

Evaluation of Services for the
Preoperative Assessment and Management
of High-Risk Surgical Patients

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Abstract

Outpatient preoperative assessment clinics, such as the physician-led high-risk clinic in a large metropolitan public hospital in South Australia, have been established to assess and manage surgical patients at high risk of morbidity and mortality due to their medical co-morbidities. To date, the design and implementation of preoperative medical assessment and management has been heterogeneous, with minimal detail on the actual services provided as part of the intervention. Further, there have been no published studies evaluating the costs and outcomes of physician-led preoperative assessment for patients with modifiable medical co-morbidities prior to elective surgery.

Five distinct projects contributed to the main aims of this research: to evaluate the preoperative assessment and management services provided by the physician-led high-risk clinic, and provide recommendations for improvement using an explanatory sequential mixed methods approach.

This research represents the first comprehensive evaluation of services for the preoperative assessment and management of high-risk surgical patients. Multiple regression analyses identified nine potentially modifiable medical co-morbidities to be associated with increased length of stay and postoperative complications, supporting the rationale that optimisation of poorly controlled medical co-morbidities prior to surgery could improve postoperative outcomes.

The costs and effects of physician-led preoperative assessment and management were evaluated using a propensity score-based approach with retrospective and prospective data. It was found that the clinic reduced the frequency of unnecessary admissions and cancellations but significant uncertainty remained around the effect of the clinic on length of hospital stay, postoperative complications, hospital costs and post-discharge mortality. Supplemental data on a prospective cohort of patients identified preoperative health-related quality of life as a potential unmeasured con-

founder in the evaluation, with high-risk clinic patients reporting lower mean index scores.

Semi-structured interviews with surgeons found that the factors influencing their decision to refer a patient to the high-risk clinic appear to be driven by the aim to manage the uncertainty and risk to the patient regarding surgery and it was seen as a strategy for managing difficult and complex cases. Additionally, the integration of the services provided by the clinic in this study appear to offer additional value in supporting the surgical decision-making process for the surgical team and patient beyond the clinical outcomes, such as managing the patient's expectations regarding care and assistance after discharge from hospital. Further perspectives from patients and other medical professionals collaborating with the clinic should be explored and would provide further insight into the aspects of care that provide additional value.

This evaluation provides a guide to the identification of elective surgical patients who are likely to benefit most from preoperative physician-led medical optimisation and provides clarity on the collaborative care provided by the high-risk clinic and surgical teams in managing complex patients, to inform the assessment of such clinics in Australia. Such models of care involving the management of high-risk patients are increasingly likely as the public hospital system is subjected to increasing demands from an ageing population. This research has demonstrated the need to plan for the robust evaluation of new health service initiatives, which may be facilitated through better co-ordinated planning and evaluation across Australian hospitals.

Manuscripts contributing to this thesis

Published

PHAM C, GIBB C, FIELD J, GRAY J, FITRIDGE R, MARSHALL V, KARNON J. Managing High Risk Surgical Patients: Modifiable Co-morbidities Matter. *Australian and New Zealand Journal of Surgery* 2014; **84**(12): 925-931. DOI: 10.1111/ans.12726

PHAM CT, GIBB CL, FITRIDGE RA, KARNON JD. Effectiveness of Preoperative Medical Consultations by Internal Medicine Physicians: a Systematic Review. *BMJ Open* 2017; **7**(12): e018632. DOI: 10.1136/bmjopen-2017-018632

PHAM C, GIBB C, MITTINTY M, FITRIDGE R, MARSHALL V, KARNON J. A Comparison of Propensity Score Based Approaches to Health Service Evaluation: a Case Study of a Preoperative Physician-led Clinic for High Risk Surgical Patients. *Journal of Evaluation in Clinical Practice* 2016; **22**(5): 761-770. DOI: 10.1111/jep.12537

Submitted

PHAM C, GIBB C, FITRIDGE R, KARNON J, HOON E. Supporting Surgeons in Patient-Centered Complex Decision Making: a Qualitative Analysis of the Impact of a Perioperative Physician Clinic.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Abbreviations

AAA	abdominal aortic aneurysm
APMS	Australian patient management system
AR-DRG	Australian refined diagnostic related groups
ASA	American society of anaesthesiologists
ATT	average treatment of effect on the treated
BMI	body mass index
CBPS	covariate balancing propensity score
CCF	congestive cardiac failure
CEM	coarsened exact matching
CGA	comprehensive geriatric assessment
CHF	congestive heart failure
CI	confidence intervals
COPD	chronic obstructive pulmonary disease
CRC	colorectal cancer
CVA	cerebrovascular accident
EQ-5D-5L	EuroQOL five dimension quality of life questionnaire
HNC	head and neck cancer
HRQOL	health-related quality of life
ICD-10	international classification of diseases, 10th revision
IHD	ischaemic heart disease
ISAAC	integrated South Australian activity collection
JHSRCS	Johns Hopkins surgical risk classification system
LoS	length of hospital stay
MI	myocardial infarction
NHCDC	national hospital cost data collection
NHMRC	National Health and Medical Research Council

OPE	outpatient preoperative evaluation
OR	odds ratio
PAPQ	preoperative assessment patient questionnaire
POHR	Perioperative High Risk Clinic
QALY	quality adjusted life year
RAH	Royal Adelaide Hospital
RCRI	revised cardiac risk index
RCBS	Red Cross blood service
RCT	randomised controlled trial
RR	relative risk
SEIFA	socioeconomic indexes for areas
TKR	total knee replacement
THR	total hip replacement
TQEH	The Queen Elizabeth Hospital
TURP	transurethral resection of the prostate
VLAD	variable life adjusted display

Part I

Introduction

Chapter 1

Background

1.1 Preoperative assessment

Advances in medical technology and public health initiatives have increased life expectancy. However, there are consequences in terms of the health and medical needs of an ageing population, with more than 80% of Australians aged 65 years and over having three or more co-morbidities (Australian Institute of Health and Welfare 2007). The presence of co-morbidities, defined as pre-existing distinct medical conditions in addition to a particular index disease (Feinstein 1970), adds to the complexity of patient care and demand on health care services and systems (Barnett *et al.* 2012, Salive 2013, Cummings *et al.* 2018). In surgical patients, medical co-morbidities and the duration and invasiveness of surgery affect the rate and extent of post-surgical recovery, resulting in higher health service costs and poorer patient outcomes (Imamura and Black 1998, Kuwabara *et al.* 2008, Liu *et al.* 2010). While the duration and invasiveness of surgery is dependent on the procedure required, there are medical co-morbidities that have the potential to be modified with preoperative assessment and management.

Outpatient preoperative assessment clinics have been established to assess and manage these high-risk patients, that is, patients undergoing surgery who are at high risk of morbidity and mortality due to coexistent diseases and/or severity of surgery, and optimise their medical conditions prior to surgery (Girbes 2000).

1.1.1 Standard preoperative assessment

Standard preoperative assessment is provided by an anaesthetist and, depending on the patient's health status, can occur within a few weeks before surgery in an outpatient setting or on the day of surgery in an inpatient setting. The assessment is focused on identifying potential implications for surgery and anaesthesia.

Standard preoperative assessment aims to:

- identify factors that may increase risks associated with surgery
- quantify the risk in order to inform decisions regarding the appropriateness and timing of surgery
- minimise risk through appropriate short- and long-term strategies for managing medical co-morbidities and their associated medication requirements (Nierman and Zakrzewski 1999)

Previous studies evaluating the impact of preoperative assessment clinics for elective surgery patients have reported reduced lengths of stay (Harari *et al.* 2007, Pollard *et al.* 1997, van Klei *et al.* 2002), fewer cancellations after admission for surgery (Pollard *et al.* 1997 1996, van Klei *et al.* 2002), and increased same-day admissions (Pollard *et al.* 1997, van Klei *et al.* 2002). Most of the clinics reported in these studies were anaesthetist-led (Parker *et al.* 2000, Pollard *et al.* 1997 1996, Schiff *et al.* 2010, van Klei *et al.* 2002) and focused on changing the setting of the clinic from inpatient to outpatient.

Schiff *et al.* (2010) conducted a randomised controlled trial of anaesthetist-led preoperative assessment 1-2 days before surgery in an outpatient clinic compared to in the ward after admission. The total consultation time was significantly reduced, resulting in cost savings per patient, but the impact on length of stay and complications were not reported. Two other studies (Pollard *et al.* 1997, van Klei *et al.* 2002) compared the effects of anaesthetist-led preoperative assessment (in an outpatient setting) 3-4 weeks before surgery with inpatient assessment 1-2 days before surgery and reported significant reductions in length of stay, fewer operating room cancellations, and increased same-day admissions for surgery. This suggests that allowing more time to assess and manage patients prior to their scheduled surgical date may have a positive effect on outcomes.

Standard preoperative assessment can also be referred to as preoperative anaes-

thetic assessment, anaesthetic preoperative evaluation or preoperative evaluation.

1.1.2 Alternative preoperative assessment

Consultant physicians, also known as hospitalists or internists, are defined as “physicians whose primary professional focus is the general medical care of hospitalised patients. Their activities include patient care, teaching, research, and leadership related to hospital medicine, such as quality improvement, effective care transitions and the efficient use of resources” (Canadian Society of Hospital Medicine 2015).

Physicians have been proposed as alternative providers of preoperative medical care and offer additional benefits to the integrated care pathway. Anaesthetists have a different focus and expertise by providing safe anaesthesia and specific perioperative management, which complements the role of the physician. The strengths of physician-led care are:

- the physician is able to optimise the patient’s pre-existing medical conditions for short- and long-term health improvement, complementing the skillset of the anaesthetic team, which provides safe anaesthesia and specific perioperative management
- the potential anaesthetic and surgical burden for the patient are recognised, and detailed patient management suggestions can be provided to the operative team
- the patient’s long-term and perioperative needs can be provided to all relevant medical professionals involved with the patient’s care, both in and out of hospital (Pham *et al.* 2014)

Preoperative assessment also has the potential to identify previously undiagnosed co-morbidities. For example, chronic obstructive pulmonary disease (COPD) can be masked in a patient with osteoarthritis whose pain limits their physical activity. An analysis of 200 patients with aortic aneurysms uncovered previously undiagnosed cardiac, respiratory and renal co-morbidity in 19%, 57% and 29% of patients, respectively (Dawson *et al.* 2007).

