admissions, as expressed by the eHSMR. The eHSMR was preferred to raw mortality for two reasons:

- The eHSMR is the risk-adjusted ratio of the observed to the expected numbers of which helps account for variations in the acuity of presentations and hospital activity.
- The HSMR has been validated in other clinical studies for monitoring patient outcomes.

Statistical analysis

Regression models of eHSMR

Several models were used to calculate the expected number of deaths for the denominator of the eHSMR. In keeping with standard practice [19,20] , the data on all included patients was separated into 2 parts: episodes coded with the top 68 diagnosis codes identified as accounting for 80% of in-hospital deaths (part 1), and those accounting for the remaining 20%, whereby the number of individual International Classification of Diseases, revision 10 (ICD-10) codes was reduced from about 1000 to 10 broad categories based on raw proportions of deaths associated with each code (part 2). Model selection for each part consisted of an elastic net model with tenfold cross validation, with the chosen penalty parameter being the largest lambda within one standard deviation of the minimum.[21] All models

initially included two-way variable interactions. Additional information about the modelling process is available in Appendix C. Area under the curve (AUC) measures assessed the predictive ability of the model, with values of 0.85 found for the part 1 model and 0.89 for the part 2 model. Similar values were found for models of the three additional cohorts described above.

Relationship between NEAT compliance rates and eHSMR

Emergency presentation data and observed and expected in-hospital mortality rates were aggregated at monthly levels for each hospital and each hospital peer group over the study period. Overall NEAT and admitted NEAT compliance rates and eHSMR were then calculated. Exploratory data analysis using linear regression models suggested a complex relationship between NEAT and eHSMR, and non-linear relationships were assessed using a restricted cubic spline with knots at 50%, 60%, 70%, 80%, 85%, 90%, and 95% NEAT compliance rates.
The primary analysis of the NEAT-eHSMR relationship excluded palliative care and short stay patients; the effects on this relationship of including these patient cohorts were explored in sensitivity analyses of the total cohort and each hospital peer group. Statistical analysis was undertaken using R (R Foundation for Statistical Computing): $P<0.05$ was defined as statistically significant.

Ethics approval

An ethics approval exemption was provided by the Metro South Human Research Ethics Committee (HREC/15/QPAH/233). The board of the Health Roundtable also provided approval in accordance with their academic research policy.

Results

Participating sites

Emergency presentation and admissions data and operating characteristics of the participating hospitals are summarised in Appendix D, Table 1. ED and inpatient data were aggregated for 12.5 million ED episodes of care and 11.6 million inpatient episodes of care.

NEAT compliance rates

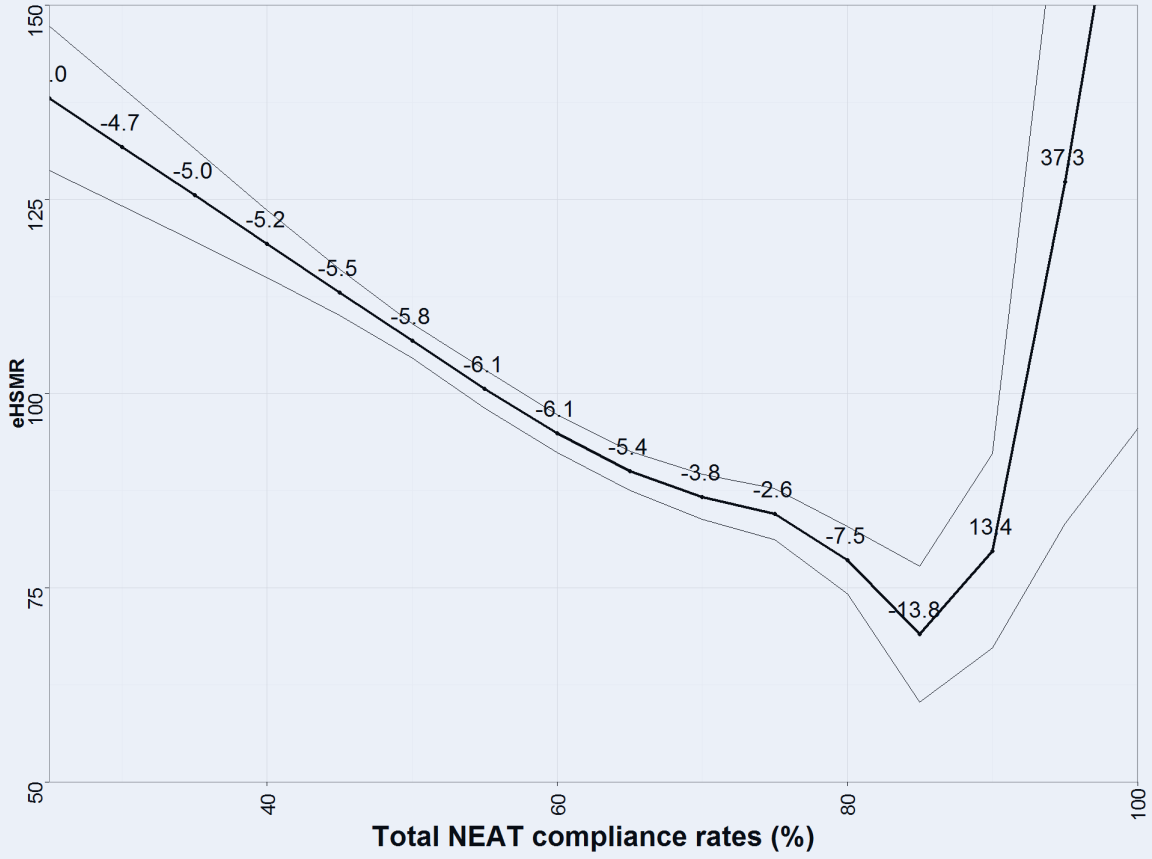
Over the 4-year study period, there was a progressive increase in mean monthly NEAT compliance rates for admitted (25% to 45%), total (56% to 70%) and non-admitted patients (70% to 80%) (Appendix D, Figure 1).

Relationship between eHSMR and NEAT compliance rates

The primary analysis of monthly plots of eHSMR versus total NEAT compliance rate (Figure 3.1) and eHSMR versus admitted NEAT compliance rate (Figure 3.2) for all hospitals combined showed similar and significant ($p<0.001$) inverse linear relationships until an inflection point was reached. Wide confidence intervals beyond these points reflect the fact that limited data were available.

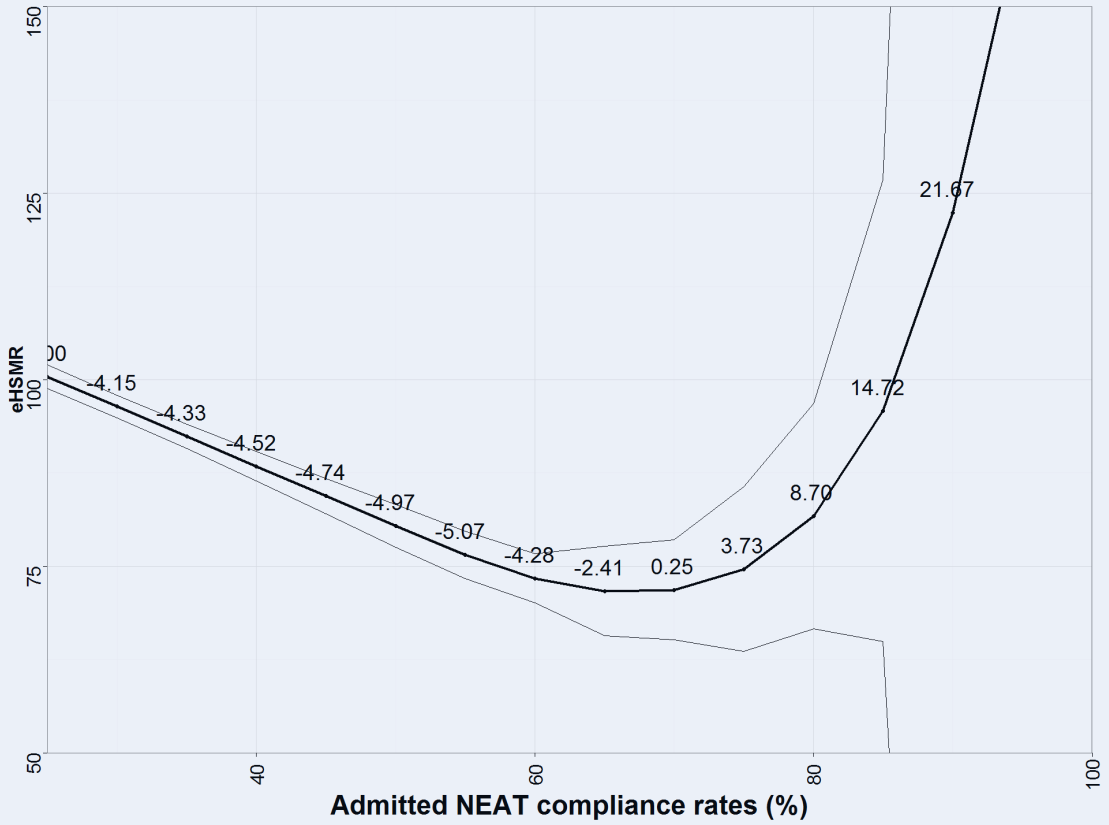
The eHSMR declined on average by 5.5% for every 5 percentage point change in total NEAT compliance rate, reaching a nadir of 73 at a compliance rate of about 83% (range (distance between the two knots in the spline analysis), 80-85%). For admitted NEAT compliance, which included short stay ward admissions, the eHSMR declined on average by 4.5% for each 5-percentage point change in the compliance rate to reach a nadir of 73 at a compliance rate of about 65% (range 60-70%).

Figure 3.1. Total National Emergency Access Targets (NEAT) compliance and hospital standardised mortality ratio for patients admitted from emergency departments (eHSMR) for 59 Australian hospitals, 1 July 2010 - 30 June 2014



P < 0.001 for regression (F-test). Pale lines, 95% confidence intervals; graph labels, change in eHSMR per five percentage point change in NEAT

Figure 3.2 Admitted National Emergency Access Targets (NEAT) compliance and hospital standardised mortality ratio for patients admitted from emergency departments (eHSMR) for 59 Australian hospitals, 1 July 2010 - 30 June 2014

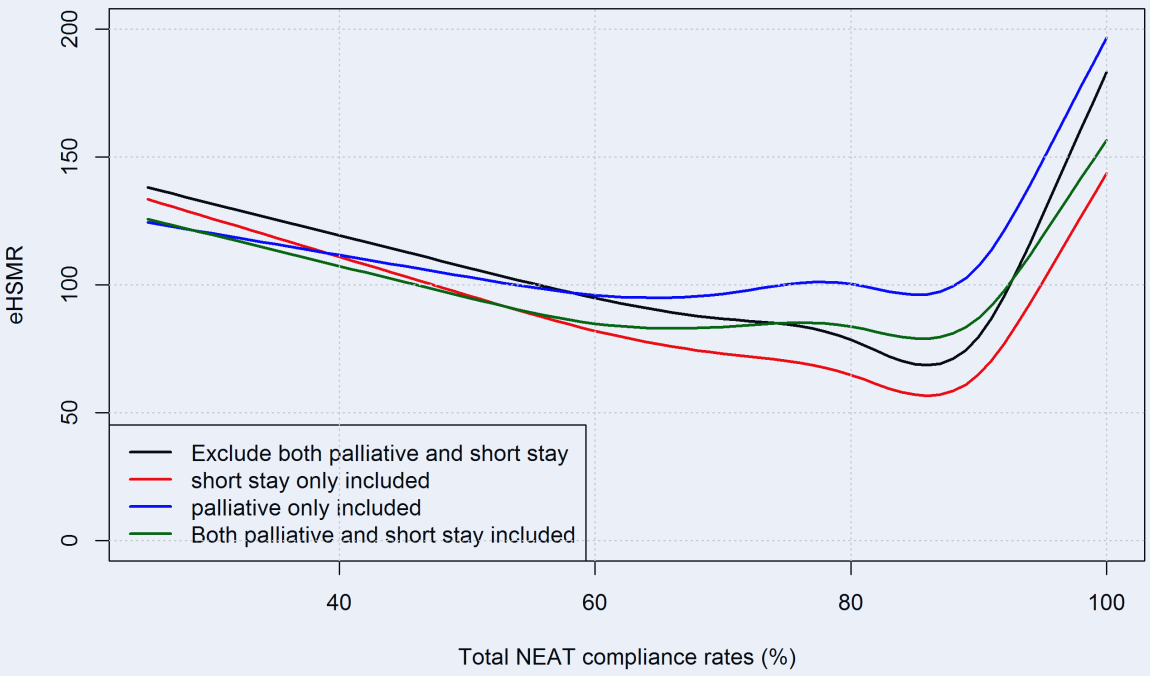


P < 0.001 for regression (F-test). Pale lines, 95% confidence intervals; graph labels, change in eHSMR per five percentage point change in NEAT.

Sensitivity analyses

When the primary analysis was repeated including either palliative care or short stay patients, or both, the previously noted relationships between eHSMR and either total or admitted NEAT compliance rates were largely unchanged (Figure 3.3).

Figure 3.3. Effects of potential confounders (palliative care and short-stay patients) on relationship between total National Emergency Access Targets (NEAT) compliance and hospital standardised mortality ratio for patients admitted from emergency departments (eHSMR) for 59 Australian hospitals, 1 July 2010 - 30 June 2014



Discussion

Overview of findings

With the recent abolition of the NEAT, the future of time-based targets for emergency care is unclear. Ours is the first multisite study to assess a relationship between NEAT compliance rates and risk-adjusted in-hospital mortality. An inverse linear relationship was seen as NEAT compliance rates increased to approximately 83% for total NEAT and 65% for admitted NEAT compliance. Differences between hospitals in the coding of palliative care patients or in the numbers of short stay patients did not affect the eHSMR-NEAT compliance rate relationships.

Strengths and limitations of the study

Our study has several strengths. First, the analysis involved a very large number of episodes of care over 4 years from a large, representative sample of Australian hospitals, including 79% of all tertiary hospitals that account for more than 85% of all ED admissions. Second, we were able to use an objective measure of mortality for emergency admissions to hospital and to assess patient outcomes over the period in which the NEAT was introduced. This study helps inform the debate on whether time-based targets should remain, and if so, what they should be.

Limitations of the study included the fact that this was an observational study. We identified a reduction in eHSMR as NEAT compliance rates increased up to certain values, but this does not prove causality. However, the relationship was highly significant, even in sensitivity analyses which accounted for potential confounders, and we are unaware of any other national hospital quality and safety initiative implemented during the study period. Our omission of some hospitals limits the generalisability of our findings to all institutions. As the primary outcome measure, eHSMR does not encompass other outcomes important to patients such as morbidity or quality of life. Further, the use of HSMRs as the basis for cross-sectional, inter-

hospital comparisons is controversial.[22] Our final models cannot account for errors associated with estimating HSMRs; the denominator is calculated using modelling and will therefore be imprecise.[20] However, the HSMR is objective, accepted as a national measure[5], and serves as a useful indicator of potentially avoidable mortality within individual hospitals when tracked over time, provided there are no major changes in coding practices or admission policies; this applied in our study.[22] Finally, the 95% confidence intervals around the mean eHSMR values corresponding to higher NEAT compliance rates broadened as the number of hospitals achieving such rates decreased, so that it is possible that mortality may further decline at higher NEAT compliance rates.

Implications for clinical practice and policy

We found that there is no robust evidence regarding a clinically significant mortality benefit associated with total and admitted NEAT compliance rates in excess of 83% and 65% respectively. Further, as the identified reduction in mortality for admitted patients was associated with increasing total and admitted NEAT compliance rates, it can be argued that both rates should be monitored. Finally, consideration should be given to embedding time-based NEAT targets within a suite of patient-focussed outcome measures that can quickly signal any unintended adverse consequences of pursuing ever higher NEAT compliance rates.

Translation Process and Progress

This work was rapidly translated into practice in Queensland.

The Queensland Emergency Access Target was modified to “greater than 80%” following the publication of this work (Figure 3.4). At this time, discussions are underway to bring an admitted patient access target of 60% into Queensland HHS service agreements (personal communication M Zanco June 2018).

Other Australian jurisdictions have undergone similar policy revisions in this area.[23]

Figure 3.4. Director General Letter to staff noting change in Emergency Access Target.

Colleagues

We are about to change the performance measure for emergency departments (ED) across the state.

The Collaboration for Emergency Access and Reform (CLEAR) analysed 12.5 million ED episodes of care across Queensland.

The research, which was recently published in the Medical Journal of Australia, clearly identifies that an emergency access target of between 80 to 85 per cent provides the best outcome when a person was admitted to hospital.

We will now lead Australia by setting a Queensland Emergency Access Target of greater than 80 per cent.

This target is set by clinicians who know the system better than anyone else, and I am very happy to take their advice on this issue.

This approach clearly demonstrates an evidence-based and clinically supported approach to monitoring the performance of our emergency departments.

From 1 July 2016, every hospital in the state will now report their emergency access times against this new target.

Kind regards

Michael Walsh
Director-General
Department of Health

References

1. Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *The Medical journal of Australia.* 2016;204(9):354.
2. Commonwealth Government of Australia. *Expert Panel: Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hospital Services* 2011.
3. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *The Medical journal of Australia.* 2006;184(5):213-216.
4. Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *The Medical journal of Australia.* 2006;184(5):208-212.
5. Australian Commission on Safety and Quality in Health Care. Indicators of safety and quality: Core hosputal-based outcome indicators. 2015; http://www.safetyandquality.gov.au/our-work/information-strategy/indicators/core-hospital-based-outcome-indicators/. Accessed 13 May, 2015.
6. Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.
7. Sullivan C, Staib A, Eley R, Scanlon A, Flores J, Scott I. National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. *Aust Health Rev.* 2015.
8. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Controller of Her Majesty's Stationery Office. 2013; http://webarchive.nationalarchives.gov.uk/20150407084003/http://www.midstaffspublicinquiry.com/report. Accessed May 18, 2015.
9. Lowthian J, Curtis A, Straney L, McKimm A, Keogh M, Stripp A. Redesigning emergency patient flow with timely quality care at the Alfred. *Emerg Med Australas.* 2015;27(1):35-41.
10. Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *The Medical journal of Australia.* 2012;196:122-126.
11. Richardson DB. Emergency department targets: a watershed for outcomes research? *Med J Aust.* 2012;196:126-127.
12. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014.
13. Stokes B. Four Hour Rule Program Progress and Issues Review. 2011; http://ww2.health.wa.gov.au/Reports-and-publications/Four-Hour-Rule-Program-Progress-and-Issues-Review. Accessed May 13, 2015.
14. Keijzers G. NEAT in need of a sweet spot. *Emerg Med Australas.* 2014;26(3):217-218.
15. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2015.

16. Jones P, Schimanski K. The four hour target to reduce Emergency Department 'waiting time': a systematic review of clinical outcomes. *Emerg Med Australas.* 2010;22(5):391-398.
17. Queensland Clinical Senate. National Emergency Access Target : Is 90% the right target. 2014; www.health.qld.gov.au/qldclinicalsenate/docs/fin-rep-mar2014.pdf. Accessed 13 May, 2015.
18. Monaghan M. A discussion on the future of the National NEAT targets. 2014; http://www.health.qld.gov.au/qldclinicalsenate/docs/pp-140328-neat-wa.pdf Accessed May 13, 2015.
19. Ben-Tovim DI, Woodman RJ, Hakendorf P, Harrison J. Standardised mortality ratios. Neither constant nor a fallacy. *BMJ.* 2009;338:b1748.
20. Ben-Tovim DI, Woodman R, Harrison JE, et al. Measuring and reporting mortality in hospital patients. 2009; http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=6442457123 Accessed May 18, 2015.
21. Hastie RT, And Friedaman, J. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction.* 2nd ed: Springer; 2009.
22. Scott IB, CA. Phelps, GE. et al Using hospital standardised mortality ratios to assess quality of care--proceed with extreme caution. *Med J Aust.* 2011;194(12):645-648.
23. Emergency Care Institute New South Wales. ETP=The Basics. 2017; https://www.aci.health.nsw.gov.au/networks/eci/administration/neat/neat-the-basics. Accessed 14 July, 2018.

Chapter 4

A clinical tool for the ED-Inpatient Interface:

The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital

Preamble

This chapter was published as a standalone paper in *Emergency Medicine Australasia*[1] and is attached as Appendix E. Relative contributions to this work by each author are included in the preliminary pages.

The process and progress of translation of this work into clinical practice is also described in this chapter.

Introduction

Access to emergency care in hospitals is critical for our sickest and most complex patients and receives extensive community and political interest as evidenced by the 4-hour rule or the National Emergency Access Targets (NEAT).

The cohort of patients who are discharged home from the Emergency Department (ED) are a relatively low acuity, low cost group to treat. EDs alone can streamline and improve the care of this group without having to engage with inpatient clinicians and complicated whole of hospital processes.

However, the group of ED patients who require admission to an inpatient unit have to negotiate the ED-inpatient interface (EDii). The EDii is the complex interplay which occurs between the ED and inpatient hospital services as a patient transfers from emergency to inpatient care. This group of patients is typically at high risk for harm, has significant clinical complexity and has a high mortality rate when compared to patients admitted electively.[2-4]

Despite a relative lack of robust, peer-reviewed research in this area, the ED-inpatient interface is one of the very few areas where governments have imposed time targets for clinical care. The National Emergency Access Target (NEAT) introduced by the Australian government in 2011, directed that 90% of patients presenting to EDs should be admitted, discharged or transferred within 4 hours of

presentation. However, there was no accompanying robust policy for monitoring patient outcomes.[5-7] The national partnership agreement underpinning the NEAT has recently been dissolved and considerable uncertainty exists as to whether time targets for emergency care should continue.[6] Recent work has provided strengthened evidence of an inverse association between 4-hour target compliance rates and in-hospital mortality.[8]

Princess Alexandra Hospital (PAH) is a large tertiary hospital which previously recorded one of the worst NEAT performances nationally. Although the hospital executive was committed to improving the NEAT compliance, there was a lack of engagement from clinicians, particularly inpatient teams.