A US-based randomised clinical trial compared outpatient preoperative evaluation (OPE) by an internist or internal medicine resident, 2-3 weeks prior to elective

surgery (intervention), and preoperative evaluation after admission for elective surgery if necessary (control) (Macpherson and Lofgren 1994). No detail on the criteria used to identify patients for referral to the OPE were provided, only that eligible patients had to be over 50 years of age and living within 100 miles of the study hospital. The only difference between the two arms of the trial was the change in the setting of the clinic from inpatient (control) to outpatient (intervention). The type of care provided as part of the preoperative evaluation did not change, which may explain the significantly shorter preoperative length of stay in the outpatient arm (1.6 days vs. 2.9 days, $p < 0.001$) and non-significant differences in postoperative and total length of stay.

However, a significant reduction in the proportion of patients who were admitted and then had surgery cancelled was observed in the intervention group (5.7% vs. 12.3%, $p = 0.03$), which demonstrates the potential cost-savings in reducing the frequency of inappropriate admissions.

Preoperative assessment provided by a physician can also be referred to as preoperative medical evaluation, preoperative medical consultation or preoperative medical optimisation.

1.1.3 Alternative preoperative assessment in South Australia

Strategies to address medical co-morbidities in surgical patients, in addition to the standard preoperative assessment performed by the anaesthetist, are being implemented in the United States (Bader *et al.* 2009, Macpherson and Lofgren 1994) and United Kingdom (Harari *et al.* 2007). However, like Australia, these specialised clinics are not currently widespread with only a handful of hospitals in each country providing this type of care.

In South Australia, two large metropolitan public hospitals, the Queen Elizabeth Hospital (TQEH) and the Royal Adelaide Hospital (RAH), established high-risk clinics for physician-led preoperative assessment and management in 2006 and 2008, respectively. Both clinics were established by Dr Catherine Gibb, a consultant physician specialising in the care of high-risk surgical patients by optimising existing medical co-morbidities prior to surgery, organising preoperative and postoperative

plans for managing co-morbidities, and providing a second opinion on whether a patient is fit for surgery.

This research was conducted at the RAH clinic, where high-risk patients receive preoperative assessment and management in an outpatient setting (i.e. prior to hospital admission for surgery). The current model of care involves the referral of patients who have been identified by either the surgeon or anaesthetist as having medical co-morbidities that may impact on the outcome of elective surgery, and present possible targets for preoperative optimisation. This is an ad hoc referral pathway that may result in missed opportunities to improve patient outcomes, but also potentially inappropriate referrals, where there is a low likelihood for improvement.

The clinic comprises two part-time physicians, one clinical practice (nurse) consultant and one administration officer. The outpatient clinic is open for four sessions per week (four hours per session) with an average of 16 new patients and eight review patients each week. New patients referred to the clinic require a 45-minute consultation and review patients a 15-minute consultation.

Figure 1.1 illustrates the differences in the timing and delivery of a preoperative medical assessment (physician-led) compared with a preoperative anaesthetic assessment (anaesthetist-led) from the time a patient is placed on the waiting list and until discharge from the hospital after surgery. Patient appointments with the clinic can occur from one week (for urgent cancer surgery) and up to 12 months (for orthopaedic surgery) prior to a hospital admission for surgery. In comparison, the anaesthetic service generally sees patients up to four weeks before surgery.

1.2 Targeted co-morbidities

It is recognised that there are a subset of modifiable co-morbidities that may be targeted in the preoperative phase with a view to optimising control and improving postoperative effects and outcomes. Observational cohort studies have investigated the impact of pre-existing co-morbidities on length of hospital stay, complications, and mortality (Crockett *et al.* 2000, Kuwabara *et al.* 2008, Librero *et al.* 1999, Liu *et al.* 2010, Rochon *et al.* 1996, Roe *et al.* 1998). A retrospective study on 520 patients admitted to hospital with a primary diagnosis of chronic airflow limita-

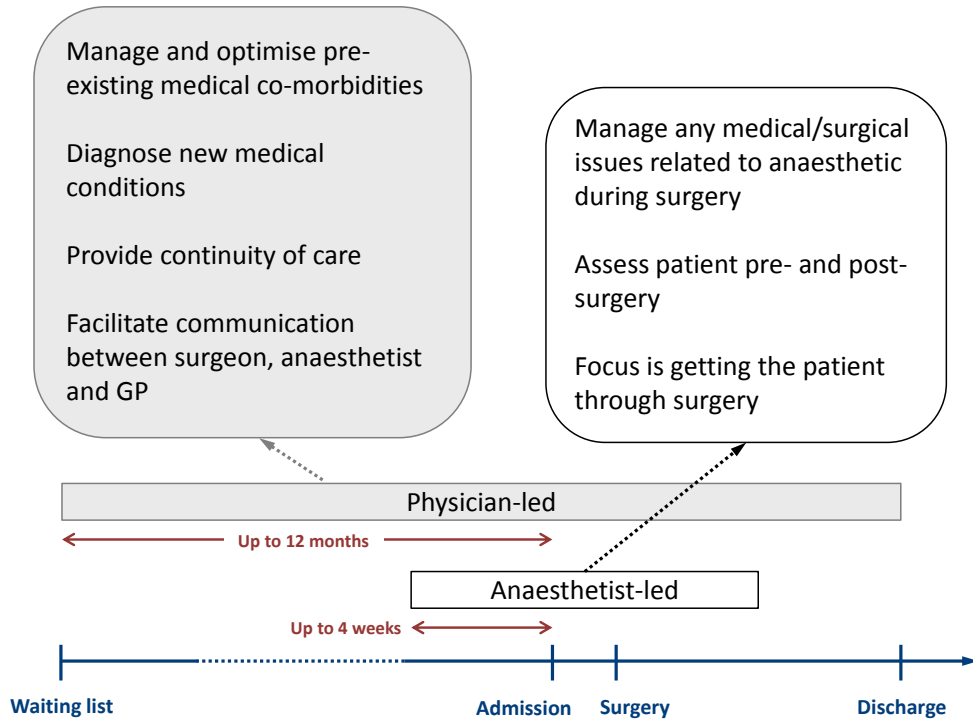


Figure 1.1: The timing of a preoperative medical assessment (shaded in grey) compared with a preoperative anaesthetic assessment.

tion reported significantly longer mean lengths of stay in patients with five or more co-morbidities (Crockett *et al.* 2000). Other retrospective cohort studies also reported increases in mean lengths of stay and mortality with increasing number of co-morbidities and complications in patients admitted for a range of hospitalisations (Kuwabara *et al.* 2008, Librero *et al.* 1999, Liu *et al.* 2010, Rochon *et al.* 1996, Roe *et al.* 1998). Librero *et al.* (1999) also reported increases in risk of readmission at 30 days and 1 year as the number of co-morbidities increased. However, these studies only indicate that there is an association between the number of co-morbidities and postoperative outcomes and readmissions, and none differentiated between co-morbidities that may or may not have the potential to be optimised prior to elective surgery.

The high-risk clinics in South Australia target eight selected co-morbidities that have the potential to be managed and optimised prior to elective surgery. Of the eight co-morbidities that are targeted by the high-risk clinics in South Australia, five

are taken from the Revised Cardiac Risk Index (RCRI) (Lee *et al.* 1999). The RCRI is a widely used and validated tool designed to predict cardiac-related complications after mixed non-cardiac surgery. This index comprises six independent predictors: high-risk type of surgery, ischaemic heart disease, history of congestive heart failure, history of cerebrovascular disease, insulin therapy for diabetes, and renal impairment. The presence of two or more of these predictors indicates an increased risk for perioperative cardiac complications. In order to broaden the scope of this index beyond cardiac-related complications, the high-risk clinic included three other clinically important predictors: respiratory disorders, anaemia and dementia.

Asthma and COPD, along with age, obesity and smoking have been identified as risk factors for postoperative pulmonary complications. Risk reduction strategies in the preoperative assessment clinics have been shown to reduce related mortality and length of stay (Khan and Hussain 2005). Preoperative anaemia is associated with an increased likelihood of red blood cell transfusion and increased risk of morbidity and mortality (National Blood Authority 2012). For elective surgical patients, undiagnosed anaemia is common, particularly in the elderly and those with co-morbidities such as diabetes, congestive heart failure or other inflammatory conditions (Goodnough *et al.* 2003). Recent patient blood management guidelines recommend the evaluation of surgical patients as early as possible to allow management and optimisation of haemoglobin and iron stores (National Blood Authority 2012).

Due to the ageing population in developed countries, dementia represents a significant challenge to health service delivery. In Australia, dementia was reported in 26.4 per 1,000 women aged over 60 and 20.3 per 1,000 men aged over 60 who were admitted to hospital in 2003-04 (Australian Institute of Health and Welfare 2006). With a mean length of hospital stay of 19.6 days for patients with any diagnosis of dementia (e.g. either as the reason for admission to hospital or as a co-morbidity) in 2003-04, co-morbid dementia has an impact on patient recovery and requires additional care and management in hospital (Australian Institute of Health and Welfare 2006, Hannan *et al.* 2001). Guidelines for the management of older persons with delirium recommend strategies for prevention, detection and treatment (Australian and New Zealand Society for Geriatric Medicine 2012).

The theoretical and clinical rationale of the high-risk clinic in South Australia is that the aforementioned co-morbidities, if not already well managed, could present

as possible targets for preoperative assessment and management and potentially improve postoperative outcomes.

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Chapter 2

Research aims

The aims of this research were to evaluate the preoperative assessment and management services provided by the physician-led high-risk clinic, and provide recommendations for improvement using an explanatory sequential mixed methods approach. Specifically, four areas were explored:

1. The effects of specific co-morbidities on postoperative outcomes and the potential for such co-morbidities to be optimised prior to surgery (Chapter 3).
2. A review of the existing evidence on the effectiveness of preoperative assessment and management provided by physicians (Chapter 4).
3. The costs and effects of preoperative assessment and management provided by physicians compared with standard practice in high-risk patients scheduled for elective surgery (Chapters 5 and 6).
4. The practices of surgeons and how their relationships with the high-risk clinic influence the management and treatment of complex patients (Chapter 7).

Key co-morbidities

A cohort of patients was sampled based on the presence of eight key co-morbidities targeted in the high-risk clinic: ischaemic heart disease, congestive heart failure, stroke, diabetes mellitus, renal impairment, anaemia, asthma or COPD, and dementia (including Alzheimer's disease).

Selected surgical procedures

To limit the heterogeneity of primary diagnoses and associated surgical procedures, the selected cohorts were restricted to: transurethral resection of the prostate, total joint replacement (hip and knee), abdominal aortic aneurysms, head and neck cancer, and colorectal cancer. These are the five most common primary diagnoses in high-risk clinic patients, and account for approximately two-thirds of all high-risk clinic referrals.

Key outcomes

The key outcomes for this evaluation were: costs, length of hospital stay, postoperative complications, quality of life, and 12-month mortality.

Significance

To date, there have been no published studies evaluating the costs and outcomes of physician-led preoperative assessment for patients with modifiable medical comorbidities prior to elective surgery. More effective preoperative management of these patients will have a significant effect on health service costs, the capacity of the hospital system in particular, and the health service in general. The importance of these improvements will increase over time as the public hospital system is subjected to increasing demands from an ageing population.

The development of a systematic and evidence-based process to guide the referral of elective surgical patients for preoperative physician-led medical optimisation will enable health care professionals to provide better, more efficient care with the potential for reduced complications, morbidity, and mortality after surgery.

Five distinct research projects were conducted, and are presented in this thesis as follows:

Part II covers two projects that focus on the **clinical rationale** and **systematic literature review**. Chapter 3 presents the data to support the rationale for targeting specific co-morbidities that have the potential to be managed and optimised prior to elective surgery. Multiple regression analyses using retrospective

data were conducted to estimate the effect of potentially modifiable co-morbidities on postoperative outcomes and to identify co-morbidities that could be targeted for preoperative assessment and management. Chapter 4 provides a full systematic review of the existing evidence on the effectiveness of preoperative assessment and management provided by physicians. This review summarises all the available evidence, the various models of care provided by physicians, and fills a gap in the literature.

Part III covers three projects that form the **evaluation** component. Chapter 5 describes the evaluation, using retrospective data, of the cost and effects of an outpatient clinic providing physician-led preoperative assessment and management in Adelaide, South Australia. A supplementary prospective study was also conducted to explore quality of life, as measured by the EQ-5D, as a potentially unmeasured confounding factor in the evaluation. Additional detail and discussion on the methodological challenges with analysing a complex patient population are also provided in this chapter. Chapter 6 details the additional follow-up data collected as an extension of the supplementary prospective study in Chapter 5 to explore the potential effects of the high-risk clinic on quality of life. Chapter 7 describes the explanatory study undertaken to assess the validity of findings from the retrospective evaluation. Figure 2.1 provides a visual representation of the explanatory sequential mixed methods approach for this evaluation component. The visual model illustrates the sequence of research activities and specifies the data collection and analysis procedures for each stage.

Part IV concludes this thesis by summarising the main findings and providing recommendations for future research.

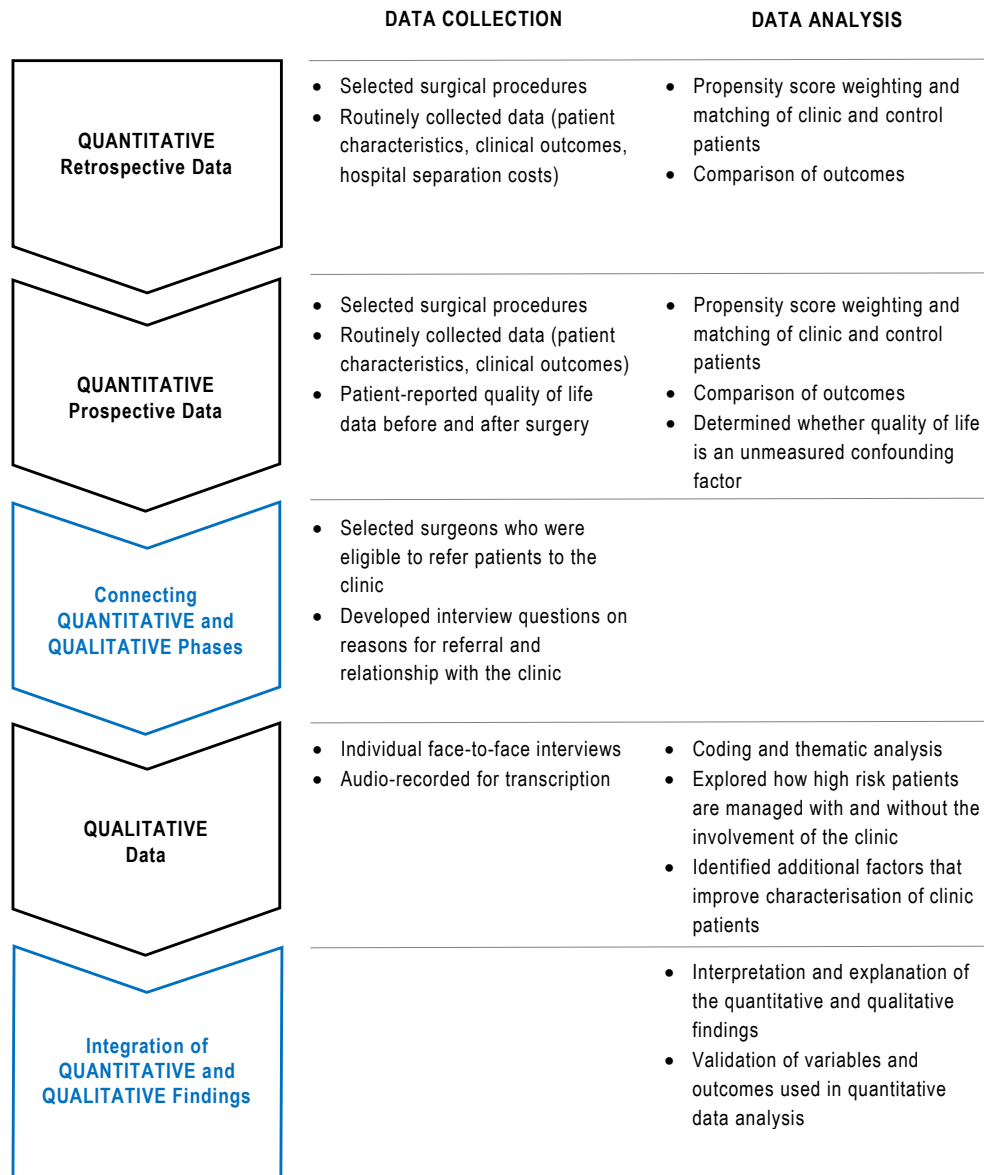


Figure 2.1: Visual model of the explanatory sequential mixed methods approach for the evaluation component.

Part II

Rationale and review

Chapter 3

Modifiable co-morbidities matter

3.1 Preface

This chapter presents an analysis of a retrospective dataset to support the theoretical and clinical rationale of the high-risk clinic, with findings published in the *Australian and New Zealand Journal of Surgery*. The article identifies a set of co-morbidities that can potentially be modified within the preoperative period, and should be targeted for physician-led medical optimisation based on their estimated impact on length of stay, postoperative complications and in-hospital mortality.

The set of potentially modifiable co-morbidities include ischaemic heart disease, congestive heart failure, stroke, diabetes mellitus, renal impairment, anaemia, dementia including Alzheimer's disease, and asthma or chronic obstructive pulmonary disease, which are currently targeted by the high-risk clinic physicians.

Findings from this analysis also identified an additional potentially modifiable co-morbidity, primary hypertension (as opposed to hypertension secondary to other disorders), which the high-risk clinic physicians now target for medical optimisation. This is the first study to report the effects of specific co-morbidities on postoperative outcomes and explores the potential for such co-morbidities to be optimised prior to surgery.

3.2 Statement of authorship

Title of paper: Managing High-Risk Surgical Patients: Modifiable Co-morbidities Matter

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Name of principal author (Candidate): Clarabelle Pham

Contribution to the paper: Conception and design, acquisition of data, analysis and interpretation of data, drafted the article and critical revisions, and acted as corresponding author.

Overall percentage: 85%

This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.

Signed: ..

.....

Date: 30/01/2019

Co-author contributions

By signing the statement of authorship, each author certifies that:

- i. the candidate's stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of co-author: Catherine Gibb

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

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Contribution to the paper: Conception and design, analysis and interpretation of data, and revised it critically for important intellectual content.

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Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important intellectual content.

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Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

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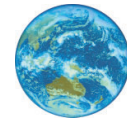
Contribution to the paper: Conception and design, acquisition of data, interpretation of data, and revised it critically for important intellectual content.

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3.3 Publication

PERIOPERATIVE CARE



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Managing high-risk surgical patients: modifiable co-morbidities matter

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Key words

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Abstract

Background: There are a subset of potentially modifiable co-morbidities that may be targeted in the preoperative phase with a view to optimizing control and improving post-operative outcomes. This study aims to estimate the effect of potentially modifiable co-morbidities on post-operative outcomes and to identify potential targets for preoperative management.

Methods: Retrospective data on hospital separations in South Australia were analyzed using multiple regression to estimate the association between nine potentially modifiable co-morbidities and length of stay, post-operative complications and in-hospital mortality.

Results: After adjusting for primary diagnosis, age, gender and other potential confounders, significant increases in length of stay and complications were recorded for eight and six of the nine modifiable co-morbidities, respectively. As examples, previous heart failure was associated with a 54% increase in length of stay and an odds ratio of 1.75 for complications. Asthma and chronic obstructive pulmonary disease was associated with a 38% increase in length of stay and an odds ratio of 1.64 for complications.

Conclusions: A set of potentially modifiable co-morbidities is associated with a range of poorer post-operative outcomes, relative to patients without those co-morbidities. There is a clinical rationale that outcomes will be worse in the subset of patients for whom such co-morbidities are poorly controlled, and that timely intervention to improve control in the period prior to surgery will improve post-operative outcomes. Further research is required on post-operative outcomes for patients with and without controlled co-morbidities and on the effects of timely intervention to improve control prior to surgery.