This lack of engagement was underpinned by concerns that rushing patients out of the ED may cause harm and a lack of confidence to undertake process change as patient outcomes were unable to be easily tracked. There were no readily available data sources on outcomes for patients requiring emergency admission to hospital. There was existing evidence from the literature that efficient ED processes were associated with better patient outcomes and reduced inpatient mortality.[9]

As part of a multi-faceted clinical redesign effort which is described elsewhere,[4] agreement was reached between emergency physicians and Division of Medicine (DOM) clinicians to develop a dashboard to monitor the efficiency and quality of care at our EDii. The DOM comprises all medical specialties, including general medicine, and are responsible for receiving the majority of emergency admissions. This divisional arrangement meant that engagement of individual medical inpatient units was undertaken by the Division of Medicine clinical leaders rather than emergency physicians. The Divisions of Surgery and Cancer Services were similarly engaged. An easily accessible dashboard amalgamating ED and inpatient data sources and process and quality of care measurements was built to give confidence to clinical redesign efforts.

The outcome measures chosen for the dashboard were:

- Emergency Admission Mortality Rate: defined as the percentage of acute patients who were admitted via the ED and who died in any hospital ward, including the ED short stay ward.
- Emergency Hospital Standardised Mortality Ratio (eHSMR): The standardised mortality ratio as calculated by the Health Roundtable using validated methodology[10,11] for patients admitted into hospital via the ED.
- Cardiac arrest within 24 hours of admission: the total number of cardiac arrests, as defined by Jacobs[12], per 1000 admissions within 24 hours of admission to a ward for patients admitted via ED.
- Rapid Response Team (RRT) activations within 24 hours of admission: the total number of RRT activations initiated for deteriorating patients (excluding cardiac arrests) per 1000 admissions. This excluded same day patients, statistical admissions, and same-day patients to "day only" wards.
- ED representation rate within 48 hours: the percentage of patients who re-presented to ED within 48 hours of the index attendance.

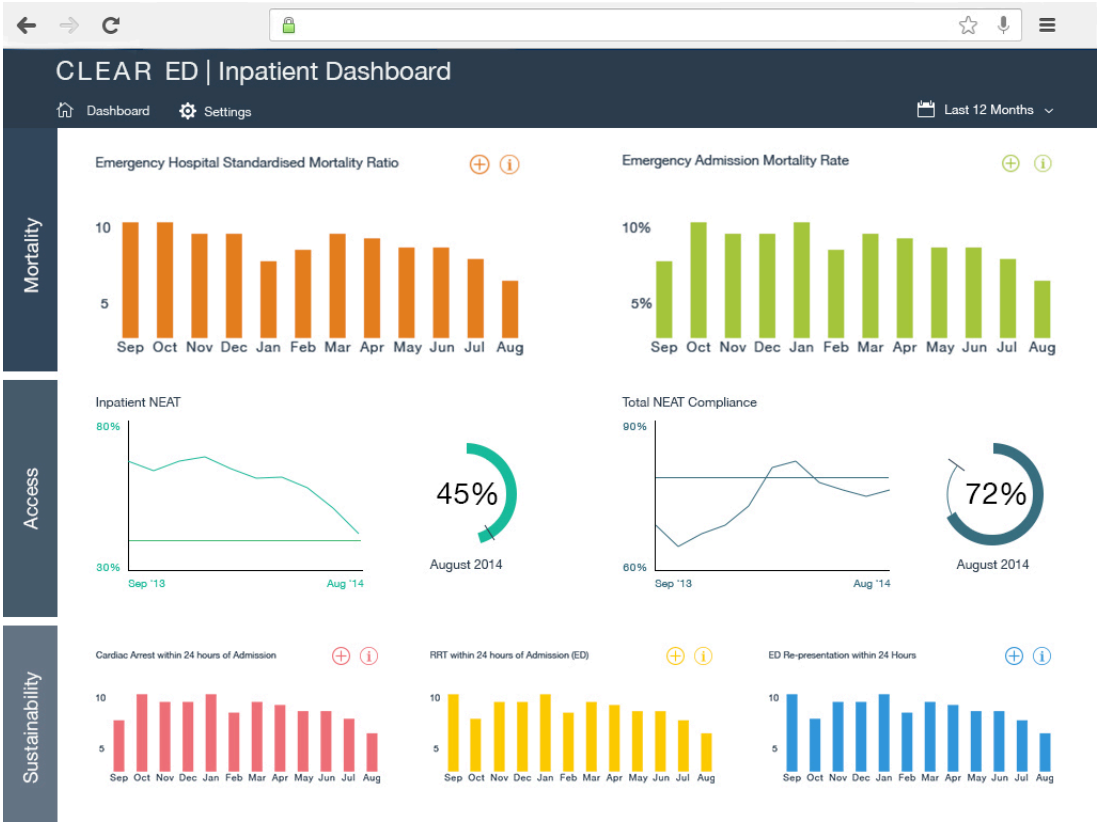
Results

Concerted cultural change and more than 25 clinical redesign interventions focussed on the performance of, and relationships among the clinical teams integral to EDii function, supported by the dashboard display of outcome and process measures culminated in a near halving of ED length of stay (from 7.2 hrs to 3.8 hrs) and a near halving of the mortality for patients (from 2.3% to 1.0%) requiring emergency admission to PAH.[4] No clinically significant adverse safety signals were seen following the implementation of these reforms as assessed by numbers of RRT activations within the first 24 hours of admission or ED representation within 48 hours.[4]

The EDii dashboard is shown in Figure 4.1. The dashboard was implemented at PAH in early 2014 and is now being utilized or implemented in several Australian

hospitals. The innovative nature and utility of the dashboard was independently recognised by the awarding of a merit certificate to the project team at the iAwards.[13]

Figure 4.1 Princess Alexandra Hospital Emergency Department-Inpatient Interface (EDii) Dashboard



Discussion

The development and implementation of the EDii dashboard has provided clinicians and hospital executives with a visual platform to ensure that time-based emergency access measures are always nested in a standardized, near real-time matrix of quality indicators. Data are now displayed in a meaningful format that assists clinical decision making. The EDii dashboard gave clinicians considerable confidence to undertake and maintain significant clinical redesign of the EDii. An example case study is provided in Box 4.1.

Box 4.1- Case Study

The changes in our processes for a representative patient before and after our clinical redesign are detailed below. The EDii dashboard has allowed us to link efficiency of care in the ED and patient outcomes and this new knowledge has changed the way inpatient teams react to emergency admissions.

Case

Mrs GL is 80 years old with a history of diabetes and poor mobility who had a fall at home and was found to be mildly hypotensive and febrile by the ambulance team. She arrived at our ED and responded well to resuscitation with fluids and antibiotics. She was found to have a urinary tract infection and mild delirium.

Clinical process *before* EDii Clinical Redesign

The medical registrar on call for emergency admissions that afternoon was a good clinician but had a strong reputation for being "a wall". There were several difficult phone conversations between him and ED staff regarding admission for Mrs GL, as he refused admission until all investigation results were returned and documented, and he had had the opportunity to review the patient after finishing his outpatient clinic. Mrs GL was eventually admitted to the general medical ward after an 8 hour stay in the ED.

Clinical process *after* EDii Clinical Redesign

The medical registrar on call for emergency admissions that afternoon was a good clinician and knew that short stays in the ED were associated with better mortality outcomes for patients like Mrs GL. He had flagged her as a potential admission on the regular combined inpatient-ED ward round and had her admitted to the general medical ward for definitive management of her urosepsis and delirium. Mrs GL spent only 3.5 hours in the ED.

The introduction of clinical and quality dashboards has been reported in the literature to have a positive effect on care outcomes and processes of care.[14,15]

The success of this dashboard is attributable to several factors

1. The dashboard was developed in response to a clearly defined, important clinical problem against a background of limited clinical engagement due to concern that pursuit of time-based process measures, by themselves, might be harmful to patients.

2. The project was led by clinicians with operational roles which allowed the effective implementation and dissemination of the dashboard into everyday clinical practice across the organization. The clinicians were able to utilize the expertly presented data to monitor the effects of health service improvement which in was able to be tracked using the dashboard.
3. The dashboard was constructed in a way that encouraged easy replication in other facilities. It was designed as a local quality improvement tool and specifically not as a tool for benchmarking across sites.
4. The dashboard formed an integral part of a coordinated whole of hospital cultural change focusing on improving patient outcomes rather than process measures in isolation.

The EDii safety dashboard, and the system reforms that it facilitated, have supported a significant culture change within PAH. We have seen patient outcomes become the centre of decision making processes. Improved patient outcomes (rather than isolated time measures) are key drivers for united clinical engagement with reform. In addition, the ability to rapidly identify any potential adverse patient safety signals has increased the appetite for innovation and a willingness to try new processes.

Interrogating ED data systems (such as Emergency Department Information Systems (EDIS), Computer Sciences Corporation) can inform clinical redesign and improve overall patient throughput and turnaround times.[16,17] Baumlin *et al* noted the major limitation in their EDIS implementation was the system's inability to be fully integrated into existing hospital applications.[16]

A data warehouse enables data integration from ED and inpatient sources and information exchange across the enterprise, supporting clinical and operational decision making by breaking down traditional clinical silos.[18,19]

Future iterations of the ED-inpatient interface dashboard will include access to more granular data, including more accurate time stamping of clinical events across EDii, and more detailed coded clinical information. Fortunately, these are primary benefits

of an integrated electronic medical record(ieMR) which Princess Alexandra Hospital has recently implemented. An EMR will allow more real time presentation of tailored information to allow clinicians to make immediate decisions about current and future service provision to maximize benefit to patients.

Limitations

There are several limitations to this work. The data remain retrospective and is a reflection of past performance rather than a real time indication of factors that can be modified to improve current performance. The outcome measures in use are important but very gross reflections of quality of care.[10] The process changes and delivery of quality care remain the responsibility of the clinical teams, and the inspiration and motivation for change comes from them.

Conclusion

The EDii dashboard has supported health system reform in this important area by bringing into clearer focus the important link between key process measures and their impact on patient outcomes.

The linking of patient outcome measures to routinely collected process measures has increased clinical engagement, focused decision making on the patient, and contributed to a culture where system innovation is promoted to maximize the efficiency, quality and safety of the care delivered to our patients.

Translation into practice

Versions of this dashboard were subsequently implemented in several EDs in Queensland and across Australia. As detailed in Chapter 3, changes in Queensland Health policy regarding emergency access to hospital included recommendations for tracking important patient outcomes. This dashboard was utilised for this purpose at the sites where it was implemented.

The principles that contributed to the success of this project and outlined in the discussion have since been applied in other areas of clinical analytics and redesign

at PAH and are now applied at a Queensland statewide level for prioritising clinical data and analytic projects utilising the digital hospital platform. For example, PAH has now developed and implemented clinical analytics-based redesign using similar dashboards for the Australian Commission for Safety and Quality in Healthcare National Safety and Quality Indicators[20], and at a Queensland-wide level, similar projects are underway to transform trauma and stroke care based on these learnings and principles. This work will be published in the near future.

In the Emergency Department setting, the digital hospital platform has indeed enabled the development of realtime dashboards incorporating actionable process and clinical information for ED clinicians. This work will also be published in the near future as part of a post-doc body of work.

Acknowledgements

The authors are grateful to the following people for their contributions and support.
Dr Richard Ashby, CEO Metro South Health
Dr Susan O'Dwyer, EDMS Metro South Health
Linda McCormack and Julie-Anne Jaques Health Innovation Unit, Queensland Department of Health
Mr Michael Draheim and Mr Cameron Ballantine PAH ICT
Chantelle Judge PAH
Michelle Winning and the Clinical Service Excellence Team (CSET) PAH
Amanda Vaux, Lisa Tewhatu and David Moore and the PAH ICU outreach team.
We would also like to acknowledge the support and sponsorship of the Chair (Dr David Rosengren) and the membership of the Queensland Clinical Senate
This study was partly funded by the Health Innovation Unit, Queensland Department of Health

Keywords

NEAT compliance, ED-Inpatient Interface, Dashboard, Business intelligence, business analytics, patient safety.

References

1. Staib A, Sullivan C, Jones M, Griffin B, Bell A, Scott I. The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emerg Med Australas.* 2017;29(3):363-366.
2. Ruiz M, Bottle A, Aylin PP. The Global Comparators project: international comparison of 30-day in-hospital mortality by day of the week. *BMJ Qual Saf.* 2015;24(8):492-504.
3. McCusker J, Vadeboncoeur A, Levesque JF, Ciampi A, Belzile E. Increases in emergency department occupancy are associated with adverse 30-day outcomes. *Acad Emerg Med.* 2014;21(10):1092-1100.
4. Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.
5. Sullivan C, Staib A, Eley R, Scanlon A, Flores J, Scott I. National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. *Aust Health Rev.* 2015.
6. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2015.
7. Commonwealth Government of Australia. Expert Panel. *Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hopsital Services.* 2011 2011. 978-1-74241-535-2.
8. Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *The Medical journal of Australia.* 2016;204(9):354.
9. Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *The Medical journal of Australia.* 2012;196:122-126.
10. Ben-Tovim DI, Woodman RJ, Hakendorf P, Harrison J. Standardised mortality ratios. Neither constant nor a fallacy. *BMJ.* 2009;338:b1748.
11. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014.
12. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa). *Resuscitation.* 2004;63(3):233-249.
13. Association AII. 2015 Queensland iAwards Winners and Merit Recipients. 2015; http://www.iawards.com.au/index.php/winners/2015-winners/2015-winners-qld. Accessed 23/1/2016.
14. Dowding D, Randell R, Gardner P, et al. Dashboards for improving patient care: review of the literature. *Int J Med Inform.* 2015;84(2):87-100.

15. Wills MJ. Decisions through data: analytics in healthcare. *Journal of healthcare management / American College of Healthcare Executives.* 2014;59(4):254-262.
16. Baumlin KM, Shapiro JS, Weiner C, Gottlieb B, Chawla N, Richardson LD. Clinical information system and process redesign improves emergency department efficiency. *Joint Commission Journal On Quality And Patient Safety / Joint Commission Resources.* 2010;36(4):179-185.
17. Baumlin KM, Shapiro JS, Weiner C, Gottlieb B, Chawla N, Richardson LD. Clinical information system and process redesign improves emergency department efficiency. *Joint Commission journal on quality and patient safety / Joint Commission Resources.* 2010;36(4):179-185.
18. Vallejo BC, Krepper R, Nora H, Fine DJ. Converting data into information. *Hosp Top.* 2012;90(1):11-15.
19. Vallejo BC, Krepper R, Nora H, Fine DJ. Converting Data into Information. *Hospital Topics.* 2012;90(1):11-15.
20. Barnett A, Winning M, Canaris S, Cleary M, Staib A, Sullivan C. Digital transformation of hospital quality and safety: real-time data for real-time action. *Aust Health Rev.* 2018.

Chapter 5

The Digitisation of the EDii

Digital transformation of the emergency department-inpatient interface (EDii): integration for future innovation

Preamble

This chapter builds on the preceding chapters to examine the impact on the EDii of another major health policy development (digital transformation of hospital care) as seen through the lens of the definition, characterisation and established monitoring measures and tools of the EDii.

Versions of this chapter have been peer reviewed and presented at the International Hospital Federation 42nd World Hospital Congress in Brisbane in November 2018 and the Australasian College for Emergency Medicine Annual Scientific Meeting in Perth in November 2018.

A version of this chapter was subsequently accepted for publication by Australian Health Review subject to minor revisions. These revisions were under review at the time of thesis submission.

Introduction

Digitisation of healthcare is occurring rapidly, and Australia is undergoing a major digital transformation of hospital care. Many states have digital transformation projects occurring across their hospital systems.[1,2] The index site underwent a rapid complete digital transformation in late 2015 with the rollout of an integrated electronic medical record (ieMR) across the inpatient, outpatient and emergency department areas.[3]

The emergency department (ED) had utilised a stand-alone electronic Emergency Department Information System (EDIS) (Computer Sciences Corporation, Los Angeles California, USA) for more than a decade. Although EDIS had provided excellent functionality for medical documentation in the ED, it did not integrate at all with the rest of the hospital which used traditional paper-based charts and workflows.

As the focus of clinicians and government shifted from specialty-based care to system-based key performance indicators such as the National Emergency Access

Target (NEAT) or the 4-hour rule, integration between ED and inpatient clinical workflows and information systems became increasingly necessary.[4] Such system measures are focussed on the patient journey throughout the hospital, rather than performance of individual departments in isolation. This new system-based performance framework saw the development of concepts such as the Emergency Department-inpatient interface (EDii).[5]

The EDii is defined as the the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.[5]

To give confidence and direction to those undertaking patient-centred clinical redesign, and based on previous work at the EDii, integrated clinical information and near real time monitoring of patient outcomes and system process measures were required.[6] It became clear that traditional siloed information systems such as paper charts and digital systems confined to a single specialty area (such as EDIS), were unable to provide linked, clinically relevant patient data across the system which is increasingly required to drive improvement.

Such frustrations with the existing siloed systems motivated the hospital to undertake the implementation of an integrated electronic medical record system (ieMR) that would provide an integrated digital platform for patient care across the whole hospital.

The index site undertook a rapid major digital transformation with the implementation of an ieMR over three weeks in December 2015.[3] This ieMR provided a single integrated digital platform for care across the ED, inpatient wards and outpatient settings. A digital “stack” that included Cerner FirstNet (Cerner Corporation, Kansas City, Missouri, USA), integrated with inpatient vital sign observations, clinical documentation and workflows in Cerner PowerChart (Cerner Corporation, Kansas City, Missouri, USA), as well as all radiology and laboratory ordering, and results reporting was implemented for all patients and all major locations within the hospital. Exceptions were ICU and anaesthesia. Medication prescribing remained on paper

for the duration of this study. ICU continued on their existing standalone clinical information system for technical reasons and the implementation of the integrated anaesthetic module was paired with the rollout of digital medications in a second phase after the study period.

This provided integrated real-time, linked clinical data available to the treating clinicians throughout a patient's hospital stay and beyond the capability of pre-existing isolated systems. ED clinicians now had immediate access to current and previous inpatient and outpatient information, and inpatient teams could view ED clinical information including vital signs, ECGs and medical and documentation in real time thus digitising the EDii for the first time.

There was significant political and clinical interest in the impact of the rapid rollout of this ieMR on the emergency department and its interface with the inpatient areas (the ED-inpatient interface (EDii).)[6] That interest was driven in part by the vulnerability of this patient group to system-related factors and anecdotal reports that ED LOS might increase, and patient outcomes could worsen.[3,7,8]

Based on clinical experience and anecdotal reports, the working hypothesis was that the digitisation of the EDii would initially slow EDii time-based performance due to the effort of clinicians adapting to a new system, but that patient clinical outcomes may improve due to greater availability to all teams of integrated clinical information.

The aim of this paper was to assess the impact of digital transformation of the EDii on hospital process measures and clinically sensitive outcome measures for patients requiring emergency admission to hospital.

Methods

Design, Participants and Setting

The Princess Alexandra Hospital is an adult tertiary academic centre seeing over 60,000 emergency presentations per year. The ED previously operated with an isolated digital system for patient tracking and medical documentation (EDIS). ED nursing documentation was undertaken on paper, as was all inpatient hospital documentation. Post digitisation, the entire hospital utilised the integrated Cerner Millennium (Cerner Corporation Kansas City USA) software except for ICU, anaesthesia. Medication prescription remained on paper for the duration of the study.

This was a pre-post intervention study using routinely collected administrative data involving all patients presenting to the ED between 28/11/2014 and 28/2/2017. For the purposes of comparative analysis and to minimise the impact of seasonal effects, two twelve-month periods were compared. The twelve-month period immediately prior to digital implementation (28/11/2014-27/11/2015) was chosen as the pre-intervention group, and the twelve-month period 1/3/2016-28/2/2017 was chosen as the post-intervention group. The digital go-live period began on 28/11/2015 with the ED and the remainder of the hospital went live over the following three-week period. To minimise the impact of temporary factors, the period 28/11/2015-29/2/2016 was considered a transition period and data for this period were not analysed. In addition, longitudinal monthly data for ED 4-hour rule compliance was obtained over the study period.

Data Collection

Data collected from routine clinical and administrative information systems as detailed in the tables below. Patients subject to the EDii were defined as patients who presented and were managed in the ED and were subsequently admitted to a true inpatient ward.

To enable meaningful comparison of pre- and post- implementation process measures and consistency of statutory reporting requirements, a new state-wide Emergency Data Collection System was developed to define, extract and match equivalent measures between the old and new systems. In my operational role, I led the development and implementation of this system.

Clinical outcome data was sourced from unchanged non-ieMR sources for both groups.

Study Outcome Measures

These established and routinely monitored measures were defined and collected as described in table 5.1. Data elements and definitions were standardised between systems as part of the requirement for routine statutory reporting of these metrics.

Table 5.1: Study outcome measures collected pre and post digitisation of the EDii

Hospital Process Measures	**Definition**	**Data Source**
Total 4-hour rule compliance	Compliance rates comprised the proportions of all patients with ED length of stay (LOS) less than 4 hours.	Pre-intervention: routine reporting extracts from EDIS Post-intervention: routine reporting extracts from Cerner FirstNet
EDii 4-hour rule compliance	Compliance rates comprised the proportions of patients with EDLOS less than 4 hours and were derived separately for patients admitted to inpatient units not including designated short stay wards	Pre-intervention: routine reporting extracts from EDIS Post-intervention: routine reporting extracts from Cerner FirstNet

Average EDLOS (ED length of stay)	The median length of stay for all patients presenting to the emergency department.	Pre-intervention: routine reporting extracts from EDIS Post-intervention: routine reporting extracts from Cerner FirstNet
EDii average LOS	The median ED length of stay for patients presenting to the emergency department who were subsequently admitted to a true inpatient ward.	Pre-intervention: routine reporting extracts from EDIS Post-intervention: routine reporting extracts from Cerner FirstNet

Patient outcome measures	**Definition**	**Data source**
eHSMR	The standardised mortality ratio as calculated by the Health Roundtable using the current version of previously validated methodology [9,10] for patients admitted into hospital via the Emergency Department.	Health Roundtable (HRT)
Raw mortality	The percentage of acute patients who are admitted to inpatient units via the Emergency Department and who die in the hospital during that episode of care.	Routinely collected inpatient mortality data- Hospital Corporate Information System (HBCIS; iSoft, Aldershot, United Kingdom).
Cardiac arrest within 24 hours of admission	The total number of cardiac arrests per 1000 admissions within 24 hours of admission to a ward for patients admitted via ED.	Routinely collected hospital cardiac arrest team data
Rapid Response Team calls (RRTs) within 24 hours of admission:	RRT within 24 hrs- the total number of RRTs initiated for deteriorating patients (excluding cardiac arrests) per 1000 admissions. This excludes same day patients, statistical admissions, and same-day patients to “day only” wards.	Routinely collected intensive care unit outreach team data

Statistical Analysis

Results were collated and checked using Microsoft Excel (Microsoft Pty. Limited, North Ryde NSW). Data were analysed in SPSS (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) using T test for parametric continuous variables, chi-squared for categorical variables and Mann-Whitney U test for non-parametric continuous variables. Statistical significance was defined as $p < 0.05$. The eHSMR was calculated de novo using the currently applied Health Roundtable version of previously described methodology [8-10] for patients admitted into hospital via the Emergency Department, and p value was calculated by comparing the log of SMR ratios to a normal distribution.[11]

Ethics Approval

This project was considered exempt from requiring formal ethical review by the Metro South Human Research Ethics Committee (HREC/17/QPAH/107).