Introduction

Medical co-morbidities in surgical patients affect the rate and extent of post-surgical recovery, resulting in higher health service costs and poorer patient outcomes.¹ Observational cohort studies have investigated the impact of co-morbidities on length of hospital stay, complications and mortality.²⁻⁷ A retrospective study on 520 patients admitted to hospital with a primary diagnosis of chronic airflow limitation reported significantly longer mean lengths of stay (LoS) in patients with five or more co-morbidities.² Other retrospective cohort studies also reported increases in mean LoS and mortality

with increasing number of co-morbidities and complications in patients admitted for a range of hospitalizations.³⁻⁷

It is recognized that there are a subset of potentially modifiable medical co-morbidities that may be targeted in the preoperative phase with a view to optimizing control and improving post-operative outcomes. However, these studies only indicate that there is an association between the number of co-morbidities and post-operative outcomes and readmissions, and none differentiate between co-morbidities that may and may not have the potential to be optimized prior to elective surgery. To inform potential improvements with respect to the management of surgical patients, it may be

more appropriate to examine the post-operative effects of medically modifiable co-morbidities (i.e. those that have the potential to be managed and optimized prior to elective surgery).

Strategies to address medical co-morbidities in surgical patients, in addition to the standard preoperative assessment performed by the anaesthetist (anaesthesiologist in the United States), are being implemented in the United States⁸ and United Kingdom.⁹ However, like Australia, these specialized clinics are not widespread with only a handful of hospitals in each country providing this type of care.

The aim of this study was to estimate the effect of potentially modifiable co-morbidities on post-operative outcomes and to identify potential targets for preoperative management. Here, we undertake statistical modelling of a large administrative dataset to estimate the burden of potentially modifiable co-morbidities on post-operative outcomes, review options for intervention to improve control of the defined co-morbidities and discuss the impact of our findings for future research in this area.

Methods

Data sources

Retrospective data from the Integrated South Australian Activity Collection (ISAAC), which contains information on every hospital separation (public and private) in South Australia, were used for the analysis. The data extracted for each record had been manually coded from patients' medical records using a pro forma common across all contributing hospitals. Ongoing audits of the coded data were undertaken to ensure accuracy and consistency. Each record contained information on patient age, gender, type of residence (e.g. nursing home), principal diagnoses, additional diagnoses with associated time of onset flags (to identify diagnoses that were present on admission), procedures undertaken, as well as a range of variables relating to the nature of the separation (e.g. elective, emergency, transfer from another hospital). Postcode level socio-economic indicators were merged into the ISAAC dataset.

All separations from 1 July 2008 to 30 June 2010 were included in a master dataset. Patients aged over 18 years, undergoing at least one elective surgical separation and who were admitted between 1 July 2009 and 30 June 2010, were selected for the main analysis. This subset provided a minimum 12-month pre-admission period over which we could identify pre-existing co-morbidities from previous separations. If multiple eligible separations occurred, the latest surgical separation was selected as the index event. Patients were excluded if they did not have surgery, the index event was cardiac or obstetric related or if the Australian Refined Diagnostic Related Group (AR-DRG) had a LoS in the 90th percentile of 1, as they were deemed to be low-risk surgical procedures, such as admissions for coronary angiography or renal dialysis.

Ethics approval was granted by the South Australian Department of Health Human Research Ethics Committee (HREC Protocol No. 490/01/2015).

Coding of co-morbidities

The following eight potentially modifiable co-morbidities were selected as the core set of conditions, based upon the protocols of

existing physician-led preoperative clinics in South Australia: anaemia, diabetes mellitus, congestive heart failure (CHF), stroke, renal impairment, ischaemic heart disease (IHD), dementia (including Alzheimer's disease) and respiratory disease (asthma or chronic obstructive pulmonary disease (COPD)). For each index separation, binary variables describing the presence or absence of these co-morbidities were coded. Additional co-morbidities were also coded (see Supporting Information Appendix S1 for a complete listing of codes for co-morbidities) to assess the impact of other potentially modifiable co-morbidities and to include as potential confounders (non-targeted co-morbidities).

Coding of co-morbidities was informed by recorded International Classification of Diseases, 10th Revision (ICD-10) principal and additional diagnostic codes, using an adaptation of the coding process used to define clinical performance indicators for the Variable Life Adjusted Display (VLAD) system.¹⁰ The VLAD coding process was amended so that the diagnostic codes for the targeted co-morbidities only included the conditions that were deemed potentially modifiable. For example, as a potentially modifiable co-morbidity, anaemia only included codes for nutritional anaemias and not haemolytic or aplastic anaemias. The ICD-10 codes for each of the targeted co-morbidities are listed in Supporting Information Appendix S2. Diagnoses listed in separations in the 12 months prior to the index event, as well as additional diagnoses at the time of the index surgical event, were used to identify relevant co-morbidities.

Outcome measures

Measures of outcome were LoS, complications and in-hospital mortality. Unadjusted LoS was measured in hours, whereas binary variables were created to represent the occurrence of post-operative complications and in-hospital mortality.

To determine the potential differences in LoS for patients with and without potentially modifiable co-morbidities, expected LoS was estimated as the mean LoS for patients with no potentially modifiable co-morbidities for each 3-character AR-DRG. The 3-character code was used as the 4-character codes differentiate between patients with and without co-morbidities and/or complications.

Complications were identified through the onset flag variable. Patients were identified as having a post-operative complication if the onset of a condition occurred during the episode of admitted patient care and was not present on admission. Complications were also stratified using ICD-10 complication codes by category: gastrointestinal, wounds, infections, renal and endocrine, cardiovascular disorders, pulmonary and neurological disorders, to provide more detail on the types of complications reported for each co-morbidity.¹¹ The complication codes used for each category are listed in Supporting Information Appendix S3.

Statistical analysis

Descriptive and regression-based analyses were undertaken on each of the defined measures of post-operative outcome. The descriptive analyses present the unadjusted mean LoS and relative risk (RR) ratios (with 95% confidence intervals) for LoS, complications and in-hospital mortality between patients with different numbers of potentially modifiable co-morbidities (1 or 2 or more) and patients

with no potentially modifiable co-morbidities, as well as between patients with each of the defined potentially modifiable co-morbidities.

A multiple regression model was fitted using ordinary least squares regression with log-transformed LoS as the dependent variable.¹² As well as binary variables for each potentially modifiable co-morbidity, other model covariates included age, gender, AR-DRG group (75 groups fitted as a series of 74 dummy variables) and non-targeted co-morbidities. Age was fitted as a restricted cubic spline with four knots to capture non-linearity. This model for LoS was used to estimate the number of bed-days saved per patient and across the patient base over the 2 years. One co-morbidity was eliminated at a time from the model, using 10 000 bootstrapped samples each time. The same method was used to estimate bed-days saved for those with at least one potentially modifiable co-morbidity, assuming that the effects of all potentially modifiable co-morbidities were eliminated with treatment.

Logistic regression models were fitted to complications and in-hospital mortality using the same covariates for the LoS regression. Model fit was assessed using the *R*² statistic and residual plots.

Analyses were undertaken using Stata, release 12.0 (StataCorp LP, College Station, TX, USA) and R statistical software (<http://www.r-project.org>, Vienna, Austria). *P*-values less than 0.05 were considered statistically significant.

Results

A total of 46 925 elective surgical patients across 75 AR-DRGs were included in the analysis. Overall mean age was 55.5 ± 16.6 years; 56% were female. Of the 75 AR-DRGs, the main major diagnostic categories were diseases and disorders of the musculoskeletal system and connective tissue (27%), digestive system (18%) and female reproductive system (10%).

In addition to the eight originally specified potentially modifiable co-morbidities, initial LoS analyses identified primary hypertension (as opposed to hypertension secondary to other disorders) as another potentially modifiable co-morbidity. The following results include primary hypertension as a ninth potentially modifiable co-morbidity. Three non-targeted co-morbidities (malignancy, circulatory system disorders (excluding IHD and CHF), and intestinal disorders) covered the highest proportion of patients and were included in the regression model as potential confounders.

Sixteen per cent of patients had at least one potentially modifiable co-morbidity. Table 1 describes the unadjusted RR ratios for the three outcome measures by number and type of potentially modifiable co-morbidities and non-targeted co-morbidities. There was a positive association between age and number of co-morbidities. Compared to the absence of any potentially modifiable co-morbidities, patients with one potentially modifiable co-morbidity had a significantly increased LoS (mean 1.1 days), likelihood of post-operative complications (RR 1.5) and in-hospital mortality (RR 7.3). These values increased exponentially for patients with more than one potentially modifiable co-morbidity (4.2 extra inpatient days, and RRs of 3.3 and 32.1 for complications and in-hospital mortality, respectively).

All of the potentially modifiable co-morbidities were associated with significantly increased LoS, and other than renal impairment,

Table 1 Patient demographics and unadjusted estimates for length of stay, complications and in-hospital mortality by co-morbidity

	<i>n</i> (%)	Age	Female (%)	LoS (days)	LoS (relative risk)	Complications (relative risk)	In-hospital mortality (relative risk)
Number of potentially modifiable co-morbidities†							
0	39 393 (84.0)	53.9 (16.5)	56.7	2.8 (2.7–2.8)	Reference	Reference	Reference
1	5922 (12.6)	62.5 (14.9)	52.3	3.9 (3.7–4.0)	1.3 (1.2–1.3)	1.5 (1.4–1.7)	7.3 (4.5–11.8)
2+	1610 (3.4)	68.0 (13.0)	48.4	7.0 (6.5–7.4)	2.2 (2.0–2.5)	3.3 (2.9–3.6)	32.1 (20.2–51.2)
Type of potentially modifiable co-morbidity‡							
Ischaemic heart disease	407 (0.9)	69.9 (11.0)	31.7	6.3 (5.4–7.2)	2.1 (1.7–2.4)	2.4 (2.0–2.8)	22.9 (13.9–37.6)
Congestive heart failure	113 (0.2)	75.7 (10.7)	40.7	10.9 (8.2–13.5)	3.7 (2.5–4.9)	3.2 (2.5–4.0)	37.7 (19.5–72.6)
Stroke	32 (0.07)	67.3 (17.4)	43.8	7.0 (4.1–9.9)	1.3 (0.8–1.7)	1.0 (0.4–2.5)	13.7 (2.0–95.2)
Diabetes mellitus	1381 (3.0)	64.1 (13.2)	50.5	6.0 (5.6–6.4)	1.9 (1.6–2.2)	2.2 (2.0–2.4)	8.0 (5.0–12.8)
Renal impairment	4139 (8.8)	62.7 (14.9)	48.9	3.5 (3.3–3.7)	1.3 (1.2–1.4)	1.1 (1.0–1.2)	3.3 (2.1–5.1)
Anaemia	1177 (2.5)	65.6 (15.3)	61.9	6.9 (6.4–7.4)	1.9 (1.7–2.1)	2.1 (1.9–2.3)	14.3 (9.4–21.8)
Dementia incl. Alzheimer's	166 (0.4)	81.9 (18.1)	53.0	8.4 (6.9–9.8)	2.9 (2.1–3.8)	2.5 (2.0–3.2)	13.7 (5.7–33.1)
Asthma/COPD	496 (1.1)	63.9 (15.4)	54.4	5.6 (4.9–6.2)	2.1 (1.7–2.4)	1.9 (1.6–2.2)	6.5 (3.0–13.9)
Primary hypertension	1802 (3.8)	66.7 (12.8)	49.7	6.4 (6.0–6.7)	1.9 (1.7–2.1)	2.5 (2.3–2.7)	7.5 (4.8–11.8)
Selected non-targeted co-morbidities							
Malignancy	6513 (13.9)	65.7 (13.6)	49.8	4.6 (4.4–4.8)	1.4 (1.3–1.5)	1.6 (1.5–1.7)	8.4 (5.7–12.2)
Circulatory system disorders§	3684 (7.9)	60.9 (15.8)	46.5	4.2 (4.0–4.4)	1.5 (1.4–1.6)	1.5 (1.4–1.6)	8.1 (5.5–11.8)
Intestinal disorders	2220 (4.7)	61.4 (14.9)	58.8	4.8 (4.5–5.1)	1.4 (1.2–1.5)	1.6 (1.4–1.7)	4.0 (2.4–6.7)

†Relative risks are relative to reference group (i.e. relative to having no potentially modifiable co-morbidities). ‡Relative risks are relative to patients without the specified co-morbidity. §Excluding ischaemic heart disease and congestive heart failure. Numbers presented for age are means with standard deviations in parentheses. LoS are means with 95% confidence intervals in parentheses, and 95% confidence intervals in parentheses for all relative risks. COPD, chronic obstructive pulmonary disease.

Table 2 Unadjusted relative risk (95% confidence interval) of complication categories by co-morbidity

	Gastrointestinal	Wounds	Infections	Renal and endocrine	Cardiovascular	Pulmonary	Neurological
Number of potentially modifiable co-morbidities†							
0	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1	1.67 (1.44–1.93)	1.38 (1.11–1.72)	1.56 (1.42–1.72)	2.14 (1.87–2.45)	1.69 (1.52–1.88)	1.45 (1.23–1.71)	1.73 (1.16–2.58)
2+	3.23 (2.75–3.81)	2.96 (2.28–3.84)	2.26 (2.02–2.51)	3.93 (3.37–4.58)	2.95 (2.62–3.32)	2.43 (2.03–2.92)	4.34 (2.87–6.55)
Type of potentially modifiable co-morbidities‡							
Ischaemic heart disease	2.22 (1.63–3.00)	2.81 (1.80–4.39)	1.69 (1.40–2.04)	1.92 (1.45–2.54)	3.25 (2.80–3.78)	2.30 (1.75–3.04)	4.39 (2.52–7.58)
Congestive heart failure	2.96 (1.94–4.52)	4.95 (2.77–8.79)	2.05 (1.61–2.62)	3.48 (2.67–4.53)	3.20 (2.49–4.12)	2.85 (1.92–4.21)	3.63 (1.19–10.92)
Stroke	2.17 (0.74–6.37)	2.30 (0.38–13.98)	1.45 (0.63–3.33)	1.31 (0.28–6.15)	1.02 (0.21–4.90)	—	—
Diabetes mellitus	2.56 (2.18–3.00)	2.13 (1.59–2.83)	1.80 (1.62–2.00)	2.43 (2.10–2.82)	2.00 (1.76–2.27)	2.20 (1.85–2.60)	1.97 (1.15–3.32)
Renal impairment	1.23 (1.06–1.44)	1.06 (0.82–1.35)	1.26 (1.15–1.38)	1.71 (1.52–1.91)	1.11 (0.98–1.25)	0.89 (0.70–1.12)	1.13 (0.72–1.74)
Anaemia	2.51 (2.11–2.97)	2.39 (1.79–3.19)	1.88 (1.68–2.09)	2.27 (1.93–2.66)	2.12 (1.86–2.41)	1.47 (1.12–1.91)	2.23 (1.30–3.74)
Dementia incl. Alzheimer's	2.12 (1.30–3.45)	3.32 (1.77–6.17)	2.01 (1.62–2.49)	2.14 (1.48–3.09)	2.14 (1.55–2.93)	2.13 (0.34–2.90)	7.93 (4.45–14.00)
Asthma/COPD	1.46 (0.98–2.17)	1.85 (1.09–3.12)	1.62 (1.35–1.94)	1.98 (1.54–2.53)	1.60 (1.24–2.06)	3.15 (2.59–3.84)	1.71 (0.63–4.53)
Primary hypertension	2.62 (2.28–3.02)	2.40 (1.90–3.02)	1.78 (1.61–1.96)	2.74 (2.40–3.11)	2.61 (2.37–2.88)	1.99 (1.68–2.34)	3.49 (2.47–4.85)
Selected non-targeted co-morbidities							
Malignancy	2.24 (2.06–2.44)	2.09 (1.84–2.36)	1.83 (1.72–1.95)	1.62 (1.48–1.78)	1.43 (1.32–1.54)	1.77 (1.60–1.96)	1.65 (1.26–2.13)
Circulatory system disorders§	1.59 (1.39–1.82)	1.67 (1.37–2.03)	1.35 (1.23–1.48)	1.64 (1.45–1.85)	1.76 (1.61–1.93)	1.54 (1.33–1.78)	2.41 (1.79–3.18)
Intestinal disorders	1.86 (1.59–2.17)	1.96 (1.54–2.47)	1.50 (1.36–1.67)	1.63 (1.40–1.89)	1.42 (1.24–1.63)	1.70 (1.43–2.01)	1.13 (0.60–2.06)

†Relative risks are relative to reference group (i.e. relative to having no potentially modifiable co-morbidities); ‡Relative risks are relative to patients without the specified co-morbidity. §Excluding ischaemic heart disease and congestive heart failure. COPD, chronic obstructive pulmonary disease.

the minimum difference in LoS between patients with and without each co-morbidity was over 4 days. All but co-morbid stroke had a significantly increased RR of complications, although the effect of renal impairment was marginal. The effect on in-hospital mortality was larger, with even renal impairment having a mean RR of 3.3.

The three selected non-targeted co-morbidities were all associated with significantly increased LoS, risk of complications and risk of in-hospital mortality (Table 1).

With regard to the types of post-operative complications (Table 2), patients with more than one potentially modifiable co-morbidity had significantly increased risk for all complication categories, particularly for renal and endocrine, and neurological complications. For each of the potentially modifiable co-morbidities, CHF had consistently higher risks of complications in all categories, IHD had very high risks for cardiovascular and neurological complications, and dementia including Alzheimer's disease increased the risks of neurological, wounds and infection complications (Table 2). The three selected non-targeted co-morbidities also had increased risk across all complication categories, with higher risks of gastrointestinal and wound complications for malignancy and intestinal disorders, and neurological complications for circulatory system disorders (Table 2).

Table 3 presents the outputs of the multivariate regression models. The coefficients for each binary co-morbidity parameter can be interpreted as the ratio of the outcome measure between patients with a co-morbidity and those without that co-morbidity, but who may have other

co-morbidities. The models with coefficients for each potentially modifiable co-morbidity and additional covariates are listed in Supporting Information Appendix S4. After adjusting for age, gender, AR-DRG group and major non-targeted co-morbidities, eight of the nine potentially modifiable co-morbidities had a significantly increased LoS. The difference in LoS was greatest between patients with and without dementia, CHF and asthma/COPD. Patients with dementia are likely to require 77% more bed-days than patients without dementia, and those with CHF require 54% more bed-days than those without. By comparison, patients with hypertension or anaemia require only 26% more bed-days than those without these co-morbidities. The ratio for stroke was 0.86, although there remains significant uncertainty around this result and a positive effect cannot be ruled out. CHF and asthma/COPD had the greatest effect on the probability of a complication, whereas IHD significantly increased the likelihood of having a complication or death in hospital. Anaemia was not significantly associated with an increased likelihood of a complication but had a significantly increased likelihood of death in hospital.

Table 4 shows the number of bed-days that could be saved per patient and over the patient group if the LoS effects for each potentially modifiable co-morbidity could be removed. For individual co-morbidities, the saving could be up to 2.6 days per patient. Across all patients with at least one potentially modifiable co-morbidity, the estimated saving is over 6000 bed-days over the 2-year period. Across all patients with at least one potentially modifiable co-morbidity, the

Table 3 Adjusted estimates comparing those with and without the co-morbidity for length of stay, complications and in-hospital mortality

Potentially modifiable co-morbidity	LoS (ratio†)	Complications (OR‡)	In-hospital mortality (OR‡)
Ischaemic heart disease	1.16 (1.06–1.26)	1.48 (1.14–1.91)	5.50 (2.83–10.67)
Congestive heart failure	1.54 (1.31–1.80)	1.75 (1.11–2.76)	1.95 (0.76–4.99)
Stroke	0.86 (0.64–1.15)	0.35 (0.11–1.05)	1.78 (0.18–17.43)
Diabetes	1.22 (1.16–1.28)	1.35 (1.15–1.59)	2.12 (1.12–3.99)
Renal impairment	1.10 (1.06–1.14)	1.26 (1.11–1.43)	1.50 (0.86–2.64)
Anaemia	1.27 (1.20–1.33)	1.07 (0.92–1.26)	2.86 (1.72–4.76)
Dementia incl. Alzheimer's	1.77 (1.55–2.01)	1.41 (0.97–2.05)	1.79 (0.61–5.27)
Asthma/COPD	1.38 (1.28–1.49)	1.64 (1.29–2.09)	1.70 (0.68–4.24)
Hypertension	1.26 (1.20–1.32)	1.37 (1.19–1.59)	0.75 (0.40–1.39)

†Ratio of the geometric mean LoS for those with the co-morbidity to the geometric mean LoS for those without. ‡Odds of a complication or death in the group with the co-morbidity relative to those without. 95% confidence intervals in parentheses. COPD, chronic obstructive pulmonary disease; OR, odds ratio.