Results

Characteristics of the pre- and post- intervention groups are detailed in Table 5.2. There was a non-significant reduction in overall ED attendances in the post digital period. There was non-significant change in patient acuity as measured by the Australasian Triage Scale (ATS) except for a small reduction in non-acute (Category 5) presentations.

There was a small but significant increase in the proportion of patients who were admitted in the post-intervention group. Most additional admissions were to the ED short stay unit, and not subject to the EDii.

Table 5.2. Group characteristics for the pre and post intervention cohorts

Patient Characteristics		**Pre-intervention N=62,374**	**Post-intervention N=60,359**	***p* value**
Age (mean years ± standard deviation)		47.01±20.29	46.73±20.18	0.035
Sex	Men	56.8%	56.8%	0.426
	Women	43.2%	43.2%	
Discharge destination	Home	41.5%	37.4%	<0.001
	Inpatient	30.5%	31.7%	<0.001
	Short Stay Unit	16.6%	19.3%	<0.001
	ED Mental Health Unit	6%	6.3%	0.02
	Other Hospital	0.9%	0.8%	0.05
	Left against medical advice or did not wait	4.5%	4.4%	0.76
	Died in the ED	0.1%	0.1%	0.76
Australasian Triage Scale	1	1.8%	2%	0.07
	2	20.6%	20.9%	0.13
	3	49.8%	50.3%	0.9
	4	22.2%	22%	0.39
	5	5.5%	4.7%	<0.001

Pre-intervention time period: 28/11/2014 to 28/11/2015
Post-intervention time period: 1/03/2016 to 28/02/2017

Hospital Process Measures for the EDii

Tables 5.3 and 5.4 demonstrate the changes in process metrics associated with the digitisation of the EDii. The median length of stay increased by 13 minutes for all patients, and 39 minutes for patients negotiating the EDii for inpatient admission.

Table 5.3. Results for ED length of stay measures pre and post digitisation of the EDii

ED LOS measures	Pre-intervention	Post-intervention	*p* value
Number of patients	62,374	60,359	
ED LOS hrs (median, IQR)	3:43 (3.08)	3:65 (3.63)	<0.001
Number of EDii patients	19044	19109	
ED LOS EDii patients hrs (median, IQR)	5:73 (4.45)	6:38 (5.22)	<0.001

Pre-intervention time period: 28/11/2014 to 28/11/2015
Post-intervention time period: 1/03/2016 to 28/02/2017
IQR: Interquartile range

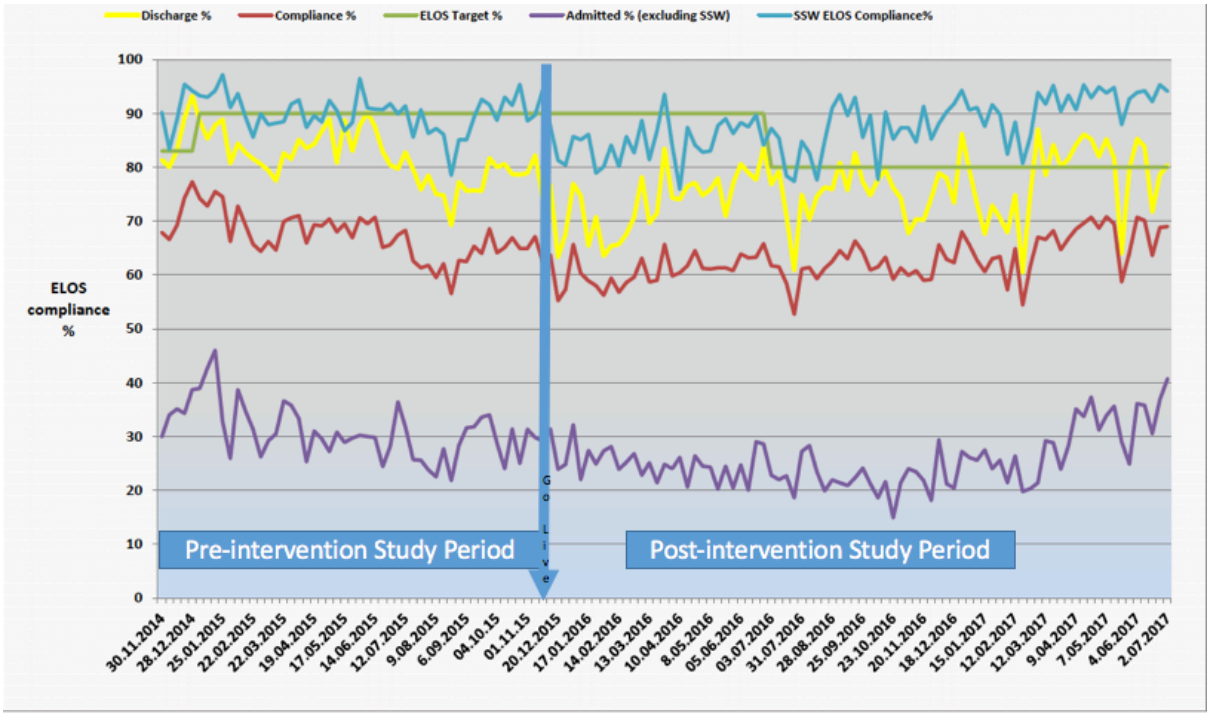
Table 5.4. Results for 4-hour rule compliance measures pre- and post-digitisation of the EDii

Performance Measure	Pre-intervention 4-hour rule compliance		Post-intervention 4-hour rule compliance		*p* value
	%	N	%	N	
Overall compliance	67.2%	62, 374	62.0%	60, 347	
Compliance for patients discharged home from the ED	79.4%	25, 862	73.8%	22, 560	<0.001
EDii compliance	33.4%	19, 044	27.3%	19, 109	
Compliance for patients admitted to a short stay ward from the ED	88.2%	10, 323	85.4%	11, 662	<0.001

Pre-intervention time period: 28/11/2014 to 28/11/2015
Post-intervention time period: 1/03/2016 to 28/02/2017

Figure 5.1 demonstrates the longitudinal time series of 4-hour rule compliance for all patient and the EDii group. The 4-hour rule compliance for all patients, and for the EDii group (admitted % excluding SSW) declined immediately after digitisation, only returning to pre-digital levels at the end of the study period.

Figure 5.1- 4-hour rule compliance time series



Discharge%; 4-hr rule compliance for discharged patients, Compliance %;4-hr rule compliance for all patients, ELOS target %; Queensland 4-hr rule policy target, Admitted %; 4-hr rule compliance for patients admitted to true inpatient units, SSW ELOS compliance; 4-hr rule compliance for patients admitted to the Short Stay Ward.

Patient Outcomes Measures for the EDii

There were 55 fewer deaths in the post-intervention group (15% relative reduction) (p=0.02). There was a 10% relative reduction in adjusted mortality as measured by eHSMR which did not reach statistical significance (Table 5.5).

Table 5.5. Results for patient outcome measures pre and post digitisation of the EDii

Patient Outcome Measures for EDii patients	Pre-intervention		Post-intervention		*p* value
	%	n	%	n	
Rapid response team calls	0.5%	287	0.7%	399	<0.001
Cardiac arrest	0.008%	5	0.013%	8	0.27
Raw Inpatient mortality	1.9%	362	1.6%	307	0.016
eHSMR	0.78		0.71		0.14

Pre-intervention time period: 28/11/2014 to 28/11/2015, N= 62,374
Post-intervention time period: 1/03/2016 to 28/02/2017, N= 60,359

Discussion

The EDii is a critical operating system for all acute hospitals and the performance of the EDii is a subject of considerable interest for politicians, hospital executives and the general public.[5] Digital transformation of a hospital is a disruptive event, and digitising the EDii is especially challenging given that time performance is subject to such close scrutiny.[12]

Process Metrics

The results demonstrate an initial increase in EDLOS and decrease in 4-hour rule compliance. This reduction in performance against process metrics occurred across all patient streams in the ED but was particularly noticeable in the patient cohort subject to the EDii. This again highlights the susceptibility of this patient group to changes in such a complex adaptive system. Such decrement in time efficiency was temporary and is described in the literature as “digital deceleration”.[12] This deceleration has been previously observed during the implementation of isolated emergency department EMRs.[13]

There are many factors that can contribute to digital deceleration. The introduction of any new system requires a period of learning and adjustment which impacts on the duration and complexity of many tasks in the patient journey.

This is likely to be particularly true in this study, as the study site was the pioneer site for the state of Queensland. Full digitisation of the EDii is complex and had not been previously undertaken in an Australian setting. This required many iterations of technical and workflow modifications This process is still undergoing fine tuning and optimisation.

Patient Outcomes

There was an increase in rapid response team calls to patients admitted via the ED within 24 hours. The digital transformation of the hospital included the introduction of a digital deteriorating patient system and linked with an existing body of work encouraging early notification of deteriorating patients. Increased detection of deteriorating patients is associated with a reduction in mortality and this is likely to be one of many factors contributing to the outcome of our study.[14] No significant difference in inpatient cardiac arrest rates was detected before or after digitisation of the EDii.

Digitisation of the EDii was associated with a significant reduction in raw in-hospital mortality for patients admitted via the emergency department despite a longer EDLOS. We also recorded a 10% relative reduction in risk adjusted in-hospital mortality for emergency admissions which did not reach statistical significance. There was no evidence of increased harm or worsening of patient mortality outcomes which was a significant clinical concern before digital transformation.

The previous literature has demonstrated an inverse association between 4-hour rule compliance and in-hospital mortality both nationally and at the index site.[7,8] This association was shown in the absence of a digital EDii. Different siloed information systems were used for the ED and inpatient wards in these previous studies. The association of improved raw mortality across the digitised EDii in this time period of

study may be unrelated to EDLOS and reflect new methods of care provision with increased availability of clinical information provided by an integrated digital platform mitigating the usual adverse clinical impact of a delayed EDii transit for patients. Further longitudinal characterisation of the relationship between EDLOS and inpatient mortality in a mature digital integrated hospital is required.

Study Limitations

The relationships demonstrated by such a retrospective observational study of a short time period are associations and do not prove causation. They are subject to confounding by other changes that impact on such a complex adaptive system. Many factors provide potential confounders to a study such as this. Although the study periods were chosen for their absence of any other major clinical redesign interventions, changes in clinical care delivery and capacity may influence the study outcome measures. For example, changes in rapid response team activation and awareness may have been a causative factor in reduced mortality. This study coincided with a non-statistically significant reduction in attendances at the emergency department. The use of raw mortality as an outcome measure can be criticised as patient complexity and acuity is not accounted for in this metric. This is a valid limitation and provides only part of an answer to a complex question. Risk adjusted mortality is a more widely accepted measure and did suggest a reduction which did not reach statistical significance. To achieve a statistically significant result in this metric, a sample size of approximately double that available in this study would be required. This was not possible in this observational study due to external factors. A multi-site study is planned to build on this initial data in an attempt to further answer this important question.

The strength of an observational study is that it reflects real world practice where digital transformation is always part of a multifaceted transformation in the delivery of patient care. A strength of an observational study in this institution at this time was the existence of an otherwise stable clinical and organisational environment where no other major executive or clinical personnel or process changes were undertaken. This study's aim was not to document the benefit of an ieMR implementation or attribute causation to the technology itself; merely to assess the impact of the

transformation of care based on transition to a digital platform at the EDii. The changes in clinical care during the study period were all informed by or contributed to digital transformation of patient care in the hospital.

Future of the Digital EDii

The safe introduction of an integrated digital platform provides new potential for improvements in care for patients requiring emergency treatment.

Better access to clinical information:

The integrated digital platform allows for greater visibility and availability of important clinical information. All records from previous attendances both at the index hospital and from all other hospitals on the digital platform are immediately available. This includes information important for time-critical decision making in the ED such as electrocardiography (ECGs), laboratory and radiology results and accurate past medical history. This better visibility of information such as this can occur for inpatient teams remotely and repeatedly and can assist in the handover period of shared care as the patient traverses the EDii.

Better care for groups of patients:

Traditionally EDs have led the hospital in the use of process data to drive clinical practice. Integration of digital systems at the EDii provides even greater transparency and granularity of process data relating to this critical interface. The expansion of these data to include clinical information such as co-morbidities, digitally recorded vital signs, medication orders and downstream clinical outcomes will allow clinically focussed efforts to improve the efficiency and quality of care provided to patients at the EDii. The digital platform allows the use of what was previously retrospectively reported audit data for real-time clinical decision making. This applied to both the ED and inpatient teams who care for this group of patients

New and innovative models of care:

We have seen an introduction to the use of predictive analytics in the area of patient flow and bed management. Application of these techniques to increasingly granular clinical data will allow the transformation of care at the EDii. An example is the use of machine learning and predictive analytics to integrated clinical data including patient demographics, vital signs, co-morbidities and lab data to allow identification and early intervention for emergency patients at high risk of inpatient deterioration or complications before that deterioration occurs. Current analytics are neither sensitive or specific enough to provide truly targeted interventions to these at-risk patients.

Conclusion

The EDii is a critical operating system in all acute hospitals. Digital transformation of hospitals is complex and impacts on patient care. This is the first study that specifically examines the impact of digitisation at the EDii. Despite some slowing of process measures of EDii performance, the transformation appeared safe, with a reduction in raw mortality and no statistically significant difference in risk-adjusted mortality. The safe introduction of an integrated digital platform provides potential for integrated, improved care of the individual patient, a more reliable system and transformation of patient care at the EDii.

Translation into practice

Digital transformation of the EDii has now occurred in eight Queensland hospitals. This accounts for over 500 000 emergency attendances/year or 36% of all Queensland emergency attendances. This transformation is planned to continue over the next two years to extend to over 90% of all Queensland hospital care. The measures detailed in this study formed the basis for quality and safety monitoring of all of those digital transformations and continue to be monitored as part of ongoing safety, quality and efficiency assessment of EDii function.

The understanding that digital deceleration will occur, but that with good patient outcome monitoring, worsening of key patient outcomes is not likely to occur now holds a key place in digital transformation planning.

Acknowledgements

The author is grateful to the following people for their contributions and support: Mr Michael Zanco, Healthcare Improvement Unit, Queensland Health; Ms Bernadette McKenna, Emergency Department Princess Alexandra Hospital and Mr Peter Thomson, Decision Support Unit Metro South Hospital and Health Service. This study was partly funded by the Healthcare Improvement Unit, Queensland Department of Health.

References

1. Digital Strategy Branch eHealth Queensland. Digital Health Strategic Vision for Queensland 2016. 2017; https://www.health.qld.gov.au/__data/assets/pdf_file/0016/645010/digital-health-strat-vision.pdf. Accessed July 4, 2017.
2. eHealth New South Wales. eHealth Strategy for NSW Health. 2016; http://www.health.nsw.gov.au/eHealth/Documents/eHealth-Strategy-for-NSW-Health-2016-2026.pdf. Accessed July 4, 2017.
3. Sullivan C, Staib A, Ayre S, et al. Pioneering digital disruption: Australia's first integrated digital tertiary hospital. *The Medical journal of Australia.* 2016;205(9):386-389.
4. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2016;40(3):319-323.
5. Staib A, Sulllivan, C., Prins, J., Burton-Jones, A., Fitzgerald, G., Scott, I. Uniting emergency and inpatient clinicians across the ED-inpatient interface: the last frontier? *Emergency Medicine Australasia.* 2017.
6. Staib A, Sullivan C, Jones M, Griffin B, Bell A, Scott I. The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emerg Med Australas.* 2017;29(3):363-366.
7. Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.
8. Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *The Medical journal of Australia.* 2016;204(9):354.
9. Ben-Tovim DI, Woodman RJ, Hakendorf P, Harrison J. Standardised mortality ratios. Neither constant nor a fallacy. *BMJ.* 2009;338:b1748.

10. Australian Institute of Health and Welfare. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014; http://www.aihw.gov.au/publication-detail/?id=60129549039. Accessed June, 2016.
11. Spiegelhalter DJ. Funnel plots for comparing institutional performance. *Stat Med.* 2005;24(8):1185-1202.
12. Sullivan C, Staib A. Digital disruption 'syndromes' in a hospital: important considerations for the quality and safety of patient care during rapid digital transformation. *Aust Health Rev.* 2018;42(3):294-298.
13. Deloitte Touche. NSW Health Independent Review of Cerner FirstNet. 2011; http://www.ecinsw.com.au/sites/default/files/Deloitte%20Report%20FirstNet.pdf. Accessed 16 March, 2016.
14. White K, Scott IA, Vaux A, Sullivan CM. Rapid response teams in adult hospitals: time for another look? *Internal medicine journal.* 2015;45(12):1211-1220.

Chapter 6
Conclusion and Future Directions

Summary

The EDii is the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services.

The EDii is characterised by a complex interplay of patient, hospital and system factors.

A patient is transitioning across the EDii from the time the decision is made that they are likely to be admitted to hospital, until they are completely under the care of an inpatient team and physically located in an inpatient space; usually a ward.

The EDii is important to the patient. The outcomes for this group of the sickest and most at-risk patients in the system are impacted by the function of the EDii. The magnitude of this impact and the ability for clinical intervention to improve these outcomes has been detailed in this thesis.

The EDii is important to overall hospital function. The function of the EDii impacts the quality and efficiency of care in many areas of the hospital, and dysfunction and poor communication can increase professional tensions. Dysfunction at the EDii can contribute to reduced scheduled hospital functions such as outpatients and elective surgery when EDii patients are seen as competing for the same scarce resources or calls to inpatient teams to admit EDii patients are treated as an unwelcome “surprise” over and above scheduled activities. Increased visibility and awareness of the EDii and its importance, assisted by clinically relevant visualisation tools can lead to changes in care delivery that benefit these patients and improve patient flow.

The EDii is important for the healthcare system. With over half of all patients entering the hospital via the EDii, and the high cost of care for this patient group, an understanding of the EDii and optimising its function has significant potential to influence the quality and efficiency of care provided by the whole healthcare system. Health policy interventions that impact the EDii can have significant impacts on clinical outcomes and efficiency of care.

Contribution to body of knowledge and translation into practice

With a clearer definition of the EDii in hand, research on how to improve the EDii to improve patient care and hospital performance will be able to proceed more systematically. The definition, its reception and interpretation has now been, and continues to be discussed and developed in many meetings and publications. Health policy in this area is now increasingly evidence based, and the principles learned in the development of this work are now applied in other high-risk clinical areas and interfaces.

Characterisation and definition of the EDii enabled meaningful linkage of process measures for EDii function and outcome measures for the patients subject to the EDii. Demonstrating the association between 4-hour rule compliance and in-hospital mortality for patients who traversed the EDii provided increased focus on patient outcomes and enabled evidence-based policy re-alignment in many states of Australia. The work contained in chapter three of this thesis was rapidly translated into practice in Queensland. The Queensland Emergency Access Target was modified by the Queensland Department of Health to “greater than 80%” following the publication of this work. Currently, discussions are underway to bring an admitted patient access target of 60% into Queensland Hospital and Health Service service (HHS) agreements. Many other Australian jurisdictions have also undergone similar policy revisions in this area.

Clinician-designed tools can provide increased visibility of patient outcomes at the EDii and provide confidence and safety monitoring in clinical redesign of EDii-related processes, thus bringing the patient into the centre of the system redesign. Development of the EDii Dashboard was followed by rapid uptake in many EDs and the published principles and lessons learned applied to other areas of clinical streaming analytics. Versions of this dashboard were subsequently implemented in many EDs in Queensland and across Australia to improve EDii function and meet the new evidence-based policy recommendations for tracking important patient outcomes. PAH has now developed and implemented clinical analytics-based redesign using similar dashboards for the Australian Commission for Safety and

Quality in Healthcare 10 National Safety and quality indicators[1], and at a Queensland-wide level, similar projects are underway to transform trauma and stroke care based on these learnings and principles. This work will be published in the near future. The principles described in this paper are now used for prioritising and designing clinical streaming analytics projects across Queensland.

Digital transformation of the EDii has now occurred in eight Queensland hospitals, providing care for over 500 000 emergency attendances/year or 36% of all Queensland emergency attendances. The measures detailed in this thesis formed the basis for quality and safety monitoring of all of those digital transformations and continue to be monitored as part of ongoing safety, quality and efficiency assessment of EDii function. The understanding that digital deceleration will occur, but that with good patient outcome monitoring, worsening of key patient outcomes is not likely to occur now holds a key place in digital transformation planning.

Future Directions

The EDii is constantly evolving. Indeed, the specialty of Emergency Medicine in Australia is only 35 years old. This is in contrast with the much more established specialties that provide the majority of inpatient care. Due to its critical place in the complex adaptive healthcare system, as the specialties and the hospitals themselves evolve, so too will the EDii.

Potential future areas of research will include developing a better understanding of the EDii factors which most influence patient outcomes; for example, are improved patient outcomes due to a less crowded ED, more rapid definitive ward care, or an integrated system that functions well at the interface?

Greater understanding of complex adaptive systems such as the EDii will require further development of research methodologies which have previously had a relatively low profile in medicine. Large scale comparative studies using massive datasets, participatory action research, and sophisticated qualitative methodologies

such as engaged scholarship techniques and grounded theory methods will be required.