Table 4 Bed-days saved by removing the effect of modifiable co-morbidities, per patient and for whole patient group

Potentially modifiable co-morbidity	Per patient	Whole patient group
Ischaemic heart disease	0.62 (0.56–0.67)	250 (228–274)
Congestive heart failure	2.42 (2.05–2.79)	274 (232–316)
Stroke	–0.75 (–1.00–0.56)	–24 (–32–18)
Diabetes	0.81 (0.77–0.84)	1112 (1066–1159)
Renal impairment	0.22 (0.21–0.23)	909 (882–936)
Anaemia	1.06 (1.01–1.11)	1248 (1191–1306)
Dementia incl. Alzheimer's	2.62 (2.31–2.93)	434 (384–486)
Asthma/COPD	1.11 (1.02–1.20)	548 (504–595)
Hypertension	1.00 (0.97–1.04)	1814 (1750–1877)
≥1 potentially modifiable co-morbidity	0.81 (0.78–0.84)	6119 (5898–6348)

Numbers reported as mean bed-days saved per patient with 95% confidence intervals in parentheses; total bed-days saved for the whole patient group with 95% confidence intervals in parentheses. COPD, chronic obstructive pulmonary disease.

number needed to optimize (to remove the effects of the co-morbidities) to save an additional bed day was 1.23.

Discussion

To date, no published studies have reported the specific effects of potentially modifiable co-morbidities on post-operative length of hospital stay and outcomes. The findings from this analysis suggest that a set of potentially modifiable co-morbidities are associated with poorer post-operative outcomes, relative to patients without those co-morbidities. This supports the theory that certain co-morbidities, if not already well managed, could present as possible targets for optimization prior to surgery and potentially improve some post-operative outcomes.

The Revised Cardiac Risk Index¹³ is a widely used validated tool designed to predict cardiac-related complications after mixed non-cardiac surgery. Six independent predictors comprise this index: high-risk type of surgery, IHD, history of CHF, history of cerebrovascular disease, insulin therapy for diabetes and renal impairment. The presence of two or more of these predictors indicates an increased risk for perioperative cardiac complications. To expand beyond cardiac-related complications, other clinically important predictors should be included. Findings from this analysis support the inclusion of additional risk factors, such as age, respiratory disorders, anaemia and dementia.

Asthma and COPD have been identified as risk factors for post-operative pulmonary complications, and risk reduction strategies in preoperative assessment clinics have been shown to reduce related mortality and LoS.¹⁴ Preoperative anaemia is associated with an increased likelihood of red blood cell transfusion and increased risk of morbidity and mortality.¹⁵ For elective surgical patients, undiagnosed anaemia is common, particularly in the elderly and those with co-morbidities such as diabetes, CHF or inflammatory conditions.¹⁶ Recent patient blood management guidelines recommend the evaluation of surgical patients as early as possible to allow management and optimization of haemoglobin and iron stores.¹⁵

Due to the ageing population in developed countries, dementia represents a significant challenge to health service delivery. With a mean LoS in 2003–2004 of 19.6 days for patients with any diagnosis of dementia (e.g. either as the reason for admission to hospital or as a co-morbidity), co-morbid dementia has an impact on patient recovery and requires additional care and management in hospital.^{17,18} Guidelines for the management of older persons with delirium recommend strategies for prevention, detection and treatment.¹⁹ Table 5 summarizes the range of strategies used by the physician-led clinics in South Australia for the medical management of patients with potentially modifiable co-morbidities.

The strengths of physician-led care, as a complement to standard anaesthetist-led care, include:

- The physician's skillset in optimizing the patient's pre-existing medical conditions for short- and long-term health improvement is, in this setting, complementary to the skillset of the anaesthetic team who provide safe anaesthesia and specific perioperative management.
- The recognition of the potential anaesthetic and surgical burden for the patient, and provision of detailed patient management suggestions to the operative team.
- Ensuring communication about the patient's long-term and perioperative needs to all relevant medical professionals involved with the patient's care, both in and out of hospital.

Preoperative assessment also has the potential to identify previously undiagnosed co-morbidities, for example, COPD can be masked by the presence of surgical co-morbidities (e.g. a person who cannot exercise to the point of symptoms because of limitation by pain from osteoarthritis). An analysis of 200 patients with aortic aneurysms uncovered previously undiagnosed cardiac (19%), respiratory (57%) and renal co-morbidities (29%).²⁷

Table 5 Preoperative interventions for the nine potentially modifiable co-morbidities

Co-morbidity	Preoperative medical intervention
Anaemia	Diagnose if previously undetected Investigate cause of anaemia Arrange appropriate iron/B12 or folate supplementation as required Consider for erythropoietin in associated renal failure [Patient Blood Management Guidelines ¹⁵]
Diabetes mellitus	Diagnose severity of diabetes Screen for suboptimal diabetic control Suggest post-operative inpatient guideline management Optimize medication prior to surgery Arrange lifestyle intervention [Perioperative Diabetes Management Guidelines ²⁰]
Congestive heart failure	Diagnose severity of symptoms and investigate if appropriate Plan appropriate post-operative fluid management Optimize medication for long-term outcome [Guidelines for the Prevention, Detection and Management of Chronic Heart Failure in Australia ²¹]
Stroke	Optimize antiplatelet therapy Optimize use of guideline therapy, e.g. ACE inhibition Consider lifestyle intervention if required [Clinical Guidelines for Stroke Management ²²]
Renal impairment	Diagnose if previously undetected Plan management of perioperative medication Consider treatment of associated anaemia Plan dialysis requirements if dialysis dependent [Chronic Kidney Disease Management in General Practice ²³]
Ischaemic heart disease	Diagnose severity of any ischaemic symptoms and investigate if appropriate Optimize medication for prevention of perioperative ischaemia [Reducing Risk in Heart Disease ²⁴]
Dementia incl. Alzheimer's	Determine the presence or extent of any cognitive impairment Plan nursing requirements for post-operative delirium Implement guidelines for delirium management [Delirium in Older People ¹⁹]
Asthma/chronic obstructive pulmonary disease	Diagnose if previously undetected Investigate severity of disease and associated respiratory failure Optimize inhaled and oral therapy for prevention and treatment Recommend post-op management plans [COPD-X Guidelines ²⁵]
Primary hypertension	Diagnose if previously undetected Optimize medication prior to surgery [Guide to Management of Hypertension ²⁶]

Limitations

The prevalence of co-morbidities in the administrative dataset that informed the reported analysis is likely to be under-estimated as such data are generated by coders, who can only extract information that is recorded in patient notes. Under-recording is likely to be more significant for co-morbidities such as previous stroke, anaemia and dementia. However, this limitation is likely to result in conservative

estimates of effect due to the misclassification of patients with potentially modifiable co-morbidities. This limitation may explain the reported non-significant effect of co-morbid stroke.

Furthermore, the available data were not granular enough to determine whether the potentially modifiable co-morbidities were well managed prior to surgery and did not require optimization. Patients with well-controlled co-morbidities would have limited scope for improved post-operative outcomes and would therefore not be the target for preoperative management. Thus, the reported effects of potentially modifiable co-morbidities are combined effects across patients with and without optimal control of those co-morbidities. It is reasonable to assume that outcomes will be worse in patients with poorly managed co-morbidities, and so the reported effects for this sub-group are likely to be underestimated.

This underestimate of effect is countered by the likelihood that optimally controlled patients with potentially modifiable co-morbidities may still experience poorer outcomes than patients without co-morbidities, and that optimal control may not be achieved prior to surgery for all patients with co-morbidities (either due to non-compliance of the patient or the need for surgery sooner rather than later). The scarcity of data describing the prevalence of surgical patients with inadequately controlled potentially modifiable co-morbidities, combined with the evidence reported in this analysis regarding the general effects of such co-morbidities, emphasizes the need for further research in this high-volume area of health service activity.

The current study describes the rationale for preoperative intervention, as well as summarizing the preoperative intervention strategies that may be used to reduce such effects. However, in a resource constrained health care system, it is necessary to provide evidence on costs and benefits to support funding decisions for new services. Moreover, the decision to fund preoperative optimization is not a single, binary decision to fund or not to fund. There are also decisions around the capacity and scope of the service. Given that the capacity is likely to be insufficient to cover all surgical patients with at least one potentially modifiable co-morbidity, there is a need to determine the prioritization of patients and to develop a systematic and evidence-based process to guide referral of elective surgical patients for preoperative physician-led medical optimization.

Conclusions

A set of potentially modifiable co-morbidities is associated with a range of poorer post-operative outcomes, relative to patients without those co-morbidities. This finding suggests that certain co-morbidities, if not already well managed, could present as possible targets for optimization prior to surgery and potentially improve post-operative outcomes. Further research is warranted on the effectiveness and cost-effectiveness of the preoperative management of surgical patients with non-optimized potentially modifiable co-morbidities. The importance of service improvements for high-risk surgical patients will increase over time as hospital systems are subjected to increasing demands from an ageing population.

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Conflict of interest

Dr Catherine Gibb is a consultant physician in the Perioperative High Risk Clinic at the Royal Adelaide Hospital.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1. ICD-10 codes used to identify non-targeted co-morbidities.

Appendix S2. ICD-10 codes used to identify the nine key modifiable co-morbidities.

Appendix S3. ICD-10 complication codes for stratification by category.

Appendix S4. Models with coefficients for each modifiable co-morbidity and additional covariates for (a) length of stay, (b) complications, and (c) in-hospital mortality.

3.3.1 Online supplementary material

Appendix S1. ICD-10 codes used to identify non-targeted co-morbidities.

ICD-10 code	ICD-10 description
Malignancy	
C00-C97	Malignant neoplasms
Circulatory system diseases	
I0	Rheumatic fever and heart diseases
I22, I23, I24	Subsequent acute myocardial infarction, certain current complications following acute myocardial infarction, other acute ischaemic heart diseases
I26-I28	Pulmonary heart disease and diseases of pulmonary circulation
I30-I49, I51, I52	Other forms of heart disease, excluding heart failure
I65-I69	Occlusion and stenosis of precerebral and cerebral arteries (not resulting in cerebral infarction), other cerebrovascular diseases and disorders
I7-I9	Diseases of arteries, arterioles and capillaries, diseases of veins, lymphatic vessels and lymph nodes, unspecified disorders of the circulatory system
Intestinal disorders	
K21	Gastro-oesophageal reflux disease
K52	Other non-infective gastroenteritis and colitis
K55-K59	Vascular disorders of intestine, paralytic ileus and intestinal obstruction without hernia, diverticular disease of intestine, irritable bowel syndrome, other functional intestinal disorders

Appendix S2. ICD-10 codes used to identify the nine key modifiable co-morbidities.

ICD-10 code	ICD-10 description
Ischaemic heart disease	
I20	Unstable angina
I21	Acute myocardial infarction
I25	Chronic ischaemic heart disease
Congestive heart failure	
I50	Heart failure
Stroke	
I60	Subarachnoid haemorrhage
I61	Intracerebral haemorrhage
I62	Other non-traumatic intracranial haemorrhage
I63	Cerebral infarction
I64	Stroke, not specified as haemorrhage or infarction
Diabetes mellitus	
E10	Insulin-dependent diabetes mellitus
E11	Non-insulin-dependent diabetes mellitus
E13	Other specified diabetes mellitus
E14	Unspecified diabetes mellitus
Renal impairment	
N0	Glomerular diseases
N1	Renal tubulo-interstitial diseases
N17-N19	Renal failure
N2	Urolithiasis, other disorders of kidney and ureter
N3	Other disease of urinary system
Anaemia	
D50-D53	Nutritional anaemias

Continued on next page

Appendix S2 (continued)

ICD-10 code	ICD-10 description
D62	Acute post-haemorrhagic anaemia
D63	Anaemia in chronic diseases classified elsewhere
D64	Other anaemias
Dementia including Alzheimer's disease	
F00	Dementia in Alzheimer's disease
F01	Vascular dementia
F03	Unspecified dementia
Asthma/chronic obstructive pulmonary disease	
J40-J47	Chronic lower respiratory diseases
Hypertension	
I10	Essential (primary) hypertension

Appendix S3. ICD-10 complication codes for stratification by category.

ICD-10 code	ICD-10 description
Gastrointestinal	
K228	Other specified diseases of oesophagus
K250	Gastric ulcer, acute with haemorrhage
K252	Gastric ulcer, acute with both haemorrhage & perforation
K254	Gastric ulcer, chronic or unspecified with haemorrhage
K256	Gastric ulcer, chronic or unspecified with both haemorrhage & perforation
K260	Duodenal ulcer, acute with haemorrhage
K261	Duodenal ulcer, acute with perforation
K262	Duodenal ulcer, acute with both haemorrhage & perforation
K264	Duodenal ulcer, chronic or unspecified with haemorrhage
K265	Duodenal ulcer, chronic or unspecified with perforation
K266	Duodenal ulcer, chronic or unspecified with both haemorrhage & perforation
K270	Peptic ulcer, acute with haemorrhage
K272	Peptic ulcer, acute with both haemorrhage & perforation
K274	Peptic ulcer, chronic or unspecified with haemorrhage
K276	Peptic ulcer, chronic or unspecified with both haemorrhage & perforation
K280	Gastrojejunal ulcer, acute with haemorrhage
K282	Gastrojejunal ulcer, acute with both haemorrhage & perforation
K284	Gastrojejunal ulcer, chronic or unspecified with haemorrhage
K286	Gastrojejunal ulcer, chronic or unspecified with both haemorrhage & perforation
K290	Acute haemorrhagic gastritis

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
K550	Acute vascular disorders of intestine
K559	Vascular disorder of intestine, unspecified
K560	Paralytic ileus
K565	Intestinal adhesions with obstruction
K566	Other & unspecified intestinal obstruction
K567	Ileus, unspecified
K625	Haemorrhage of anus and rectum
K631	Perforation of intestine (non-traumatic)
K638	Other specified diseases of intestine
K660	Peritoneal adhesions
K650	Acute peritonitis
K720	Acute and subacute hepatic failure
K729	Hepatic failure, unspecified
K85	Acute pancreatitis
K913	Post-operative intestinal obstruction
K914	Colostomy and enterostomy malfunction
K918	Other post-procedural disorders of digestive system, not elsewhere classified
K919	Post-procedural disorder digestive system, unspecified
K92	Other diseases of digestive system
T792	Traumatic secondary & recurrent haemorrhage
T810	Haemorrhage & haematoma complicating a procedure, not elsewhere classified
T888	Other specified complications of surgical & medical care, not elsewhere classified

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
Wounds	
K603	Anal fistula
K604	Rectal fistula
K605	Anorectal fistula
K632	Fistula of intestine
K829	Disease of gallbladder, unspecified
K832	Perforation of bile duct
L89	Decubitus ulcer and pressure area
N360	Urethral fistula
N824	Other female intestinal-genital tract fistulae
T812	Accidental puncture and laceration during a procedure, not elsewhere classified
T813	Disruption of operation wound, not elsewhere classified
T815	Foreign body accidentally left in body cavity or operation wound following a procedure
T818	Other complications of procedures, not elsewhere classified
Infections	
A40	Streptococcal sepsis
A41	Other sepsis
A49	Bacterial infection of unspecified site
B95	Streptococcus & staphylococcus as the cause of diseases classified to other chapters
B96	Other specified bacterial agents as the cause of diseases classified to other chapters
J100	Influenza with pneumonia, other influenza virus identified
J110	Influenza with pneumonia, virus not identified
J12	Viral pneumonia, not elsewhere classified

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
J13	Pneumonia due to <i>Streptococcus pneumoniae</i>
J14	Pneumonia due to <i>Haemophilus influenzae</i>
J15	Bacterial pneumonia, not elsewhere classified
J16	Pneumonia due to other infectious organisms, not elsewhere classified
J17	Pneumonia in diseases classified elsewhere
J18	Pneumonia organism, unspecified
J690	Pneumonitis due to food and vomit
J85	Abscess of lung and mediastinum
J86	Pyothorax
K61	Abscess of anal and rectal regions
K630	Abscess of intestine
K65	Peritonitis
L03	Cellulitis
L04	Acute lymphadenitis
N10	Acute tubulo-interstitial nephritis
N12	Tubulo-interstitial nephritis, not specified as acute or chronic
N151	Renal and peri-nephric abscess
N159	Renal tubulo-interstitial disease, unspecified
N300	Acute cystitis
N309	Cystitis, unspecified
N390	Urinary tract infection, site not specified
R788	Finding of other specified substances, not normally found in blood
T793	Post-traumatic wound infection, not elsewhere classified

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Appendix S3 (continued)

ICD-10 code	ICD-10 description
T802	Infections following infusion, transfusion and therapeutic injection
T814	Infection following a procedure, not elsewhere classified
T816	Acute reaction to foreign substance accidentally left during a procedure
T827	Infection & inflammatory reaction due to other cardiac & vascular devices, implants and grafts
T836	Infection & inflammatory reaction due to prosthetic device, implant and graft in genital tract
T857	Infection & inflammatory reaction due to other internal prosthetic devices, implants and grafts
Renal & Endocrine	
E15	Non-diabetic hypoglycaemic coma
E272	Addisonian crisis
E86	Volume depletion
E87	Other disorders of fluid, electrolyte & acid-base balance
N139	Obstructive & reflux uropathy, unspecified
N17	Acute kidney failure
N19	Unspecified kidney failure
N312	Flaccid neuropathic bladder, not elsewhere classified
N990	Post-procedural renal failure
N999	Post-procedural disorder of genitourinary system, unspecified
R33	Retention of urine
Cardiovascular	
I21	Acute myocardial infarction
I26	Pulmonary embolism
I46	Cardiac arrest

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
I48	Atrial fibrillation and flutter
I49	Other cardiac arrhythmias
I50	Heart failure
I74	Arterial embolism and thrombosis
I80	Phlebitis and thrombophlebitis
I81	Portal vein thrombosis
I82	Other venous embolism and thrombosis
I950	Idiopathic hypotension
I952	Hypotension due to drugs
I959	Hypotension, unspecified
I978	Other post-procedural disorders of circulatory system, not elsewhere classified
I979	Post-procedural disorder of circulatory system, unspecified
R57	Shock, not elsewhere classified
T790	Air embolism (traumatic)
T800	Air embolism following infusion, transfusion and therapeutic injection
T801	Vascular complications following infusion, transfusion and therapeutic injection
T811	Shock during or due to a procedure, not elsewhere classified
T817	Vascular complications following a procedure, not elsewhere classified
T882	Shock due to anaesthesia
Pulmonary	
J80	Adult respiratory distress syndrome
J81	Pulmonary oedema
J90	Pleural effusion, not elsewhere classified

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
J91	Pleural effusion in conditions classified elsewhere
J93	Pneumothorax
J955	Post-procedural subglottic stenosis
J958	Other post-procedural respiratory disorders
J959	Post-procedural respiratory disorder, unspecified
J960	Acute respiratory failure
J969	Respiratory failure, unspecified
J981	Pulmonary collapse
R09	Other symptoms & signs involving the circulatory & respiratory systems
Neurological	
F05	Delirium, not induced by alcohol & other psychoactive substances
F13	Mental & behavioural disorders due to use of sedatives or hypnotics
F15	Mental & behavioural disorders due to use of other stimulants, including caffeine
F19	Mental & behavioural disorders due to multiple drug use & use of other psychoactive substances
G45	TIAs (cerebral) & related syndromes
G46	Vascular syndromes of brain in cerebrovascular diseases
G81	Hemiplegia
G82	Paraplegia and tetraplegia
G931	Anoxic brain damage, not elsewhere classified
G936	Cerebral oedema
G970	Cerebrospinal fluid leak from spinal puncture
G971	Other reaction to spinal & lumbar puncture

Continued on next page

Appendix S3 (continued)

ICD-10 code	ICD-10 description
G978	Other post-procedural disorders of nervous system
G979	Post-procedural disorder of nervous system, unspecified
I63	Cerebral infarction
I65	Occlusion & stenosis of pre-cerebral arteries, not resulting in cerebral infarction

Appendix S4. Models with coefficients for each modifiable co-morbidity and additional covariates for (a) length of stay, (b) complications, and (c) in-hospital mortality.