The widespread implementation of integrated electronic medical records and digitisation of the EDii will provide opportunities to create unprecedented insights into this operating system. Integrated clinical information systems with sophisticated analytic capability will allow the development of new, more sensitive patient outcome measures and ultimately evidence-based lead indicators which can be used to supplement or replace the relatively unsophisticated process measures on which we currently rely. For example, machine learning using sophisticated deep learning algorithm systems, applied to large scale quality clinical datasets applicable to EDii patients may enable accurate identification of patients at risk of delayed in-hospital deterioration at the point of ED presentation. Specific interventions could be undertaken to modify ED and inpatient care and smooth the transition of care at the EDii for high risk patients, thus preventing deterioration rather than just responding to it. This move from a “break-fix” model of care to a “predict-prevent” model is a key strategy to improving the healthcare system. Work on this specific example has now commenced in Queensland and will be part of the author’s post-doctoral research. When coupled with good clinical leadership, the breaking down of data silos that integrated digital systems can provide can lead to the breaking down of traditional clinical silos and improved care for patients.

The addition of economic data to the developing use of clinical and administrative process data will enable a better understanding of efficiency of care at the EDii and enable a greater understanding of warranted and unwarranted variation in care for this patient group.

Another area where further information is required is in understanding the best type of EDii. The widespread development of clinical decision units is changing the nature of the EDii in many areas. Currently, little is understood about the impact of these units on EDii patient outcomes, and cost efficiency. Despite being designed to reduce EDLOS, it is possible that for some patients, the use of clinical decision units may increase the time taken to negotiate the EDii, by delaying their disposition to the appropriate inpatient setting and definitive care.

Changing models of care may potentially extend the EDii into the pre-hospital arena. A patient may already be under the care of an inpatient team, and thus transitioning the EDii before they even arrive at the ED with an acute exacerbation of a chronic condition. An example of this potential extension of the EDii would be a patient under the shared care of an inpatient team and a community or primary care team who experiences a clinical deterioration requiring emergent admission to hospital.

As we develop a greater understanding of the EDii, the management of the EDii within the hospital system may require modification. Tools such as dashboards which display the progress of patients across the EDii will become more common, and the current mixed system of clinical governance during this vulnerable period may require refinement with more dedicated interventions and attention. Perhaps the evidence will evolve to support the need for a dedicated EDii service.

Greater focus on the intended and unintended consequences of clinical redesign activities on the EDii will allow for more evidence based, patient centred health system reform.

The EDii is just one of many critical interfaces in the healthcare system. Lessons learned through this work and about the EDii in general are now beginning to be applied to other areas of the system. Examples include the interface between the operating theatre and the ward, the intensive care unit and the inpatient ward, and the hospital and community health services.

Conclusion

Definition, analysis and greater understanding of the EDii as detailed in this thesis has already led to policy change, clinical redesign, and improved patient outcomes for this vulnerable patient group.

Building further on this knowledge by focussed research and using the microscope of integrated clinical data provided by digital transformation will enable even greater improvements in outcomes and efficiency through clinical redesign of the EDii.

References

1. Barnett A, Winning M, Canaris S, Cleary M, Staib A, Sullivan C. Digital transformation of hospital quality and safety: real-time data for real-time action. *Aust Health Rev.* 2018.doi 10.1071/AH18125

List of References

ABC News. Gurrumul Yunupingu: Formal Investigation into singer's treatment at Darwin hospital ruled out. 2016; http://www.abc.net.au/news/2016-04-05/no-investigation-into-gurrumul-yunupingu-hospital-treatment/7299640. Accessed April 6, 2016.

ABC News. Mental Health patients at Royal Hobart Hospital not being given access to natural light advocates warn. 2016. Accessed March 25, 2016.

Alexander H. NSW emergency departments relax four hour patient targets. 2015; http://www.smh.com.au/nsw/nsw-emergency-departments-relax-fourhour-patient-targets-20150115-12r3yh.html. Accessed April 22, 2016.

Apker J, Mallak LA, Applegate EB, 3rd, et al. Exploring emergency physician-hospitalist handoff interactions: development of the Handoff Communication Assessment. *Ann Emerg Med.* 2010;55(2):161-170.

Apker J, Mallak LA, Gibson SC. Communicating in the "gray zone": perceptions about emergency physician hospitalist handoffs and patient safety. *Acad Emerg Med.* 2007;14(10):884-894.

Association AII. 2015 Queensland iAwards Winners and Merit Recipients. 2015; http://www.iawards.com.au/index.php/winners/2015-winners/2015-winners-qld. Accessed 23/1/2016.

Australian Commission on Safety and Quality in Health Care. Indicators of safety and quality: Core hospital-based outcome indicators. 2015; http://www.safetyandquality.gov.au/our-work/information-strategy/indicators/core-hospital-based-outcome-indicators/. Accessed 13 May, 2016.

Australian Institute of Health and Welfare. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014; http://www.aihw.gov.au/publication-detail/?id=60129549039. Accessed June, 2016.

Barnett A, Winning M, Canaris S, Cleary M, Staib A, Sullivan C. Digital transformation of hospital quality and safety: real-time data for real-time action. *Aust Health Rev.* 2018.

Baumlin KM, Shapiro JS, Weiner C, Gottlieb B, Chawla N, Richardson LD. Clinical information system and process redesign improves emergency department efficiency. *Joint Commission Journal On Quality And Patient Safety / Joint Commission Resources.* 2010;36(4):179-185.

Beach C, Cheung DS, Apker J, et al. Improving interunit transitions of care between emergency physicians and hospital medicine physicians: a conceptual approach. *Acad Emerg Med.* 2012;19(10):1188-1195.

Bekmezian A, Chung PJ. Boarding admitted children in the emergency department impacts inpatient outcomes. *Pediatr Emerg Care.* 2012;28(3):236-242.

Ben-Tovim DI, Woodman R, Harrison JE, et al. Measuring and reporting mortality in hospital patients. 2009; http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=6442457123

Ben-Tovim DI, Woodman RJ, Hakendorf P, Harrison J. Standardised mortality ratios. Neither constant nor a fallacy. *BMJ.* 2009;338:b1748.

Caterino JM, Hoover EM, Moseley MG. Effect of advanced age and vital signs on admission from an ED observation unit. *Am J Emerg Med.* 2013;31(1):1-7.

Centres for Disease Control: National Ambulatory and Hospital Care Statistics Branch. National Ambulatory Medical Care Survey 2010 Emergency Department Summary Tables. 2010; http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf. Accessed 20 March, 2016.

Commonwealth Government of Australia. *Expert Panel: Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hospital Services* 2011.

Commonwealth Government of Australia. Expert Panel. *Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hopsital Services.* 2011 2011. 978-1-74241-535-2.

Considine J, Charlesworth D, Currey J. Characteristics and outcomes of patients requiring rapid response system activation within hours of emergency admission. *Critical care and resuscitation : journal of the Australasian Academy of Critical Care Medicine.* 2014;16(3):184-189.

Considine J, Jones D, Pilcher D, Currey J. Patient physiological status at the emergency department-ward interface and emergency calls for clinical deterioration during early hospital admission. *Journal Of Advanced Nursing.* 2016.

Deloitte Touche. NSW Health Independent Review of Cerner FirstNet. 2011; http://www.ecinsw.com.au/sites/default/files/Deloitte%20Report%20FirstNet.pdf. Accessed 16 March, 2016.

Digital Strategy Branch eHealth Queensland. Digital Health Strategic Vision for Queensland 2016. 2017;

https://www.health.qld.gov.au/__data/assets/pdf_file/0016/645010/digital-health-strat-vision.pdf. Accessed July 4, 2017.

Dowding D, Randell R, Gardner P, et al. Dashboards for improving patient care: review of the literature. *Int J Med Inform.* 2015;84(2):87-100.

eHealth New South Wales. eHealth Strategy for NSW Health. 2016; http://www.health.nsw.gov.au/eHealth/Documents/eHealth-Strategy-for-NSW-Health-2016-2026.pdf. Accessed July 4, 2017.

Emergency Care Institute New South Wales. ETP=The Basics. 2017; https://www.aci.health.nsw.gov.au/networks/eci/administration/neat/neat-the-basics. Accessed 14 July, 2018.

Farley H, Zubrow MT, Gies J, et al. Emergency department tachypnea predicts transfer to a higher level of care in the first 24 hours after ED admission. *Acad Emerg Med.* 2010;17(7):718-722.

Fischer M, Hemphill RR, Rimler E, et al. Patient communication during handovers between emergency medicine and internal medicine residents. *Journal Of Graduate Medical Education.* 2012;4(4):533-537.

FitzGerald G. Uncomfortable truth about emergency care. *MJA InSight* 2016; https://www.mja.com.au/insight/2016/8/uncomfortable-truth-about-emergency-care. Accessed 23 April, 2016.

Forero R, Hillman KM, McCarthy S, Fatovich DM, Joseph AP, Richardson DB. Access block and ED overcrowding. *Emerg Med Australas.* 2010;22(2):119-135.

Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Controller of Her Majesty's Stationery Office. 2013; http://webarchive.nationalarchives.gov.uk/20150407084003/http://www.midstaffspublicinquiry.com/report.

Galipeau J, Pussegoda K, Stevens A, et al. Effectiveness and safety of short-stay units in the emergency department: a systematic review. *Acad Emerg Med.* 2015;22(8):893-907.

Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *The Medical journal of Australia.* 2012;196:122-126.

Gonzalo JD, Yang JJ, Stuckey HL, Fischer CM, Sanchez LD, Herzig SJ. Patient care transitions from the emergency department to the medicine ward: evaluation of a standardized electronic signout tool. *International journal for quality in health care : journal of the International Society for Quality in Health Care / ISQua.* 2014;26(4):337-347.

Greenhalgh T. Assisted dying debate: Try another approach, BMJ. *BMJ.* 2011;342:d451.

Hastie RT, And Friedaman, J. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction.* 2nd ed: Springer; 2009

Hillier DF, Parry GJ, Shannon MW, Stack AM. The effect of hospital bed occupancy on throughput in the pediatric emergency department. *Ann Emerg Med.* 2009;53(6):767-776.e763.

Hilligoss B, Mansfield JA, Patterson ES, Moffatt-Bruce SD. Collaborating-or "Selling" Patients? A Conceptual Framework for Emergency Department-to-Inpatient Handoff Negotiations. *Joint Commission journal on quality and patient safety / Joint Commission Resources.* 2015;41(3):134-143.

Hilligoss B, Zheng K. Chart biopsy: an emerging medical practice enabled by electronic health records and its impacts on emergency department-inpatient admission handoffs. *J Am Med Inform Assoc.* 2013;20(2):260-267.

Hilligoss B. Selling patients and other metaphors: a discourse analysis of the interpretive frames that shape emergency department admission handoffs. *Soc Sci Med.* 2014;102:119-128.

Horwitz LI, Meredith T, Schuur JD, Shah NR, Kulkarni RG, Jenq GY. Dropping the baton: a qualitative analysis of failures during the transition from emergency department to inpatient care. *Ann Emerg Med.* 2009;53(6):701-710 e704

Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa). *Resuscitation.* 2004;63(3):233-249.

Jalili M, Barzegari H, Pourtabatabaei N, et al. Effect of door-to-antibiotic time on mortality of patients with sepsis in emergency department: a prospective cohort study. *Acta Med Iran.* 2013;51(7):454-460.

Jensen A, Boyle J, Khanna S. Visualising patient flow. *Stud Health Technol Inform.* 2012;178:77-82.

Johnson JK, Farnan JM, Barach P, et al. Searching for the missing pieces between the hospital and primary care: mapping the patient process during care transitions. *BMJ Qual Saf.* 2012;21 Suppl 1:i97-105.

Jones P, Schimanski K. The four hour target to reduce Emergency Department 'waiting time': a systematic review of clinical outcomes. *Emerg Med Australas.* 2010;22(5):391-398.

Josephson SA, Engstrom JW, Wachter RM. Neurohospitalists: an emerging model for inpatient neurological care. *Ann Neurol.* 2008;63(2):135-140.

Keijzers G. NEAT in need of a sweet spot. *Emerg Med Australas.* 2014;26(3):217-218.

Kessler C, Scott NL, Siedsma M, Jordan J, Beach C, Coletti CM. Interunit handoffs of patients and transfers of information: a survey of current practices. *Ann Emerg Med.* 2014;64(4):343-349.e345.

Kocher KE, Haggins AN, Sabbatini AK, Sauser K, Sharp AL. Emergency department hospitalization volume and mortality in the United States. *Ann Emerg Med.* 2014;64(5):446-457.e446.

Krall SP, Cornelius AP, Addison JB. Hospital factors impact variation in emergency department length of stay more than physician factors. *The western journal of emergency medicine.* 2014;15(2):158-164.

Levin S, Dittus R, Aronsky D, Weinger M, France D. Evaluating the effects of increasing surgical volume on emergency department patient access. *BMJ Qual Saf.* 2011;20(2):146-152.

Lowthian J, Curtis A, Straney L, McKimm A, Keogh M, Stripp A. Redesigning emergency patient flow with timely quality care at the Alfred. *Emerg Med Australas.* 2015;27(1):35-41.

Lucas R, Farley H, Twanmoh J, et al. Emergency department patient flow: the influence of hospital census variables on emergency department length of stay. *Acad Emerg Med.* 2009;16(7):597-602.

Mannix L. Emergency Room row over controversial stroke drug, Alteplase. *Sydney Morning Herald* 2016; http://www.smh.com.au/national/health/emergency-room-row-over-controversial-stroke-drug-alteplase-20160321-gnnh58.html. Accessed March 21, 2016.
McCusker J, Vadeboncoeur A, Levesque JF, Ciampi A, Belzile E. Increases in emergency department occupancy are associated with adverse 30-day outcomes. *Acad Emerg Med.* 2014;21(10):1092-1100.

Medew J. Ambulance emergency: When speed is a casualty of care. 2014; http://www.smh.com.au/national/ambulance-emergency-when-speed-is-a-casualty-of-care-20141024-11b362.html. Accessed April 22, 2016.

Monaghan M. A discussion on the future of the National NEAT targets. 2014; http://www.health.qld.gov.au/qldclinicalsenate/docs/pp-140328-neat-wa.pdf

Moore BL, K. Elixhauser A. Cost for Hospital Stays in the United States, 2012. HCUP Statistical Brief #181. *Healthcare Cost and Utilization Project* 2014; http://www.hcup-us.ahrq.gov/reports/statbriefs/sb181-Hospital-Costs-United-States-2012.pdf. Accessed April 23, 2016.

Morse A. Emergency Admissions to hospital: managing the demand. Report by the Comptroller and Auditor General. 2013; https://www.nao.org.uk/report/emergency-admissions-hospitals-managing-demand/. Accessed 29 May, 2016.

Mullins PM, Goyal M, Pines JM. National growth in intensive care unit admissions from emergency departments in the United States from 2002 to 2009. *Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine.* 2013;20(5):479-486.

Pare G, Trudelb, M-C., Mirou, J., Kitsioud, S. Synthesizing information systems knowledge: Atypology of literatire reviews *Information and management* 2015;52:183-199.

Pitts SR, Niska RW, Xu J, Burt CW. National Hospital Ambulatory Medical Care Survey: 2006 emergency department summary. *Natl Health Stat Report.* 2008(7):1-38.

Pitts SR, Vaughns FL, Gautreau MA, Cogdell MW, Meisel Z. A cross-sectional study of emergency department boarding practices in the United States. *Acad Emerg Med.* 2014;21(5):497-503.

Pluye P, Hong QN. Combining the power of stories and the power of numbers: mixed methods research and mixed studies reviews. *Annu Rev Public Health.* 2014;35:29-45.

Powell ES, Khare RK, Courtney DM, Feinglass J. Volume of emergency department admissions for sepsis is related to inpatient mortality: results of a nationwide cross-sectional analysis. *Crit Care Med.* 2010;38(11):2161-2168. Queensland Clinical Senate. National Emergency Access Target : Is 90% the right target. 2014; www.health.qld.gov.au/qldclinicalsenate/docs/fin-rep-mar2014.pdf. Accessed 13 May, 2015.

Rathlev NK, Bryson C, Samra P, et al. Reducing patient placement errors in emergency department admissions: right patient, right bed. *The western journal of emergency medicine.* 2014;15(6):687-692.

Richardson DB. Emergency department targets: a watershed for outcomes research? *Med J Aust.* 2012;196:126-127.

Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *The Medical journal of Australia.* 2006;184(5):213-216.

Ruiz M, Bottle A, Aylin PP. The Global Comparators project: international comparison of 30-day in-hospital mortality by day of the week. *BMJ Qual Saf.* 2015;24(8):492-504.

Russell PT, Hakendorf P, Thompson CH. A general medical short-stay unit is not more efficient than a traditional model of care. *The Medical journal of Australia.* 2014;200(8):482-484.

Ryan S, O'Riordan JM, Tierney S, Conlon KC, Ridgway PF. Impact of a new electronic handover system in surgery. *International Journal Of Surgery (London, England).* 2011;9(3):217-220.

Scott IB, CA. Phelps, GE. et al Using hospital standardised mortality ratios to assess quality of care--proceed with extreme caution. *Med J Aust.* 2011;194(12):645-648.

Secretary of State for Health. The NHS Plan: A plan for Investment, A plan for reform. 2000; http://www.nhshistory.net/nhsplan.pdf. Accessed 27 February, 2016.

Shen JJ, Cochran CR, Moseley CB. From the emergency department to the general hospital: hospital ownership and market factors in the admission of the seriously mentally ill. *Journal of healthcare management / American College of Healthcare Executives.* 2008;53(4):268-279; discussion 279-280.

Spiegelhalter DJ. Funnel plots for comparing institutional performance. *Stat Med.* 2005;24(8):1185-1202.

Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *The Medical journal of Australia.* 2006;184(5):208-212.

Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. *Aust Health Rev.* 2016;40(3):319-323.

Staib A, Sullivan C, Jones M, Griffin B, Bell A, Scott I. The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emerg Med Australas.* 2017;29(3):363-366.

Staib A, Sullivan C, Prins JB, Burton-Jones A, Fitzgerald G, Scott I. Uniting emergency and inpatient clinicians across the ED-inpatient interface: The last frontier? *Emerg Med Australas.* 2017;29(6):740-745.

Stokes B. Four Hour Rule Program Progress and Issues Review. 2011; http://ww2.health.wa.gov.au/Reports-and-publications/Four-Hour-Rule-Program-Progress-and-Issues-Review. Accessed May 13, 2015.

Sullivan C, Staib A, Ayre S, et al. Pioneering digital disruption: Australia's first integrated digital tertiary hospital. *The Medical journal of Australia.* 2016;205(9):386-389.

Sullivan C, Staib A, Eley R, et al. Who is less likely to die in association with improved National Emergency Access Target (NEAT) compliance for emergency admissions in a tertiary referral hospital? *Aust Health Rev.* 2015.

Sullivan C, Staib A, Eley R, Scanlon A, Flores J, Scott I. National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. *Aust Health Rev* 2015;39(5):533-8.

Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *The Medical journal of Australia.* 2016;204(9):354.

Sullivan C, Staib A. Digital disruption 'syndromes' in a hospital: important considerations for the quality and safety of patient care during rapid digital transformation. *Aust Health Rev.* 2018;42(3):294-298

Sullivan CM, Staib A, Flores J, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. *Aust Health Rev.* 2014;38(5):564-574.

Sullivan CS, A. Emergency Admissions:Processes and outcomes for our most vulnerable patients. 2015(33):8-9.

Vallejo BC, Krepper R, Nora H, Fine DJ. Converting Data into Information. *Hospital Topics.* 2012;90(1):11-15.

Viccellio A, Santora C, Singer AJ, Thode HC, Jr., Henry MC. The association between transfer of emergency department boarders to inpatient hallways and mortality: a 4-year experience. *Ann Emerg Med.* 2009;54(4):487-491.

White BA, Biddinger PD, Chang Y, Grabowski B, Carignan S, Brown DF. Boarding inpatients in the emergency department increases discharged patient length of stay. *J Emerg Med.* 2013;44(1):230-235.

White K, Scott IA, Vaux A, Sullivan CM. Rapid response teams in adult hospitals: time for another look? *Internal medicine journal.* 2015;45(12):1211-1220.

Whitt N, Harvey R, McLeod G, Child S. How many health professionals does a patient see during an average hospital stay? *The New Zealand Medical Journal.* 2007;120(1253):U2517-U2517.

Wills MJ. Decisions through data: analytics in healthcare. *Journal of healthcare management / American College of Healthcare Executives.* 2014;59(4):254-262.

Wu D, Zhou X, Ye L, Gan J, Zhang M. Emergency department crowding and the performance of damage control resuscitation in major trauma patients with hemorrhagic shock. *Acad Emerg Med.* 2015;22(8):915-921.

Wu FM, Newman JM, Lasher A, Brody AA. Effects of initiating palliative care consultation in the emergency department on inpatient length of stay. *J Palliat Med.* 2013;16(11):1362-1367.

Ye K, Mc DTD, Knott JC, Dent A, MacBean CE. Handover in the emergency department: deficiencies and adverse effects. *Emerg Med Australas.* 2007;19(5):433-441.

Appendices

Appendix A

Uniting emergency and inpatient clinicians across the ED–inpatient interface: The last frontier?

Staib, A., et al. (2017). "Uniting emergency and inpatient clinicians across the ED- inpatient interface: The last frontier?" Emerg Med Australas **29**(6): 740-745.

ABSTRACT

Unwell patients in the emergency department requiring inpatient admission must negotiate the interface between the emergency department and inpatient wards. Despite its importance and scale, this emergency department-inpatient interface (EDii) is poorly characterised.

The aim of this paper is to clearly define the EDii and to describe its importance to the:

- **Patient:** delays to admission and errors in communication across the EDii can increase adverse outcomes
- **Hospital:** poor EDii function reduces hospital efficiency and effectiveness
- **Healthcare system**: half of all hospital inpatient admissions occur via the EDii and so EDii affects system wide performance.

The EDii can be defined as the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.

A clear definition of the EDii and an understanding of its importance will assist future research and interventions to improve patient outcomes.

INTRODUCTION

Access to emergency hospital care is essential. However, the emergency healthcare system is currently facing considerable challenges due to system wide congestion and growing demand. Providing emergency care is challenging due to the high acuity, undifferentiated casemix and the highly skilled, resource-rich environments needed to deliver this care effectively.

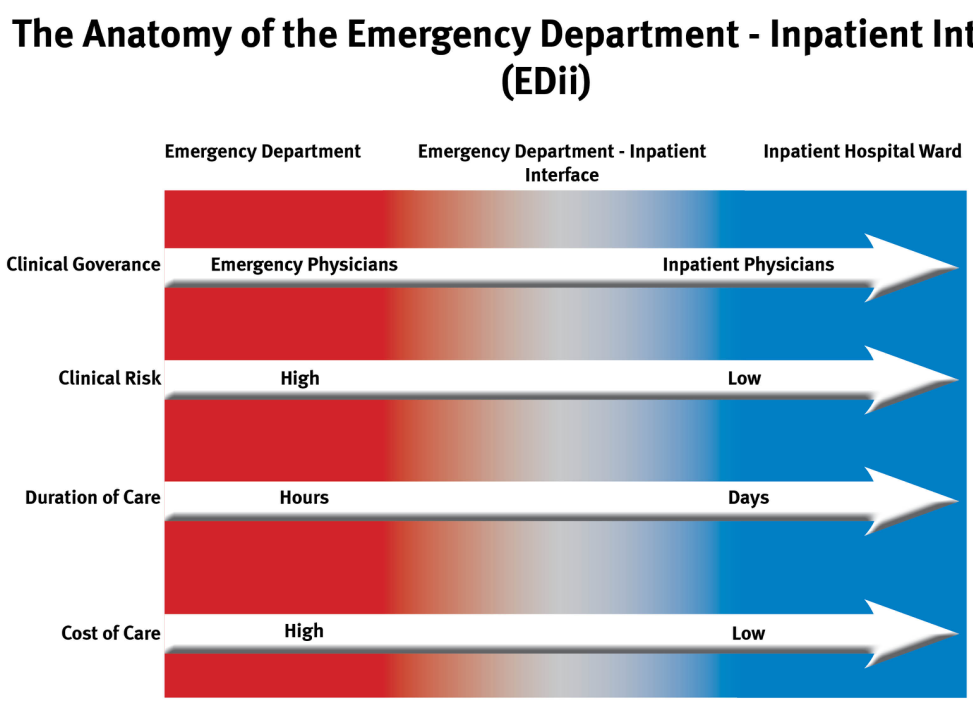
Patients requiring inpatient admission are often particularly complex and it is these patients who must negotiate the transition from the Emergency Department (ED) to hospital inpatient care. This ED-inpatient interface (EDii) is a poorly defined yet critical operating system for the patient, the hospital and the healthcare system.

A patient is subject to the EDii from the ED decision to admit until they are under the care of the inpatient team and located in their destination ward. The EDii involves the transition between ED and inpatient care and has been identified as a period when errors in communication and confused accountability may lead to missed care or clinical errors.[1, 2] In addition, the EDii is physically indistinct as patients at the interface may often be located in transitory spaces such as corridors or waiting areas which may be less well serviced with clinical equipment and facilities.[3, 4]

The challenge may be compounded by cultural and attitudinal differences. ED teams are traditionally focussed on the initiation of appropriate care and timeliness of admission given their need to manage patient flow and to meet government time targets. Inpatient teams have competing priorities including scheduled admissions and fixed commitments such as clinics and operating lists. Inpatient teams may be understandably disengaged from ED time pressures and place greater emphasis on comprehensive formulation of a definitive diagnosis and management plan. These differing goals can create tension across the EDii and distract from patient care.[1, 2]

The EDii has not been previously clearly and consistently defined in the literature. Partial definitions of the ED-inpatient interface have been published as listed in Table 1. Most of these definitions have transit or handover as their core principles and do not fully encapsulate the process of emergency admission to hospital as an example of a complex adaptive system.[2, 5] The term “ED-inpatient interface” (EDii) attempts to take account of the inherent complexity of the system. Figure 1 illustrates the dynamic transitions of patient location, governance and other factors which occur at the EDii.

Figure 1



Research into the EDii has traditionally been separated by discipline: with ED research and redesign centred around ED overcrowding[3] and ED efficiency[6], and inpatient research centred around disease specific models of care.[7, 8] Because prior research has not been guided by a clear definition of EDii, the profiling of issues between ED and inpatient teams and whole of hospital reform is difficult.

The aims of this paper are to define and describe the importance of the EDii for both emergency and inpatient physicians. The EDii can be defined as the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.

It is proposed that this understanding can inform further research and clinical redesign to improve outcomes for patients, hospitals and the healthcare system.

The ED-inpatient interface is important for the patient

Admitted emergency patient mortality and the EDii

Patients requiring emergency admission to hospital are at approximately 6-fold higher risk of death in hospital than patients undertaking elective admission. [9-12] There is significant observational evidence that delayed transfer to inpatient wards for patients requiring

emergency admission is associated with an estimated 20-30% increase in inpatient mortality.[3, 4, 13-16]

Further, the main beneficiaries of improved EDii efficiency appear to be elderly patients and those with acute cardiac and respiratory disease. [17] However, the overly rapid transfer of these patients into an inpatient space while still requiring emergency care can also be hazardous[18].

Unexpected deterioration of admitted emergency patients and the EDii

There is also evidence that improving the efficiency of patients' transit across the EDii can be associated with other improved patient outcomes such as fewer episodes of acute in-hospital deterioration and fewer ED re-presentations.[8-12]

The ED-inpatient interface is important for hospital function

An efficient EDii facilitating high quality, safe care is essential for a well-functioning acute care hospital. Patients presenting to the EDii require unscheduled care that competes with other scheduled hospital activities such as elective surgery and outpatient departments.

Measuring EDii performance

Performance in regards to emergency access to hospital has traditionally been monitored using time-based ED process measures[6]. The relationship of these measures to the EDii is depicted in Figure 2.

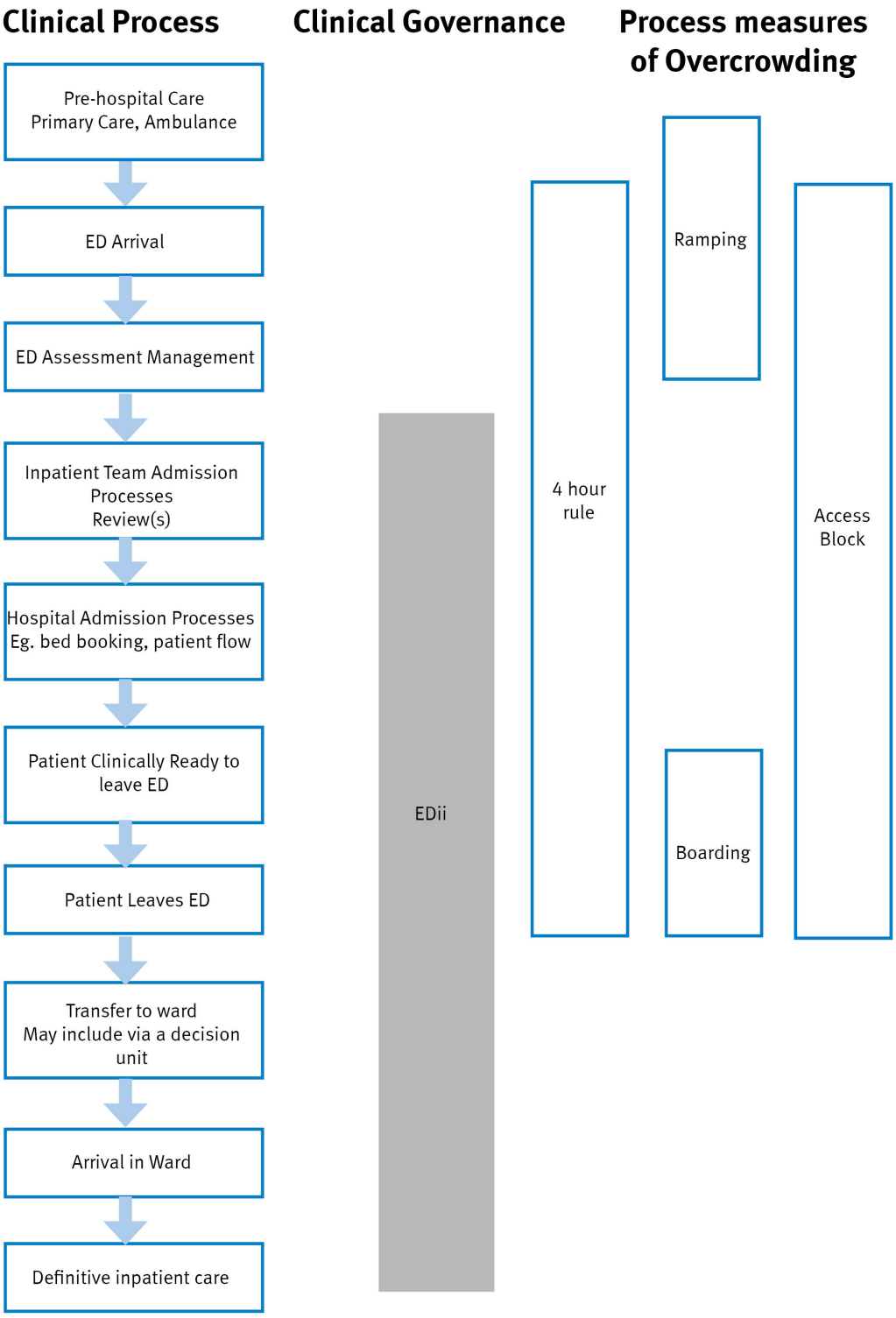
Despite the focus on these ED time measures, clinically meaningful EDii patient outcomes such as unexpected deterioration on the ward, cardiac arrests and deaths are not widely reported or met with the same public scrutiny.[6]

Clinical handover across the EDii

Whitt found that a patient being admitted to hospital via the ED had contact with between 17 and 28 health professionals, highlighting extent of involvement of different clinicians in care at the EDii and the critical need for accurate and timely transfer of clinical information at the EDii. [19]

Handover (handoff) is the process whereby a patient's clinical governance and details are transferred from one treating clinician to another.[1, 20] Factors such as physical location of the patient, trust, and methods of communication can influence the effectiveness of handover.[1, 21]

Figure 2. Relationship of ED Process Measures to the EDii



It is clear that handovers at the EDii are difficult for several reasons: 1) their unscheduled nature interrupting scheduled inpatient activities; 2) clinical uncertainty; 3) delays of uncertain duration; 4) confusion over clinical ownership; and 5) a high risk of adverse clinical

outcomes. These factors increase the professional tensions that can impair efficiency and safety at the EDii.[1, 8, 22]

EDii dysfunction and hospital efficiency

EDii dysfunction, manifesting as increased wait times and large numbers of boarding patients in the ED awaiting inpatient beds, creates difficulties for the emergency department (in terms of overcrowding and delivery of ongoing care), and for the inpatient teams (in terms of patient visibility and impaired ability to provide definitive inpatient care). These difficulties impact on the quality and efficiency of care across the whole hospital.[13, 23-28]

Conversely, the pressure to expedite transit through ED can sometimes lead to clinically unstable and inadequately worked-up patients being too hastily transferred to inpatient wards which may also be unsuitable to care for specific types of patient.[18]

Lack of integration between the ED and inpatient systems of care have made quality improvement and clinical redesign across the interface difficult. Cultural issues such as distrust between units, separate data collection systems and the pursuit of time targets relating to isolated steps in such a complex process can hinder improvement efforts.[29]

The EDii is important for the healthcare system

The EDii is a central component of the acute healthcare system and, as such, is influenced by a complex interplay of multiple factors that can facilitate or inhibit its function and resultant outcomes.

Scale of the EDii

The scale of the EDii worldwide is significant with approximately half of all inpatient admissions to hospital in developed countries occurring via the EDii.[13, 30-33] In many smaller hospitals, the majority of patients entering hospital do so via the EDii[32]. The number of patients negotiating the EDii is growing in excess of population growth.[32-34] Factors contributing to this growth include demographic factors (such as an ageing population), public expectations of ED care and organisational culture and policy. Growth in emergency admissions to hospitals and subsequent issues with accessing inpatient care appear to be worse in larger hospitals looking after more complex, and sicker, patients.[13, 34]

The scale of the EDii means that even small interventions and alterations in the quality, efficiency and cost of EDii can have a significant impact. Interventions that fail to appreciate the complexity of the EDii could result in unintended, negative consequences.[18]

The political significance of the EDii

The EDii is a politically sensitive interface in that ED overcrowding and ramping of ambulances quickly draw public concern. This has resulted in political and bureaucratic pressure on hospitals to increase the efficiency of emergency care provision.

Despite the lack of robust, peer reviewed research in this area or even a clear definition, the EDii is one of the very few areas where governments have imposed time targets for clinical care. In the USA, ED accreditation and reimbursement is affected by nationally reportable data on median ED boarding time.[13] In the UK, the National Health Service (NHS) introduced the Four Hour Rule for emergency departments in 2000.[35] In Australia, the National Emergency Access Target (NEAT) was introduced in 2011[6] and devolved to the states in 2016. Constant media interest ensures that the EDii remains very topical and a target for ongoing political and bureaucratic debate and intervention.

Defining the EDii is important

We propose that evidence of EDii dysfunction, disruptions in inpatient and elective activity caused by EDii processes, and the lack of integration between ED and inpatient systems are manifestations of a lack of understanding of the importance and complexity of the EDii. With a clearer definition of the EDii in hand, research on how to improve the EDii to improve patient care and hospital performance will be able to proceed more systematically.

Interventions that fail to appreciate the complexity of the EDii could result in unintended, negative consequences. Because prior research has not been guided by a clear definition of the EDii, it is not surprising that only a subset of EDii-related factors has been examined and that their effects on patient outcomes are only partially understood.

Areas of future research that may be assisted by a clear definition of the EDii include the development of alternative acute admission pathways such as clinical decision units and ED avoidance strategies, development of quality and performance indicators relating to emergency care and digital transformation of acute hospital care.

CONCLUSION

The EDii is a critical operating system for patients, hospitals and our increasingly strained healthcare system. The EDii is traditionally fragmented because it involves two or more very different clinical groups with differing work styles, priorities and cultures and so is hard to reform.

The EDii can be defined as the dynamic, transitional phase of patient care in which responsibility for, and delivery of care, is shared between ED and inpatient hospital services. The EDii is characterised by a complex interplay of patient, hospital and system factors.

EDii dysfunction may manifest as suboptimal process outcomes, patient outcomes, or a combination of both. A focus on patient outcomes is required to complement the existing suite of process measures relating to EDii.

By defining EDii for both ED and inpatient teams, we hope to instil a common understanding of its complexity and importance and to motivate and support patient-centred health system reform.

REFERENCES

1. Apker J, Mallak LA, Gibson SC. Communicating in the "gray zone": perceptions about emergency physician hospitalist handoffs and patient safety. Acad Emerg Med. 2007;14(10):884-94.
2. Quinn GR, Le E, Soni K, Berger G, Mak YE, Pierce R. "Not so fast!" the complexity of attempting to decrease door-to-floor time for emergency department admissions. Joint Commission journal on quality and patient safety / Joint Commission Resources. 2014;40(1):30-8.
3. Forero R, Hillman KM, McCarthy S, Fatovich DM, Joseph AP, Richardson DB. Access block and ED overcrowding. Emerg Med Australas. 2010;22(2):119-35.
4. Viccellio A, Santora C, Singer AJ, Thode HC, Jr., Henry MC. The association between transfer of emergency department boarders to inpatient hallways and mortality: a 4-year experience. Ann Emerg Med. 2009;54(4):487-91.
5. Nugus P, Carroll K, Hewett DG, Short A, Forero R, Braithwaite J. Integrated care in the emergency department: a complex adaptive systems perspective. Soc Sci Med. 2010;71(11):1997-2004.
6. Staib A, Sullivan C, Griffin B, Bell A, Scott I. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. Aust Health Rev. 2015.
7. Ford W, Self WH, Slovis C, McNaughton CD. Diabetes in the Emergency Department and Hospital: Acute Care of Diabetes Patients. Curr Emerg Hosp Med Rep. 2013;1(1):1-9.
8. Hilligoss B. Selling patients and other metaphors: a discourse analysis of the interpretive frames that shape emergency department admission handoffs. Soc Sci Med. 2014;102:119-28.
9. McCusker J, Vadeboncoeur A, Levesque JF, Ciampi A, Belzile E. Increases in emergency department occupancy are associated with adverse 30-day outcomes. Acad Emerg Med. 2014;21(10):1092-100.
10. Sullivan CM, Staib A, Flores J, Aggarwal L, Scanlon A, Martin JH, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. Aust Health Rev. 2014;38(5):564-74.
11. Kocher KE, Haggins AN, Sabbatini AK, Sauser K, Sharp AL. Emergency department hospitalization volume and mortality in the United States. Ann Emerg Med. 2014;64(5):446-57.e6.
12. Ruiz M, Bottle A, Aylin PP. The Global Comparators project: international comparison of 30-day in-hospital mortality by day of the week. BMJ Qual Saf. 2015;24(8):492-504.
13. Pitts SR, Vaughns FL, Gautreau MA, Cogdell MW, Meisel Z. A cross-sectional study of emergency department boarding practices in the United States. Acad Emerg Med. 2014;21(5):497-503.
14. Chadaga SR, Shockley L, Keniston A, Klock NE, Van Dyke S, Davis Q, et al. Hospitalist-led medicine emergency department team: associations with throughput, timeliness of patient care, and satisfaction. Journal of hospital medicine. 2012;7(7):562-6.

15. Howell E, Bessman E, Marshall R, Wright S. Hospitalist bed management effecting throughput from the emergency department to the intensive care unit. Journal of critical care. 2010;25(2):184-9.
16. Sullivan C, Staib A, Khanna S, Good NM, Boyle J, Cattell R, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. The Medical journal of Australia. 2016;204(9):354.
17. Sullivan C, Staib A, Eley R, Griffin B, Cattell R, Flores J, et al. Who is less likely to die in association with improved National Emergency Access Target (NEAT) compliance for emergency admissions in a tertiary referral hospital? Aust Health Rev. 2015.
18. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Controller of Her Majesty's Stationery Office. London2013 [cited 2017 January 16]. Available from: http://webarchive.nationalarchives.gov.uk/20150407084003/http://www.midstaffspublicinquiry.com/report.
19. Whitt N, Harvey R, McLeod G, Child S. How many health professionals does a patient see during an average hospital stay? The New Zealand Medical Journal. 2007;120(1253):U2517-U.
20. Nelson P, Bell AJ, Nathanson L, Sanchez LD, Fisher J, Anderson PD. Ethnographic analysis on the use of the electronic medical record for clinical handoff. Intern Emerg Med. 2016;2017(17 January).
21. Sivakumar S, Taccone FS, Desai KA, Lazaridis C, Skarzynski M, Sekhon M, et al. ESICM LIVES 2016: part two : Milan, Italy. 1-5 October 2016. Intensive Care Med Exp. 2016;4(Suppl 1):30.
22. Nelson P, Bell AJ, Nathanson L, Sanchez LD, Fisher J, Anderson PD. Ethnographic analysis on the use of the electronic medical record for clinical handoff. Intern Emerg Med. 2016.
23. White BA, Biddinger PD, Chang Y, Grabowski B, Carignan S, Brown DF. Boarding inpatients in the emergency department increases discharged patient length of stay. J Emerg Med. 2013;44(1):230-5.
24. Sullivan C, Staib A, Eley R, Scanlon A, Flores J, Scott I. National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. Aust Health Rev. 2015.
25. Hillier DF, Parry GJ, Shannon MW, Stack AM. The effect of hospital bed occupancy on throughput in the pediatric emergency department. Ann Emerg Med. 2009;53(6):767-76.e3.
26. Krall SP, Cornelius AP, Addison JB. Hospital factors impact variation in emergency department length of stay more than physician factors. The western journal of emergency medicine. 2014;15(2):158-64.
27. Levin S, Dittus R, Aronsky D, Weinger M, France D. Evaluating the effects of increasing surgical volume on emergency department patient access. BMJ Qual Saf. 2011;20(2):146-52.
28. Lucas R, Farley H, Twanmoh J, Urumov A, Olsen N, Evans B, et al. Emergency department patient flow: the influence of hospital census variables on emergency department length of stay. Acad Emerg Med. 2009;16(7):597-602.
29. Lawrence S, Sullivan C, Patel N, Spencer L, Sinnott M, Eley R. Admission of medical patients from the emergency department: An assessment of the attitudes, perspectives and practices of internal medicine and emergency medicine trainees. Emerg Med Australas. 2016.

30. Hilligoss B, Mansfield JA, Patterson ES, Moffatt-Bruce SD. Collaborating-or "Selling" Patients? A Conceptual Framework for Emergency Department-to-Inpatient Handoff Negotiations. Joint Commission journal on quality and patient safety / Joint Commission Resources. 2015;41(3):134-43.
31. Centres for Disease Control: National Ambulatory and Hospital Care Statistics Branch. National Ambulatory Medical Care Survey 2010 Emergency Department Summary Tables 2010 [Available from: http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf.
32. Australian Institute of Health and Welfare. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014 [updated 2014; cited 2016 June]. Available from: http://www.aihw.gov.au/publication-detail/?id=60129549039.
33. Morse A. Emergency Admissions to hospital: managing the demand. Report by the Comptroller and Auditor General London2013 [cited 2016 29 May]. Available from: https://www.nao.org.uk/report/emergency-admissions-hospitals-managing-demand/.
34. Mullins PM, Goyal M, Pines JM. National growth in intensive care unit admissions from emergency departments in the United States from 2002 to 2009. Academic Emergency Medicine: Official Journal Of The Society For Academic Emergency Medicine. 2013;20(5):479-86.
35. Secretary of State for Health. The NHS Plan: A plan for Investment, A plan for reform. London2000 [cited 2016 November 23]. Available from: http://www.nhshistory.net/nhsplan.pdf.

Appendix B

The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target

Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target. *The Medical journal of Australia.* 2016;204(9):354.

‡Dr Clair Sullivan MBBS (Hons) MD FRACP *(‡ co-first author)*
Deputy Chair of Medicine, Consultant Endocrinologist,
Princess AlexandraHospital, Metro South Health
MMRI University of Queensland
Translational Research Institute
199 Ipswich Road Woolloongabba QLD 4102
t. 07 3176 5363 e. clair.sullivan@health.qld.gov.au |

‡Dr Andrew Staib MBBS FACEM (‡*co-first author)*
Deputy Director of Emergency Medicine,
Princess AlexandraHospital. Metro South Health
MMRI University of Queensland
Translational Research Institute

Dr Sankalp Khanna, PhD,MInf.Tech(Research), BEng
Research Scientist, CSIRO Australian e-Health Research Centre, Queensland, Australia

Mr Norm M Good BSc(Hons)MSc
Senior Experimental Scientist, CSIRO Australian e-Health Research Centre, Queensland, Australia

Dr Justin Boyle,PhD, BEng (Hons1), Research Scientist, CSIRO Australian e-Health Research Centre, Queensland, Australia

Dr Rohan Cattell, PhD

Mr Liam Heiniger, BPharm, BSc (Mathematics), Intern,CSIRO Australian e-Health Research Centre, Queensland,

Dr Bronwyn Griffin, PhD, GDipEmerg, BNurs.
Nurse Researcher, Emergency Department, Princess Alexandra Hospital.

Associate Professor Anthony Bell, MBBS FACEM FRACMA MPH MBA,
Director Emergency Medicine, Royal Brisbane and Women's Hospital
Associate Professor, QueenslandUniversity of Technology

Dr James LindBS BM BMedSci FACEM
Emergency Physician, GoldCoastUniversityHospital
Associate Professor,GriffithUniversity

Associate Professor Ian Scott MBBS FRACP MHA Med
Director of Internal Medicine and Clinical Epidemiology,PrincessAlexandraHospital
Associate Professor of Medicine, University of Queensland,

Abstract

Objective:

We sought to explore the relationship between risk-adjusted in-hospital mortality of patients admitted acutely from emergency departments (EDs) and the National Emergency Access Target (NEAT) compliance rates defined as the proportions of presenting patients admitted or discharged from ED within 4 hours of presentation.

Design, setting and participants:

Retrospective observational study of all de-identified episodes of care involving patients presenting acutely to EDs of 59 Australian hospitals between July 1st, 2010 and June 30th 2014.

Main outcome measure:

The relationship between risk-adjusted inpatient mortality of patients admitted acutely from ED expressed as emergency hospital standardised mortality ratio (eHSMR) (the ratio of observed to expected deaths) and NEAT compliance rates for all presenting patients (total NEAT) and admitted patients (admitted NEAT).

Results:

ED and inpatient data were aggregated for 12.5 million ED episodes of care and 11.6 million inpatient episodes of care. A highly significant ($p<0.001$) linear, inverse relationship was seen between eHSMR and both total and admitted NEAT. eHSMR reduced to a nadir of 73 as total NEAT and admitted NEAT compliance rates rose to approximately 83% and 65% respectively. Sensitivity analyses revealed no confounding effects from the inclusion of palliative care or short stay patients.

Conclusion:

As NEAT compliance rates increase, in-hospital mortality of emergency admissions declines, although this direct inverse relationship is lost once total and admitted NEAT compliance rates exceed specific threshold values. This association between NEAT compliance rates and in-hospital mortality should be considered when formulating targets for access to emergency care.

.

Introduction

The National Emergency Access Target (NEAT) stipulates that a certain proportion of patients should be admitted, discharged or transferred from Australian emergency departments (EDs) within four hours. Targets which varied from state to state were set for all Australian EDs via the National Partnership Agreement in 2012 (1) in response to evidence that ED overcrowding and prolonged length of stay were associated with increased in-hospital mortality (2,3). The original aim was to increase the target incrementally to 90% across all jurisdictions by 2015, in line with the target set in the UK in 2010. 'the 4-hour rule' was coined.

Despite the potentially large impact of the NEAT upon patient care, there was no prospective standardised framework for monitoring patient outcomes for those patients admitted to the hospital from the ED. Measuring patient outcomes is difficult and no method is beyond criticism. The eHSMR (HSMR for patients admitted from the ED) is an objective screening tool which aims to alert clinicians to potentially avoidable harm and has been accepted as a core indicator of hospital safety (4). The eHSMR gives clinicians a ratio of observed deaths to expected deaths. Unlike raw mortality, eHSMR screens out the deaths of palliative patients and attempts to risk adjust for clinically relevant factors such as age, sex and principal diagnosis. The HSMR has been clinically useful in Australia where it has helped guide clinical redesign of ED admission processes (5, 6, 7) and in the UK where elevated HSMRs helped identify potentially avoidable adverse clinical events at the Mid Staffordshire Trust Hospitals(8)

Retrospective studies from large hospitals in Perth (9) and Brisbane (5) have shown that clinical redesign induced by the NEAT has been associated with reduced ED crowding,

enhanced patient flow through ED, and decreased in-hospital mortality. In one study, a rise in NEAT compliance rates from 30% to 70% was strongly correlated with a decrease in the risk adjusted ratio of observed to expected deaths for emergency admissions, embodied in the hospital standardised mortality ratio for emergency admissions (eHSMR), from 110 to 67 ($R=0.914$, $p=0.0006$) (5).

However, certain factors may potentially confound these mortality reductions. Following the introduction of the NEAT, more low acuity patients who are less likely to die - may now be admitted to short stay wards whereas, prior to NEAT, they would have been discharged from ED at various times after four hours. This could potentially introduce a bias if the risk adjustment were to overestimate the mortality risk of these low risk patients. In addition, a potential increase in the coding of patients as receiving palliative care following acute admission will increase the number of expected deaths while the number of observed deaths remains unchanged, again lowering the eHSMR (10).

Putting these interpretive considerations to one side, no hospital in Australia, apart from small rural institutions, has consistently reached targets in excess of 85% (11). Moreover, despite evidence associating ED overcrowding with increased in-hospital mortality, and reduced mortality following introduction of a time-based target in some jurisdictions, uncertainty persists as to whether time based targets consistently improve patient outcomes across most, if not all, hospitals (3, 5-8,10).

Overzealous pursuit of stringent time-based targets may actually compromise quality of care and endanger patient safety, as suggested by the Mid-Staffordshire experience in the UK where elevated HSMRs pointed to potentially avoidable patient harm (8). A focus on NEAT

has to be coupled with patient-centred outcome measures to balance the dual needs for hospital efficiency and safe, effective care (8-10,12-14).

The ideal NEAT compliance rate which maximises the benefits of decongesting EDs while minimising the potential harms of rushed and suboptimal management of acutely ill patients has not been determined on the basis of empirical data. A recent literature review on 4-hour targets in Australia and the UK noted all stated targets to be arbitrary and lacking validation (14). Another review noted that the introduction of the 4-hour rule in the UK, undertaken at considerable financial cost had not resulted in consistent improvements in care, with markedly varying effects between hospitals being reported (15). In Australia, the need to determine the optimal NEAT has been heightened because of the opportunity costs involved in achieving high compliance rates and the loss of financial incentives following dissolution of the National Partnership Agreement in 2014 (16, 17).

The aims of our study were to explore the relationship between risk-adjusted mortality for patients admitted to the hospital from the ED (eHSMR) and NEAT compliance rates using a large dataset from multiple Australian hospitals, and to assess the effects on this association of potential confounding due to the inclusion of palliative care patients and short stay patients.

Methods

Study Design, Participating Sites and Data Sources

This retrospective observational study covered the 4 year period from 1st July 2010 to 30th June 2014 spanning the introduction and subsequent focus on NEAT by Australian

Governments following the signing of the National Partnership Agreement on Improving Public Hospital Services in February 2011(1).

De-identified data on hospital admissions during the study period were obtained from The Health Roundtable Ltd (HRT) in accordance with its academic research policy. The final dataset comprised 59 Australian hospitals; all 33 New Zealand hospitals, which were working towards a 6 hour target were excluded, as were 26 sites in Australia that had no general emergency departments, two specialist hospitals with a different mortality profile and 48 hospitals for which ED data over the study period was incomplete. With approval from HRT, the de-identified dataset was analysed independently by investigators from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) e-Health Research Centre.

Episodes of care and patient cohorts

All patients presenting to an ED of one of the study hospitals and were either admitted to or discharged from the hospital were included in the analysis. For admitted patients, the unit of analysis was the entire hospital stay, while preserving any changes in care type during the admission. Elective patients, patients coded as dead-on-arrival with a principal diagnosis of sudden unexplained death or who died in ED, organ donation episodes, non-acute and geriatric evaluation and management episodes, and all neonates were excluded. Patients coded as palliative and short stay patients (defined as being an inpatient for less than 24 hours) were also excluded from the primary analysis.

In addition to the original cohort, three additional patient cohorts were analysed: 1. patients coded as palliative care at the time of death, 2. patients with short stays, defined as length of hospital stay (LOS) <24 hours which served as a proxy for those patients admitted to short

stay observation wards or clinical decision units and thereby compensating for inconsistencies among hospitals in how transfers to such wards were coded as inpatient admissions and 3. these two cohorts combined.

NEAT compliance rates

NEAT compliance rate was defined as the proportion of patients with an ED length of stay (LOS) less than 4 hours. The rate was calculated separately for all patients (total NEAT), and patients admitted to inpatient units and designated short stay units (admitted NEAT).

Main Outcome Measure

The main outcome measure was the relationship between NEAT compliance rates and in-patient mortality of emergency admissions expressed as eHSMR. The eHSMR was preferred to raw mortality rates for two reasons:

1. eHSMR is the risk adjusted ratio of observed to expected deaths which helps account for variation in acuity of presentations and hospital activity.

2.HSMR has been validated in other clinical studies to monitor patient outcomes.

Statistical analysis

Regression models of eHSMR

Several models were used to calculate the expected number of deaths as the denominator in eHSMR. In keeping with convention (18), the data on all included patients was split into 2 parts: episodes coded with the top 68 diagnosis codes identified as accounting for 80% of in-hospital deaths (part 1), and those accounting for the remaining 20%, wherein the number of individual ICD-10 codes was reduced from ~1000 to 10 broad categories based on raw proportions of deaths associated with each code (part 2). Model selection for each part consisted of an elastic net model via 10 fold cross validation, with chosen penalty parameter

being the lambda within one standard deviation of the minimum (19). All models initially included two-way variable interactions. Additional information about the modelling process is available in Appendix A. Area under the curve (AUC) measures assessed model predictive ability, with values of 0.85 noted for the part 1 model and 0.89 for the part 2 model. Similar values were found for models which included either or both patients coded as palliative or having short stays.

Relation between NEAT compliance rates and eHSMR

Emergency presentation data, and observed and expected in-hospital mortality rates were aggregated at monthly levels for each hospital and each hospital peer group over the study period. Overall NEAT and admitted NEAT compliance rates and eHSMR were then calculated. As exploratory data analysis using linear regression models suggested a complex relationship between NEAT and eHSMR, non-linear relationships were assessed using a restricted cubic spline with knots at 50, 60, 70, 80, 85, 90, and 95% NEAT compliance rates. The primary analysis of the NEAT-eHSMR relationship excluded palliative care and short stay patients; the effects on this relation of including these patient cohorts were explored in sensitivity analyses of the total cohort and each hospital peer group. Statistical analysis was undertaken using R and statistical significance of all tests was denoted as $P \leq 0.05$.

Ethics Approval

An ethics approval exemption was provided by the Metro South Human Research Ethics Committee (HREC/15/QPAH/233).

Results

Participating sites

Emergency presentation and admission data and operating characteristics of participating hospitals are summarised in Appendix B, Table 1.

NEAT compliance rates

Over the 4 year study period, there was a progressive increase in mean monthly NEAT compliance rates for admitted, total and non-admitted patients: 25% to 45%, 56% to 70%, and 70% to 80% respectively (Appendix B, Figure 1).

Relationship between eHSMR and NEAT compliance rates

The primary analysis of monthly plots of eHSMR versus total NEAT (Figure 1) and eHSMR versus admitted NEAT (Figure 2) for all hospitals combined showed similar and significant ($p<0.0001$) inverse linear relationships until certain inflection points were reached. Relatively wide confidence intervals beyond these points indicates limited data were available.

With respect to total NEAT, the eHSMR declined on average by 5.5% for every 5 percentage point change in total NEAT compliance rate to reach a nadir of 73 corresponding to an approximate compliance rate of 83% (range 80-85%). For admitted NEAT, which included short stay ward admissions, the eHSMR declined on average by 4.5% for every 5 percentage point change in NEAT compliance rate to reach a nadir of 73 corresponding to an approximate compliance rate of 65% (range 60-70%).

Sensitivity analyses

When the primary analysis was repeated including either or both palliative care patients and short stay patients, the previously noted relationships between eHSMR and either total or admitted NEAT compliance rates remained unchanged (Figure 3)

Discussion

Overview of findings

With the recent abolition of the National Emergency Access Target, the future of time-based targets for emergency care is unclear. As far as we are aware, this is the first multisite study to define a relationship between NEAT compliance rates and risk-adjusted in-hospital mortality. An inverse linear relationship was seen as NEAT compliance rates increased to approximately 83% (80-85%) for total NEAT and 65% (60-70%) for admitted NEAT. Differences among hospitals in coding of palliative care patients or numbers of short stay patients did not confound the eHSMR-NEAT compliance rate relationships.

Strengths and limitations

Our study has several strengths. First, the analysis involved a very large number of episodes of care over 4 years from a large, representative sample of Australian hospitals, including 79% of all tertiary hospitals which account for more than 85% of all emergency admissions. Secondly, we were able to use an objective measure of mortality for emergency admissions to hospital and assess patient outcomes over the period of introduction of the NEAT. This study helps inform the debate on whether time targets should remain, and if so, what they should be.

Study limitations were that this was an observational study showing a decrease in eHSMR as NEAT compliance rates increased up to certain threshold values, but this does not prove causality. However, the relationship was highly significant, even in sensitivity analyses which accounted for potential confounders, and we are unaware of any other national hospital quality and safety initiative implemented during the study period. Omission of some hospitals limits the generalisability of our findings to all institutions. The eHSMR as the primary outcome measure does not encompass other patient-important outcomes such as morbidity or quality of life, and HSMRs are controversial measures when used for cross-sectional, inter-hospital comparisons (20). Our final models cannot account for errors associated with estimating HSMRs. The denominator of the eHSMR is calculated using modelling and so will have some imprecision (18). However, HSMR is objective, accepted as a national indicator (4), and serves as a useful indicator of potentially avoidable mortality within individual hospitals when tracked over time in the absence of major changes in coding practices or admission policies as in this study (20). Finally, the 95% confidence intervals (CI) around the mean eHSMR corresponding to above-threshold compliance rates did widen as the number of hospitals achieving such rates decreased, thus raising the possibility of some further diminution in mortality at higher rates based on the lower 95% CI.

Implications for clinical practice and policy

Our study holds several implications. First, we have demonstrated that there is currently no robust evidence to support or refute a clinically significant mortality benefit associated with total and admitted NEAT compliance rates in excess of 83% (80-85%) and 65% (60%-70%). Second, as the demonstrated benefit in mortality for admitted patients is associated with increasing total and admitted NEAT compliance rates, it can be argued that both rates should

be monitored. Finally, consideration should be given to embedding time-based NEAT compliance rates within a suite of patient-focussed outcome measures that can quickly signal any unintended adverse consequences of pursuing ever higher NEAT compliance rates.

Figure 1. The Relationship between Total NEAT Compliance and eHSMR.

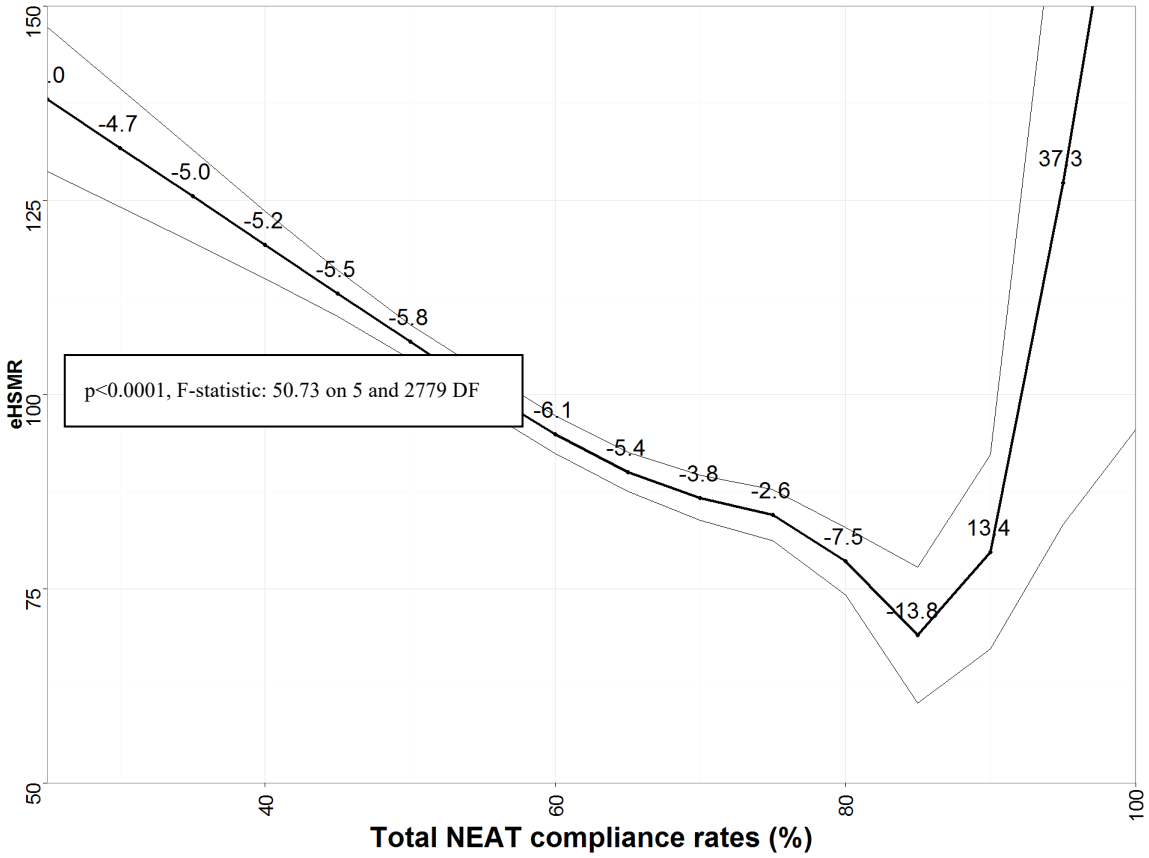
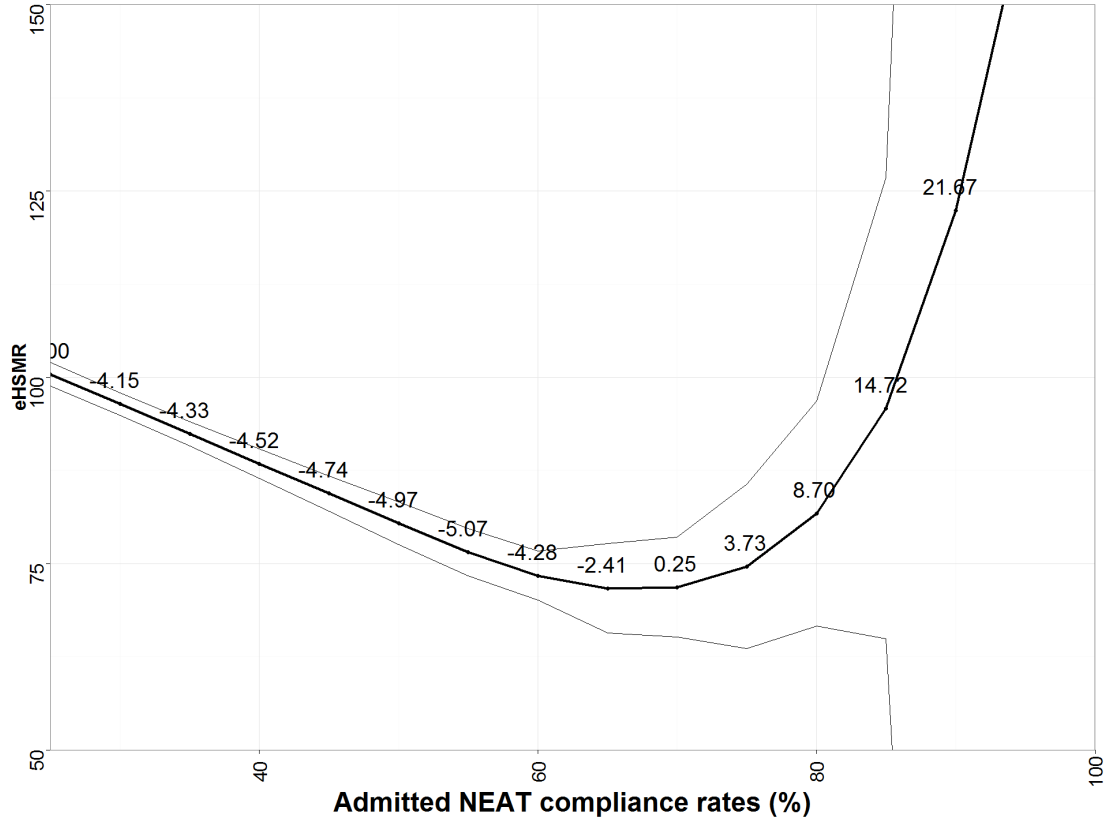


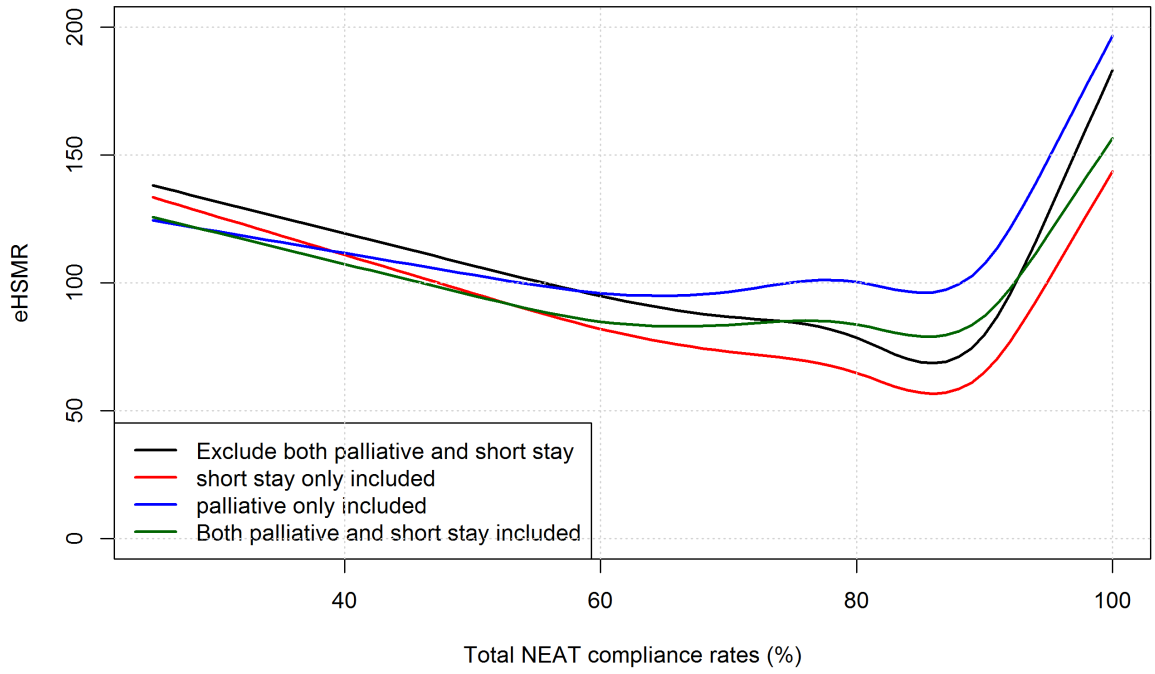
Figure 2 The Relationship between Admitted NEAT Compliance and eHSMR.



Faint lines represent 95% confidence intervals.

Graph labels are % change in eHSMR per 5% change in NEAT

Figure 3 The Relationship of NEAT compliance and eHSMR to Potential Confounders (Short Stay Patients and Patients Coded as Palliative)



References

1. Commonwealth Government of Australia. Expert Panel: Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hospital Services 2011.

2. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. Med J Aust. 2006 Mar 6;184(5):213-6. PubMed PMID: 16515430. Epub 2006/03/07. eng.

3. Spirvulis PC, Da Silva JA, Jacobs IG et al. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. Med J Aust 2006;184:208-212.

4. Australian Commission on Safety and Quality in Health Care. Indicators of safety and quality: Core, Hospital-based Outcome Indicators Sydney: Commonwealth of Australia; 2015 [cited 2015 April 5th 2015]. Available from: http://www.safetyandquality.gov.au/our-work/information-strategy/indicators/core-hospital-based-outcome-indicators/. (accessed 13 May 2015)

5. Sullivan CM, Staib A, Flores J, Aggarwal L, Scanlon A, Martin JH, et al. Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital. Aust Health Rev. 2014;38(5):564-74

6. Sullivan C, Staib, A., Eley, R., et al. NEAT metrics of the ED-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital. Aust Health Rev. 2015; DOI 10.1071/ah14162.

7 Lowthian J, Curtis A, Straney L, McKimm A, Keogh M, Stripp A. Redesigning emergency patient flow with timely quality care at the Alfred. Emerg Med Australas. 2015;27(1):35-41.
8. Francis R. Report of the Mid Staffordshire NHS Foundation Trust Public Inquiry. Controller of Her Majesty's Stationery Office. 2013 London. http://webarchive.nationalarchives.gov.uk/20150407084003/http://www.midstaffspublicinquiry.com/report. (Accessed 18 May 2015)

9 Geelhoed GC, de Klerk NH. Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. Med J Aust. 2012 Feb 6;196:122-6. PubMed PMID: 22304606. Epub 2012/02/07. eng.

10. Richardson DB. Emergency department targets: a watershed for outcomes research? Med J Aust. 2012;196:126-7.

11. Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW. 2014.

12 Four Hour Rule Program Progress and Issues Review. Perth: Department of Health WA, 2011. http://www.health.wa.gov.au (Accessed 13 May 2015)
13. Keijzers G. NEAT in need of a sweet spot. Emerg Med Australas 2014; 26 (3): 217-218.

14. Staib A, Sullivan C, Griffin B, Bell A, Scott I. 2015. Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review. Aust Health Rev. doi:10.1071/ah15071

15. Jones P, Schimanski K. The four hour target to reduce Emergency Department 'waiting time': a systematic review of clinical outcomes. Emerg Med Australas 2010; 22: 391-8.

16. Queensland Clinical Senate. National Emergency Access Target: is 90% the right target,. Brisbane: 2014. Available at: www.health.qld.gov.au/qldclinicalsenate/docs/fin-rep-mar2014.pdf (accessed 13 May 2015)

17 Monaghan M. A discussion on the future of the National NEAT targets. 2014. Available at http://www.health.qld.gov.au/qldclinicalsenate/docs/pp-140328-neat-wa.pdf (accessed 13 May 2015)

18. Ben-Tovim D, Woodman R, Harrison JE, et al. Measuring and reporting mortality in hospital patients. Canberra: AIHW, 2009. http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=6442457123 (accessed 18 May 2015)

19. Hastie, R. Tribshirani, and J. Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, second edition, February 2009.

20. Scott IA, Brand CA, Phelps GE, et al. Using hospital standardised mortality ratios to assess quality of care--proceed with extreme caution. Med J Aust. 2011 Jun 20;194(12):645-8. PubMed PMID: 21692724. Epub 2011/06/23. eng.

Appendix C
Details of eHSMR Modelling

This Appendix was published as Appendix 1 to: Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule for emergency departments: time to review the target. **Med J Aust** 2016; 204: 354. doi: 10.5694/mja15.01177..

APPENDIX 1

Details of the eHSMR Modelling

Data Preparation:

Of the available 168 hospitals in the extract obtained from The Health Roundtable Ltd (HRT), 33 hospitals located in New Zealand were excluded as New Zealand has different targets. Of the remaining 135 Australian hospitals, 26 sites were excluded as no ED data was available for them in the extract. Another two sites were excluded as they represented specialist hospitals that are known to have a mortality profile very different to general hospitals (1). A further 48 sites were excluded as they had between 1 and 3 years of missing ED data in the extract. The remaining 59 sites were included in the analysis. Of these, 8 had between 1 and 9 days of missing ED data, possibly indicating no ED activity on the day. Inpatient activity was available for the entire study period for the included 59 hospital sites.

The study focused on calculating the hospital standardised mortality ratio (HSMR) for patients admitted via the emergency department, hereafter referred to as the emergency hospital standardised mortality ratio (eHSMR). Elective patients, patients coded as dead-on-arrival with a principal diagnosis of sudden unexplained death or who died in ED, organ donation episodes, non-acute and geriatric evaluation and management episodes, and all neonates were excluded. Palliative care patients were excluded from the primary analysis in accordance with other published work in the area of in-hospital mortality (1). Short stay inpatients (defined as inpatient LOS<24 hour regardless of inpatient destination), were excluded from the mortality analysis because of variability in the use of short stay unit and clinical decision units and inconsistencies in coding practices between hospitals. Multiple patient episodes representing the same stay in hospital were merged to ensure each episode represented a single stay in hospital. This ensured that statistical discharges resulting from change of caretype etc. did not affect the calculation of eHSMR.

In addition to the primary analysis patient cohort, two additional patient cohorts were created to analyse any potential bias introduced by including palliative care and short stay unit stays on the relationship between NEAT and eHSMR : 1.A cohort that represented the primary analysis patient cohort but included patients coded as palliative care at the time of death, 2. A cohort that represented the primary analysis patient cohort but included patients with short stays, defined as length of hospital stay (LOS) <24 hours which served as a proxy for those patients admitted to short stay observation wards or clinical decision units which overcame inconsistencies between hospitals in how transfers to such wards were coded as inpatient admissions and 3. A cohort including both patients coded as palliative care at the time of death and patients with short stays.

eHSMR Modelling :

Risk-adjusted regression models of in-hospital mortality resulting from ED admissions were used to calculate expected mortality for each hospital. This was then employed in calculating eHSMRs (see equation 1).

$$eHSMR = \frac{Actual\ number\ of\ in{-}hospital\ deaths\ among\ patients\ admitted\ through\ ED}{Expected\ number\ of\ in{-}hospital\ deaths\ among\ patients\ admitted\ through\ ED} \quad (1)$$

In keeping with established methodology for calculating standardised in-hospital mortality, we applied the approach advocated by Ben-Tovin (1) and developed models in two groups. The first 3 characters of the principal diagnosis (ICD10 code) were used to segregate the episodes into two groups - the first comprising 68 ICD10 codes that accounted for 80% of in-hospital deaths (see Table A.1), and the second comprising the rest of the ICD10 codes that accounted for the balance 20% of in-hospital deaths.

ICD code	Description	ICD code	Description
A41	Other sepsis	I50	Heart failure
C15	Malignant neoplasm of oesophagus	I60	Subarachnoid haemorrhage
C16	Malignant neoplasm of stomach	I61	Intracerebral haemorrhage
C18	Malignant neoplasm of colon	I62	Other nontraumatic intracranial haemorrhage
C20	Malignant neoplasm of rectum	I63	Cerebral infarction
C22	Malignant neoplasm of liver and intrahepatic bile ducts	I64	Stroke, not specified as haemorrhage or infarction
C25	Malignant neoplasm of pancreas	I70	Atherosclerosis
C34	Malignant neoplasm of bronchus and lung	I71	Aortic aneurysm and dissection
C45	Mesothelioma	J15	Bacterial pneumonia, not elsewhere classified
C50	Malignant neoplasm of breast	J18	Pneumonia, organism unspecified
C56	Malignant neoplasm of ovary	J22	Unspecified acute lower respiratory infection
C61	Malignant neoplasm of prostate	J44	Other chronic obstructive pulmonary disease
C64	Malignant neoplasm of kidney, except renal pelvis	J69	Pneumonitis due to solids and liquids
C67	Malignant neoplasm of bladder	J84	Other interstitial pulmonary diseases
C71	Malignant neoplasm of brain	J90	Pleural effusion, not elsewhere classified
C78	Secondary malignant neoplasm of respiratory and digestive organs	J96	Respiratory failure, not elsewhere classified
C79	Secondary malignant neoplasm of other sites	K52	Other noninfective gastroenteritis and colitis
C80	Malignant neoplasm without specification of site	K55	Vascular disorders of intestine
C83	Diffuse non-Hodgkin lymphoma	K56	Paralytic ileus and intestinal obstruction without hernia
C85	Other and unspecified types of non-Hodgkin lymphoma	K57	Diverticular disease of intestine
C90	Multiple myeloma and malignant plasma cell neoplasms	K63	Other diseases of intestine
C91	Lymphoid leukaemia	K70	Alcoholic liver disease
C92	Myeloid leukaemia	K72	Hepatic failure, not elsewhere classified
E11	Type 2 diabetes mellitus	K85	Acute pancreatitis
E86	Volume depletion	K92	Other diseases of digestive system

E87	Other disorders of fluid, electrolyte and acid-base balance	L03	Cellulitis
G93	Other disorders of brain	N17	Acute renal failure
I20	Angina pectoris	N18	Chronic renal failure
I21	Acute myocardial infarction	N39	Other disorders of urinary system
I25	Chronic ischaemic heart disease	R55	Syncope and collapse
I26	Pulmonary embolism	S06	Intracranial injury
I46	Cardiac arrest	S32	Fracture of lumbar spine and pelvis
I48	Atrial fibrillation and flutter	S72	Fracture of femur
I49	Other cardiac arrhythmias	T81	Complications of procedures, not elsewhere classified

Table A.1 : List of 68 Principal Diagnosis Codes representing highest frequency of in-hospital deaths[1]

Receiver Operating Characteristic (ROC) curve analysis was employed to measure the performance of the models, with the c-statistic (or AUC), representing the area under the ROC curve, used as a measure of discrimination and used to compare the performance of the models. Models were developed using 64-bit version of the R project for statistical computing on an Intel E5-2630 CPU machine with 2x2.6GHz processors and 128GB of RAM.

For calculating eHSMR, two methods of model selection were employed; namely, elastic net (2) and backwards stepwise variable selection. All models were a binary generalized linear model, with the response variable being whether or not a subject died or not coded as 1,0 respectively.

Elastic Net is a regularization and variable selection method for building generalised linear models when you have either many more predictors than data or you have some sparseness in your model matrix. To calculate the eHSMR is this study we looked at a number of variables and all two-way interactions between them. Ordinary stepwise regression techniques failed to converge due to small cell counts in some two-way interaction terms.

Initial models included the following variables and all their two-way interactions; DRG7 complexity score, Hospital ID, Length Of Stay (1,2,3,7,14,28,>28days), Gender, Admission Source, Number of Procedures (0,1,2,3,4,5,>5), Number of Diagnoses (0,1,2,3,4,5,>5), Charlson Comorbidity Index Group (0,1,2,3,4,5,>5), Age in Years, Age Squared, Age Cubed, Age Group (1,16,34,49,64,79,>79) and Hospital Type.

ICD codes from the low mortality ICD codes group were collapsed into ten groups using k-means clustering according to frequency of mortality for each ICD-10 code and included in all two-way interactions. The 68 ICD from the high mortality group were not included in two-way interactions, they were added as a main effect only.

Variable selection for the elastic net was done via 10 fold cross validation, with the penalty tuning parameter chosen as the lambda within one standard deviation of the minimum.

The above modelling was carried out for the principal patients cohort and then repeated for the palliative patients included cohort and short stay patients incuded cohort to obtain individual models for the high mortality and low mortality groups for each of the 3 cohorts.

References :

1. Ben-Tovim D, Woodman R, Harrison JE, et al. Measuring and reporting mortality in hospital patients. Canberra: AIHW, 2009.
2. T. Hastie, R. Tribshirani, and J. Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, second edition, February 2009.

Appendix D

Supplementary Tables and Figures to The National Emergency Access Target (NEAT) and the 4-hour rule for emergency departments: time to review the target.

Published as Appendix 2 to: Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule for emergency departments: time to review the target. Med J Aust 2016; 204: 354. doi: 10.5694/mja15.01177.

APPENDIX 2

Supplementary Tables and Figures

Table 1. Profile of datasets from study hospitals

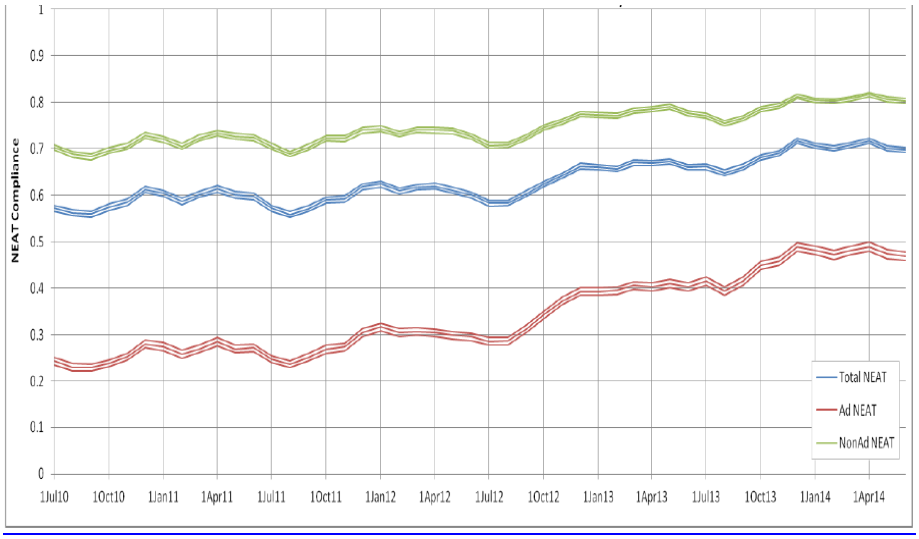
AIHW Definition (based on number of casemix-adjusted separations per annum)	Number of hospitals (Percentage of all Australian hospitals within peer group)	Total number of ED records	Mean number of daily ED Presentations	Total number of inpatient records (emergency and elective)
Principal Referral Hospital*	23	5.8 million	171	6.6 million
Large Hospital**	25	4.9 million	134	3.8 million
Medium Hospital	11	1.9 million	116	1.1 million
Total numbers	**59**	**12.5 million**	**146**	**11.6 million**

*Defined as major city and >20000 separations or regional and> 16000 separations.

**Defined as major city and>10000 separations or regional and> 8000 separations or remote and >5000 separations.

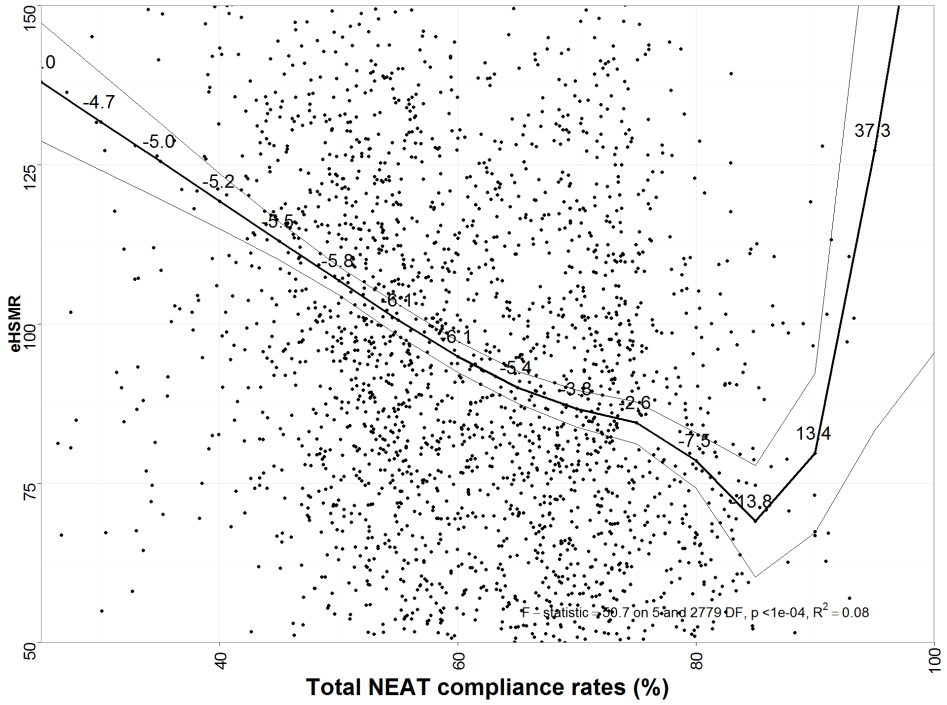
***Defined as major city or regional and 2000-10000 separations.

Figure 1 NEAT Compliance by month for 59 Australian Hospitals from 2010-2014



Faint lines represent 95% confidence intervals

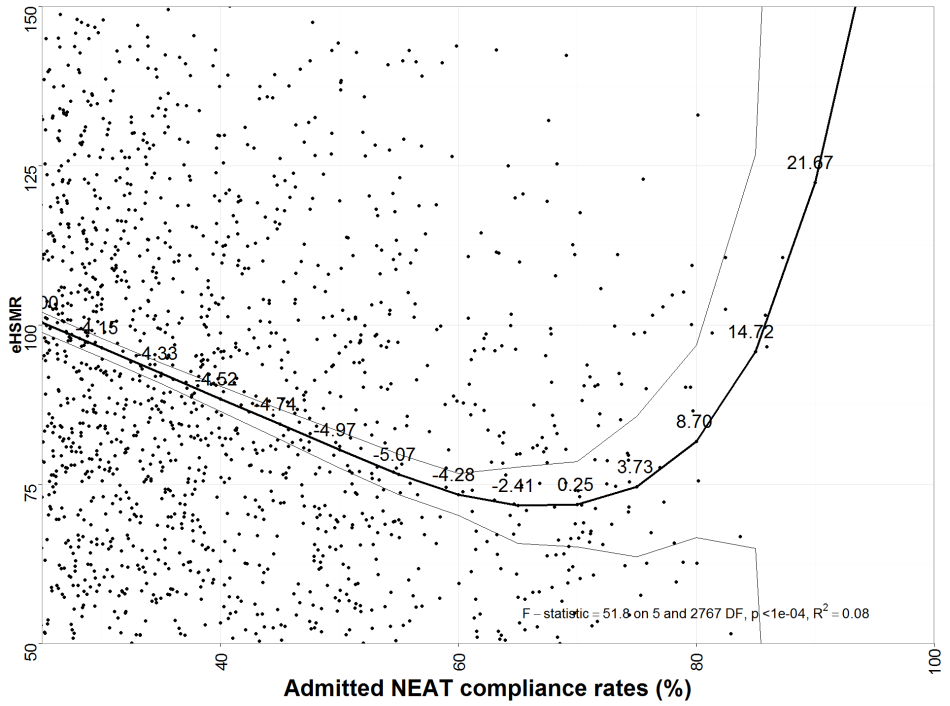
Figure 2 The Relationship between Total NEAT Compliance and eHSMR.



Faint lines represent 95% confidence intervals.

Graph labels are % change in eHSMR per 5% change in NEAT

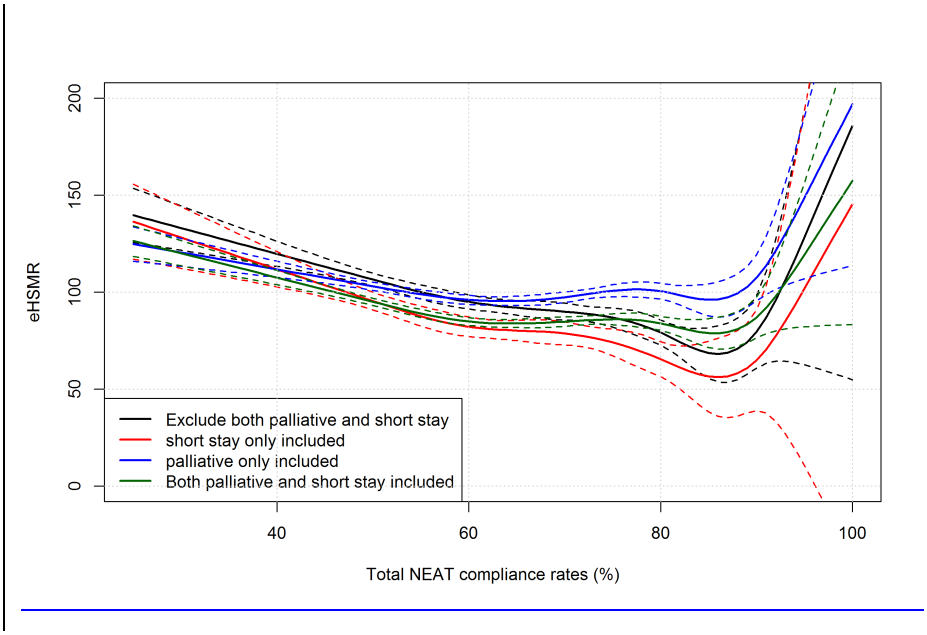
Figure 3 The Relationship between Admitted NEAT Compliance and eHSMR.



Faint lines represent 95% confidence intervals.

Graph labels are % change in eHSMR per 5% change in NEAT

Figure 4. The Relationship of NEAT compliance and eHSMR to Potential Confounders



Dashed lines represent 95% confidence intervals

Appendix E

The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital

Staib A, Sullivan C, Jones M, Griffin B, Bell A, Scott I. The ED-inpatient dashboard: Uniting emergency and inpatient clinicians to improve the efficiency and quality of care for patients requiring emergency admission to hospital. *Emerg Med Australas.* 2017;29(3):363-366.

‡Dr Andrew Staib MBBS FACEM (‡*co-first author)*
Deputy Director of Emergency Medicine,
Princess Alexandra Hospital. Metro South Health
MMRI University of Queensland
Translational Research Institute
199 Ipswich Road Woolloongabba QLD 4102
t. 07 3176 7526 e. Andrew.Staib@health.qld.gov.au

‡Dr Clair Sullivan MBBS (Hons) MD FRACP *(‡ co-first author)*
Deputy Chair of Medicine, Consultant Endocrinologist,
Princess Alexandra Hospital, Metro South Health
MMRI University of Queensland
Translational Research Institute

Mr Matt Jones MInfTech
Delivery Director Metro South Digital Hospital Program, Princess Alexandra Hospital.

Dr Bronwyn Griffin, PhD, GDipEmerg, BNurs.
Nurse Researcher, Emergency Department, Princess Alexandra Hospital.

Associate Professor Anthony Bell, MBBS FACEM FRACMA MPH MBA,
Director Emergency Medicine, Royal Brisbane and Women's Hospital
Associate Professor, Queensland University of Technology

Associate Professor Ian Scott MBBS FRACP MHA Med
Director of Internal Medicine and Clinical Epidemiology,
Princess Alexandra Hospital
Associate Professor of Medicine, University of Queensland

Word Count 1464

Abstract

Patients who require emergency admission to hospital require complex care which can be fragmented, occurring in the Emergency Department (ED), across the ED-inpatient interface (EDii) and subsequently in their destination inpatient ward. Our hospital had poor process efficiency with slow transit times for patients requiring emergency care.

ED clinicians alone were able to improve the processes and length of stay for the patients discharged directly from the ED . However, improving the efficiency of care for patients requiring emergency admission to true inpatient wards required collaboration with reluctant inpatient clinicians.

The inpatient teams were uninterested in improving time-based measures of care in isolation, but they were motivated by improving patient outcomes. We developed a dashboard showing process measures such as 4-hour rule compliance rate coupled with clinically important outcome measures such as inpatient mortality. This EDii dashboard helped unite both ED and inpatient teams in clinical redesign to improve both efficiency of care and patient outcomes.

Introduction

Access to emergency care in hospitals is critical for our sickest and most complex patients and attracts extensive community and political interest as evidenced by the 4-hour rule or the National Emergency Access Targets (NEAT).

The cohort of patients who are discharged home from the Emergency Department (ED) are a relatively low acuity, low cost group to treat. EDs alone can streamline and improve the care of this group without having to engage with inpatient clinicians and complicated whole of hospital processes.

However, the group of ED patients who require admission to an inpatient unit have to negotiate the ED-inpatient interface (EDii). The EDii is the complex interplay which occurs between the ED and inpatient hospital services as a patient transfers from emergency to inpatient care. This group of patients is typically at high risk for harm, has significant clinical complexity and has a high mortality rate when compared to patients admitted electively [1-3].

Despite a relative lack of robust, peer-reviewed research in this area, the ED-inpatient interface is one of the very few areas where governments have imposed time targets for clinical care. The National Emergency Access Target (NEAT) introduced by the Australian government in 2011 directed that 90% of patients presenting to EDs were admitted, discharged or transferred within 4 hours of presentation. However, there was no accompanying robust policy for monitoring patient outcomes [4-6]. The national partnership agreement underpinning the NEAT has recently been dissolved and considerable uncertainty exists as to whether time targets for emergency care should

continue [5]. Recent work has provided strengthened evidence of an inverse association between 4-hour target compliance rates and in-hospital mortality [7].

Princess Alexandra Hospital (PAH) is a large tertiary hospital which previously recorded one of the worst NEAT performances nationally. Although the hospital executive was committed to improving NEAT compliance, there was a lack of engagement from clinicians, particularly inpatient teams.

This lack of engagement was underpinned by concerns that rushing patients out of the ED may cause harm and a lack of confidence to undertake process change as patient outcomes were unable to be easily tracked. There were no readily available data sources on outcomes for patients requiring emergency admission to hospital. There was existing evidence from the literature that efficient ED processes were associated with better patient outcomes and reduced inpatient mortality. [8]

As part of a multi-faceted clinical redesign effort which is described elsewhere [3], agreement was reached between the ED and the Division of Medicine (DOM) clinicans to develop a dashboard to monitor the efficiency and quality of care at our EDii. The DOM includes general medicine and all medical specialties and receives the majority of emergency admissions. This divisional arrangement meant that engagement of individual medical inpatient units was undertaken by the DOM clinical leaders rather than emergency physicians. The Divisions of Surgery and Cancer Services were similarly engaged. An easily accessible dashboard amalgamating ED and inpatient data sources and process and quality of care measurements was built to give confidence to clinical redesign efforts.

The outcome measures chosen for the dashboard were:

- Emergency Admission Mortality Rate: defined as the percentage of acute patients who were admitted via the Emergency Department and who died in any hospital ward, including the ED short stay ward.
- Emergency Hospital Standardised Mortality Ratio (eHSMR): The standardised mortality ratio as calculated by the Health Roundtable using validated methodology [9, 10]for patients admitted into hospital via the ED.
- Cardiac arrest within 24 hours of admission: the total number of cardiac arrests, as defined by Jacobs [11], per 1000 admissions within 24 hours of admission to a ward for patients admitted via ED.
- Rapid Response Team (RRT) activations within 24 hours of admission: the total number of RRT activations initiated for deteriorating patients (excluding cardiac arrests) per 1000 admissions. This excluded same day patients, statistical admissions, and same-day patients to "day only" wards.
- ED representation rate within 48 hours: was defined as the percentage of patients who re-presented to ED within 48 hours of the index attendance.

Results

Concerted cultural change and more than 25 clinical redesign interventions supported by the dashboard display of outcome and process measures culminated in a near halving of ED

length of stay (from 7.2 hrs to 3.8 hrs) and a near halving of the mortality (from 2.3% to 1.0%) for patients requiring emergency admission to the PAH [3]. No clinically significant adverse safety signals were seen following the implementation of these reforms as assessed by numbers of RRT activations within the first 24 hours of admission or ED representation within 48 hours [3].

The EDii dashboard is shown in Figure 1. The dashboard was implemented at PAH in early 2014, and is now being utilized or implemented in several Australian hospitals.(pers com, J-J Jacques Qld Dept of Health 18/1/2016). The innovative nature and utility of the dashboard was independently recognised by the awarding of a merit certificate to the project team at the iAwards [12].

Discussion

The development and implementation of the EDii dashboard has provided clinicians and hospital executives with a visual platform to ensure that time based emergency access measures are always nested in a standardized, near real-time matrix of quality indicators. Data is now displayed in a meaningful format that assists clinical decision making. The EDii dashboard gave clinicians considerable confidence to undertake significant clinical redesign of the ED inpatient interface.

The introduction of clinical and quality dashboards has been reported to have a positive effect on care outcomes and processes of care [13, 14].

The success of this dashboard is attributable to several factors

5. The dashboard was developed in response to a clearly defined, important clinical problem; limited clinical engagement due to concern that pursuit of isolated process measures might be harmful to patients.
6. The project was led by clinicians with operational roles which allowed the effective implementation and dissemination of the dashboard into everyday clinical practice across the organization. The clinicians were able to utilize the expertly presented data to undertake health service improvement which in turn was able to be tracked using the dashboard.
7. The dashboard was constructed in a way that encouraged easy replication in other facilities. It was designed as a local quality improvement tool and specifically not as a tool for benchmarking across sites.
8. The dashboard formed an integral part of a coordinated whole of hospital cultural change focusing on improving patient outcomes rather than process measures in isolation.

The EDii safety dashboard, and the system reforms that it facilitated, have supported a significant culture change within the PAH. We have seen patient outcomes become the centre of the decision making process. Improved patient outcomes (rather than isolated process measures) are a key driver for united clinical engagement with reform. In addition, the ability to rapidly identify any potential adverse patient safety signals has increased the appetite for innovation and a willingness to try new processes.

Interrogating ED data systems (such as Emergency Department Information Systems (EDIS), Computer Sciences Corporation) can inform clinical redesign and improve overall patient throughput and turnaround times [15, 16]. Baumlin et al noted the major limitation in their EDIS implementation was the system's inability to be fully integrated into existing hospital applications [15].

A data warehouse enables data integration from ED and inpatient sources and information exchange across the enterprise, supporting clinical and operational decision making by breaking down traditional clinical silos [17].

Future iterations of the ED-inpatient interface dashboard will include access to more granular data, including more accurate time stamping of clinical events across EDii, and more detailed coded clinical information. Fortunately, these are primary benefits of an integrated electronic medical record (EMR)which Princess Alexandra Hospital has recently implemented. An EMR will allow more real time presentation of tailored information to allow clinicians to make immediate decisions about current and future service provision to maximize benefit to patients.

Limitations

There are several limitations to this work. . The data remains retrospective and is a reflection of past performance rather than a real time indication of factors that can be modified to improve current performance. The outcome measures in use are important but very gross reflections of quality of care [9]. The process changes and delivery of quality care

remain the responsibility of the clinical teams, and the inspiration and motivation for change comes from them.

Conclusion

The EDii dashboard has supported health system reform in this important area by bringing into clearer focus the important link between key process measures and their impact on patient outcomes.

The linking of patient outcome measures to routinely collected process measures has increased clinical engagement, focused decision making on the patient, and contributed a culture where system innovation is fostered and tested to maximize the efficiency, quality and safety of the care delivered to our patients.

Acknowledgements

The authors are grateful to the following people for their contributions and support.
Dr Richard Ashby, CEO Metro South Health
Dr Susan O'Dwyer, EDMS Metro South Health
Linda McCormack and Julie-Anne Jaques Health Innovation Unit, Queensland Department of Health
Mr Michael Draheim and Mr Cameron Ballantine PAH ICT
Chantelle Judge PAH
Michelle Winning and the Clinical Service Excellence Team (CSET) PAH
Amanda Vaux, Lisa Tewhatu and David Moore and the PAH ICU outreach team.
We would also like to acknowledge the support and sponsorship of the Chair (Dr David Rosengren) and the membership of the Queensland Clinical Senate
This study was partly funded by the Health Innovation Unit, Queensland Department of Health

Keywords

NEAT compliance, ED-Inpatient Interface, Dashboard, Business Intelligence, Business Analytics, Patient Safety.

Box 1- Case Study

The changes in our processes for a representative patient before and after our clinical redesign are detailed below. The EDii dashboard has allowed us to link efficiency of care in the ED and patient outcomes and this new knowledge has changed the way inpatient teams react to emergency admissions.

Case

Mrs GL is 80 years old with a history of diabetes and poor mobility who had a fall at home and was found to be mildly hypotensive and febrile by the ambulance team. She arrived at our ED and responded well to resuscitation with fluids and antibiotics. She was found to have a urinary tract infection and mild delirium.

Clinical process *before* EDii Clinical Redesign

The medical registrar on call for emergency admissions that afternoon was a good clinician but had a strong reputation for being "a wall". There were several difficult phone conversations between him and ED staff regarding admission for Mrs GL, as he refused admission until all investigation results were returned and documented, and he had had the opportunity to review the patient after finishing his outpatient clinic. Mrs GL was eventually admitted to the general medical ward after an 8 hour stay in the ED.

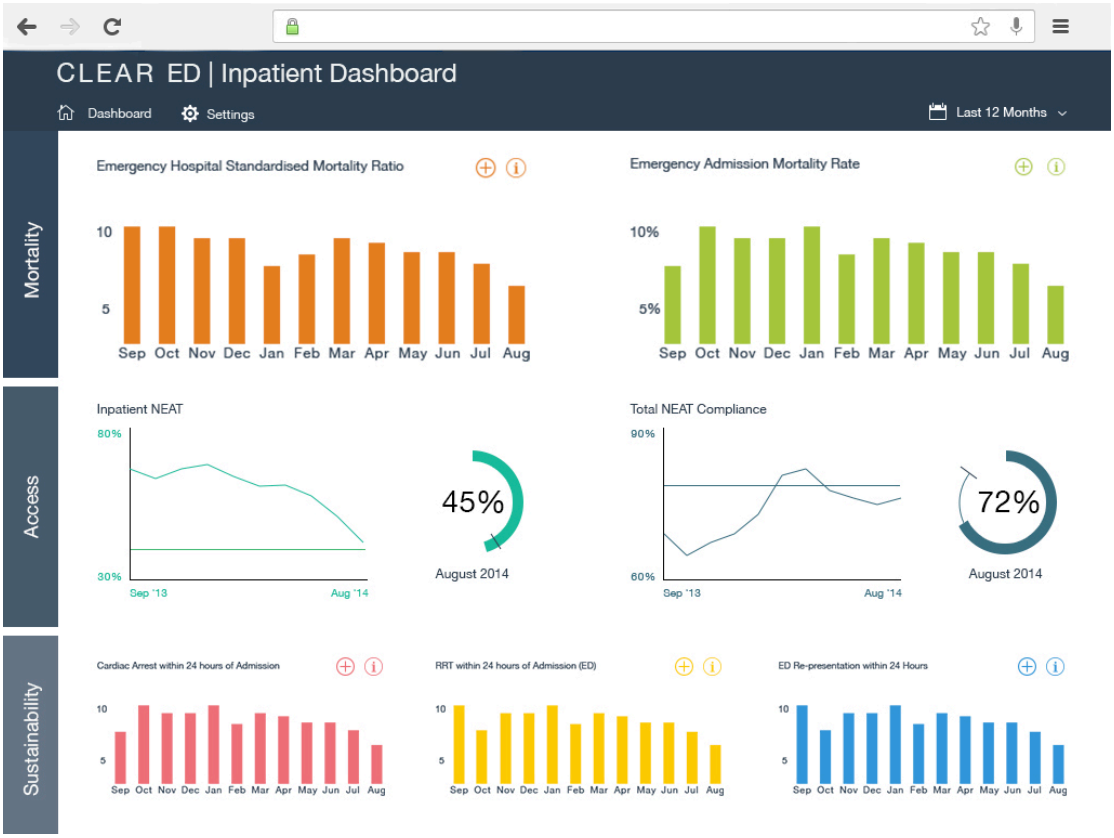
Clinical process *after* EDii Clinical Redesign

The medical registrar on call for emergency admissions that afternoon was a good clinician and knew that short stays in the ED were associated with better mortality outcomes for patients like Mrs GL. He had flagged her as a potential admission on the regular combined inpatient-ED ward round and had her admitted to the general medical ward for definitive management of her urosepsis and delirium. Mrs GL spent only 3.5 hours in the ED.

References

1. Ruiz, M., A. Bottle, and P.P. Aylin, *The Global Comparators project: international comparison of 30-day in-hospital mortality by day of the week.* BMJ Qual Saf, 2015. **24**(8): p. 492-504.
2. McCusker, J., et al., *Increases in emergency department occupancy are associated with adverse 30-day outcomes.* Acad Emerg Med, 2014. **21**(10): p. 1092-100.
3. Sullivan, C.M., et al., *Aiming to be NEAT: safely improving and sustaining access to emergency care in a tertiary referral hospital.* Aust Health Rev, 2014. **38**(5): p. 564-74.
4. Sullivan, C., et al., *National Emergency Access Targets metrics of the emergency department-inpatient interface: measures of patient flow and mortality for emergency admissions to hospital.* Aust Health Rev, 2015.
5. Staib, A., et al., *Report on the 4-h rule and National Emergency Access Target (NEAT) in Australia: time to review.* Aust Health Rev, 2015.
6. Commonwealth Government of Australia. Expert Panel, *Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hopsital Services*. 2011.
7. Sullivan, C., et al., *The National Emergency Access Target (NEAT) and the 4-hour rule: time to review the target.* Med J Aust, 2016. **204**(9): p. 354.
8. Geelhoed, G.C. and N.H. de Klerk, *Emergency department overcrowding, mortality and the 4-hour rule in Western Australia.* Med J Aust, 2012. **196**: p. 122-6.
9. Ben-Tovim, D.I., et al., *Standardised mortality ratios. Neither constant nor a fallacy.* BMJ, 2009. **338**: p. b1748.
10. *Australian Institute of Health and Welfare: Australian hospital statistics 2013–14: emergency department care. Health services series no. 58. Cat. no. HSE 153. Canberra: AIHW.* 2014.
11. Jacobs, I., et al., *Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa).* Resuscitation, 2004. **63**(3): p. 233-49.
12. Association, A.I.I. *2015 Queensland iAwards Winners and Merit Recipients*. 2015 23/1/2016]; Available from: http://www.iawards.com.au/index.php/winners/2015-winners/2015-winners-qld.
13. Dowding, D., et al., *Dashboards for improving patient care: review of the literature.* Int J Med Inform, 2015. **84**(2): p. 87-100.
14. Wills, M.J., *Decisions through data: analytics in healthcare.* J Healthc Manag, 2014. **59**(4): p. 254-62.
15. Baumlin, K.M., et al., *Clinical information system and process redesign improves emergency department efficiency.* Joint Commission Journal On Quality And Patient Safety / Joint Commission Resources, 2010. **36**(4): p. 179-185.
16. Baumlin, K.M., et al., *Clinical information system and process redesign improves emergency department efficiency.* Jt Comm J Qual Patient Saf, 2010. **36**(4): p. 179-85.
17. Vallejo, B.C., et al., *Converting data into information.* Hosp Top, 2012. **90**(1): p. 11-5.

Figure 1 Princess Alexandra Hospital Emergency Department-Inpatient Interface (EDii) Dashboard



Appendix F

Ethics Approvals

Metro South Health

Enquiries to: Metro South Human Research Ethics Committee
Phone: (07) 3443 8049
Fax: (07) 3443 8003
Our Ref: HREC/15/QPAH/233
E-mail Ethicsresearch.pah@health.qld.gov.au

Dr Andrew Staib
Deputy Director, Emergency Department
Princess Alexandra Hospital
199 Ipswich Road
Woolloongabba QLD 4102

Dear Dr Staib

Exempt From HREC Review

HREC Reference number: HREC/15/QPAH/233
Protocol title: National Emergency Access Targets: time to generate an evidence based, patient focussed target

I am pleased to advise that the above project has been reviewed in line with the National Statement (2007) and considered to be exempt from requiring formal ethical review as it does not meet the definition of a research project as per National Statement (2007).

Your project can proceed, subject to compliance throughout the duration of the project with the requirements as outlined in the *National Statement on Ethical Conduct in Human Research (2007)* and the *Australian Code for the Responsible Conduct of Research.*

If the project involves the recruitment of patients from the Metro South Hospital and Health Service (MSHHS), it is my responsibility to remind you of your ongoing duty of care for all people recruited into projects whilst public patients. All conditions and requirements regarding confidentiality of public information and patient privacy apply. You are required to comply at all times with any application requirements of Australian and Queensland Laws including the Health Services Act, the Privacy Act, Public Health Act (2005) and other relevant legislation, ethics obligations and guidelines which may be applicable to the MSHHS from time to time including, without limitation, any requirement in respect of the maintenance, preservation or destruction of patient records.

When the study involves patient contact, it is your responsibility as the principal investigator to notify the relevant consultant and request their approval.

A copy of this letter should be presented when required for publication purposes.

We wish you every success in undertaking this project.

Yours sincerely,

Scott Campbell

A/Prof Scott Campbell
Deputy Chair
Metro South
Human Research Ethics Committee (EC00167)
Centres for Health Research
Princess Alexandra Hospital
Woolloongabba QLD 4102
17/4/15

C.c. Dr Clair Sullivan, PAH
Vikki Tomlinson, Quality and Improvement Unit, PAH

Queensland Government

Metro South Health

Enquiries to: Metro South Human Research Ethics Committee
Phone: (07) 3443 8049
Fax: (07) 3443 8003
Our Ref: HREC/17/QPAH/107
E-mail Ethicsresearch.pah@health.qld.gov.au

Dr Andrew Staib and Dr Clair Sullivan
Princess Alexandra Hospital

Dear Dr Staib and Dr Sullivan,

Exempt From HREC Review

HREC Reference number: HREC/17/QPAH/107
Protocol title: The impact of digitisation on the EDii

I am pleased to advise that the above project has been reviewed in line with the National Statement (2007) and considered to be exempt from requiring formal ethical review.

Your project can proceed, subject to compliance throughout the duration of the project with the requirements as outlined in the *National Statement on Ethical Conduct in Human Research (2007)* and the *Australian Code for the Responsible Conduct of Research.*

If the project involves the recruitment of patients from the Metro South Hospital and Health Service (MSHHS), it is my responsibility to remind you of your ongoing duty of care for all people recruited into projects whilst public patients. All conditions and requirements regarding confidentiality of public information and patient privacy apply. You are required to comply at all times with any application requirements of Australian and Queensland Laws including the Health Services Act, the Privacy Act, Public Health Act (2005) and other relevant legislation, ethics obligations and guidelines which may be applicable to the MSHHS from time to time including, without limitation, any requirement in respect of the maintenance, preservation or destruction of patient records.

When the study involves patient contact, it is your responsibility as the principal investigator to notify the relevant consultant and request their approval.

A copy of this letter should be presented when required for publication purposes.

We wish you every success in undertaking this project.

Yours sincerely,

A/Professor Scott Campbell
A/Chair
Metro South
Human Research Ethics Committee (EC00167)
Centres for Health Research
Princess Alexandra Hospital
Woolloongabba QLD 4102
28/2/17

Queensland Government