(a) Length of stay

Ordinary least squares regression

Covariates	Coefficient estimate	95% CI	P(> t)
Age (rcs1)	0.004	0.002, 0.006	0.000
Age (rcs2)	0.001	-0.003, 0.006	0.538
Age (rcs3)	0.017	-0.003, 0.037	0.097
Sex (female)	0.060	0.042, 0.078	0.000
Ischaemic heart disease	0.147	0.063, 0.232	0.000
Congestive heart failure	0.430	0.273, 0.588	0.000
Stroke	-0.154	-0.446, 0.137	0.300
Diabetes	0.196	0.144, 0.248	0.000
Renal impairment	0.097	0.061, 0.132	0.000
Anaemia	0.235	0.184, 0.286	0.000
Dementia incl. Alzheimer's	0.571	0.441, 0.700	0.000
Asthma/COPD	0.321	0.245, 0.397	0.000
Hypertension	0.232	0.184, 0.280	0.000
Malignancy	0.303	0.272, 0.334	0.000
Circulatory system diseases	0.068	0.032, 0.104	0.000
Intestinal disorders	0.061	0.023, 0.098	0.002

CI, confidence interval; COPD, chronic obstructive pulmonary disease; rcs, restricted cubic spline.

Adjusted R²: 0.525 (DRG dummy variables have been omitted from the table)

Appendix S4 (continued)**(b) Complications**

Logistic regression

Covariates	Coefficient estimate	95% CI	P(> z)
Age (rcs1)	0.005	-0.004, 0.014	0.289
Age (rcs2)	0.006	-0.015, 0.026	0.574
Age (rcs3)	0.026	-0.058, 0.110	0.549
Sex (female)	0.017	-0.052, 0.086	0.631
Ischaemic heart disease	0.391	0.132, 0.645	0.003
Congestive heart failure	0.560	0.101, 1.012	0.016
Stroke	-1.060	-2.323, -0.062	0.060
Diabetes	0.299	0.136, 0.460	0.000
Renal impairment	0.230	0.101, 0.359	0.000
Anaemia	0.071	-0.089, 0.229	0.381
Dementia incl. Alzheimer's	0.342	-0.037, 0.710	0.073
Asthma/COPD	0.494	0.249, 0.733	0.000
Hypertension	0.317	0.172, 0.461	0.000
Malignancy	0.361	0.247, 0.474	0.000
Circulatory system diseases	0.058	-0.073, 0.187	0.385
Intestinal disorders	-0.006	-0.136, 0.123	0.930

CI, confidence interval; COPD, chronic obstructive pulmonary disease; rcs, restricted cubic spline.

Nagelkerke's R^2 : 0.216 (DRG dummy variables have been omitted from the table) Bootstrapping calibration and validation methods showed the model to be reasonable for prediction.

Appendix S4 (continued)**(c) In-hospital mortality**

Logistic regression

Covariates	Coefficient estimate	95% CI	P(> z)
Age (rcs1)	0.213	0.051, 0.465	0.043
Age (rcs2)	-0.243	-0.537, -0.030	0.059
Age (rcs3)	1.337	0.323, 2.592	0.020
Sex (female)	-0.410	-0.854, 0.022	0.066
Ischaemic heart disease	1.704	1.016, 2.347	0.000
Congestive heart failure	0.665	-0.330, 1.563	0.166
Stroke	0.578	-2.450, 2.544	0.619
Diabetes	0.750	0.100, 1.368	0.020
Renal impairment	0.408	-0.170, 0.955	0.153
Anaemia	1.051	0.529, 1.549	0.000
Dementia incl. Alzheimer's	0.584	-0.613, 1.575	0.289
Asthma / COPD	0.531	-0.472, 1.378	0.255
Hypertension	-0.292	-0.932, 0.318	0.360
Malignancy	1.244	0.678, 1.824	0.000
Circulatory system diseases	0.845	0.331, 1.338	0.000
Intestinal disorders	0.034	-0.581, 0.598	0.910

CI, confidence interval; COPD, chronic obstructive pulmonary disease; rcs, restricted cubic spline.

Nagelkerke's R^2 : 0.271 (DRG dummy variables have been omitted from the table)
 Analysis includes only 34 of the 75 DRGs as no deaths occurred in the other 41.

Chapter 4

Effectiveness of preoperative assessment and management: a systematic literature review

4.1 Preface

This chapter details the systematic review of the available evidence on preoperative assessment and management provided by physicians in elective surgery patients, published in the *BMJ Open* journal. The reviewers for this manuscript noted that this was an important area of perioperative practice that currently lacks a previously published systematic review. With an ageing population, increasing co-morbidities and an increase in surgical procedures, this article draws attention to the limitations in previous research and provides recommendations that may stimulate further research in this area.

For the purposes of publication in a US journal, preoperative assessment and management by consultant physicians has been referred to as preoperative medical consultation by internal medicine physicians.

This is the first systematic review of the literature evaluating the effects of preoperative medical consultation on postoperative outcomes.

4.2 Statement of authorship

Title of paper: Effectiveness of Preoperative Medical Consultations by Internal Medicine Physicians: a Systematic Review

Publication status: Published

Publication details: PHAM CT, GIBB CL, FITRIDGE RA, KARNON JD. Effectiveness of Preoperative Medical Consultations by Internal Medicine Physicians: a Systematic Review. *BMJ Open* 2017; **7**(12): e018632. DOI: 10.1136/bmjopen-2017-018632

Name of principal author (Candidate): Clarabelle T Pham

Contribution to the paper: Conception and design, conducted literature searches and critical appraisal, extraction, analysis and interpretation of data, drafted the article and critical revisions, and acted as corresponding author.

Overall percentage: 85%

This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.

Signed: ...

..

Date: 30/01/2019

Co-author contributions

By signing the statement of authorship, each author certifies that:

- i. the candidate's stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of co-author: Catherine L Gibb

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Robert A Fitridge

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Jonathan D Karnon

Contribution to the paper: Conception and design, extraction, analysis and interpretation of data, and revised it critically for important intellectual content.

Signed: .

Date: 30/01/2019

4.3 Publication

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Research

BMJ Open Effectiveness of preoperative medical consultations by internal medicine physicians: a systematic review

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ABSTRACT

Objective Clinics have been established to provide preoperative medical consultations, and enable the anaesthetist and surgeon to deliver the best surgical outcome for patients. However, there is uncertainty regarding the effect of such clinics on surgical, in-hospital and long-term outcomes. A systematic review of the literature was conducted to determine the effectiveness of preoperative medical consultations by internal medicine physicians for patients listed for elective surgery.

Design Systematic searches of MEDLINE, EMBASE, CINAHL, PubMed, Current Contents and the NHS Centre for Reviews and Dissemination were conducted up to 30 April 2017.

Setting Elective surgery.

Study selection Randomised controlled trials and non-randomised comparative studies conducted in adults.

Outcome measures Length of hospital stay, perioperative morbidity and mortality, costs and quality of life.

Results The one randomised trial reported that preadmission preoperative assessment was more effective than the option of an inpatient medical assessment in reducing the frequency of unnecessary admissions with significantly fewer surgical cancellations following admission for surgery. A small reduction in length of stay in patients was also observed. The three non-randomised studies reported increased lengths of stay, costs and postoperative complications in patients who received preoperative assessment. The timing and delivery of the preoperative medical consultation in the intervention group differed across the included studies.

Conclusion Further research is required to inform the design and implementation of coordinated involvement of physicians and surgeons in the provision of care for high-risk surgical patients. A standardised approach to perioperative decision-making processes should be developed with a clear protocol or guideline for the assessment and management of surgical patients.

INTRODUCTION

Preoperative medical consultations are an important component in the care of patients undergoing elective surgery. Patients who are at high risk of morbidity and mortality due to pre-existing comorbidities and the severity of surgery¹ are targeted for preoperative medical consultations by internal medicine physicians. Such consultations involve optimising

Strengths and limitations of this study

- The effectiveness of preoperative medical consultation is uncertain due to a lack of high-level comparative evidence.
- The design of services applied to date is heterogeneous, but the consolidation of existing evidence has identified potential elements of preoperative assessment that may contribute to better outcomes, such as eligibility criteria for referral, and the timing and process of assessment.
- Despite the limited evidence base, the presented review assembles and critically appraises the available evidence and draws some preliminary findings that may inform the design and adaptation of new and existing preoperative clinics.

pre-existing medical conditions (eg, diabetes mellitus, ischaemic heart disease); assessing and managing risk of morbidity and mortality; initiating interventions intended to decrease perioperative risk (eg, delirium management, pulmonary preoperative evaluation with postoperative recommendations) and where appropriate, recommending the deferment or cancellation of surgery. This differs to but complements the care provided during a preoperative anaesthetic assessment that every patient receives prior to surgery.

With increasing patient age and complexity of medical conditions, there is a need for comprehensive preoperative evaluation and medical optimisation to enable the anaesthetist and surgeon to deliver the best surgical outcome.^{2 3} The concept of preoperative medical assessment by internal medicine physicians is moving beyond the early adopter stage, with preoperative physician-led clinics being set up across the USA and internationally. In the USA, several dedicated preoperative assessment clinics have been established to address this need and provide high-quality care.⁴ Centres such as the Internal Medicine Perioperative Assessment, Consultation, and Treatment Center have been included as part of the preoperative evaluation model at the

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Cleveland Clinic Foundation, with the aim to provide thorough, timely and cost-effective assessment of surgical patients.³ In Australia, the Royal Adelaide Hospital and the Queen Elizabeth Hospital have consultant physician-led clinics dedicated to providing medical assessment and management to high-risk patients in elective surgery.

There is a strong rationale for the beneficial effects of preoperative medical consultations by internal medicine physicians in reducing postoperative length of stay and complications, and improving long-term recovery and rehabilitation. However, no systematic review of the literature reporting evaluations of preoperative medical consultation has been reported. Thus, we conducted a systematic review of the published literature reporting on preoperative medical consultations by internal medicine physicians in high-risk surgical patients.

METHODS**Data sources and searches**

Systematic searches of MEDLINE, EMBASE, CINAHL, PubMed, Current Contents and the NHS Centre for Reviews and Dissemination (including Cochrane Database of Systematic Reviews, Database of Abstracts of Review and Effects, Health Technology Assessment Database and NHS Economic Evaluation Database) were conducted from database inception to 30 April 2017. A full list of search terms used is provided in the online supplementary appendix 1.

Searches were conducted without language restriction. The reference lists of all included articles were then manually searched for relevant references that may have been missed during the database searches.

Study selection

Studies were selected for inclusion on the basis of the following criteria:

Type of studies

Randomised controlled trials (RCTs) and non-randomised comparative studies (eg, quasi-RCTs, controlled before and after studies and cohort studies) were considered in the review.

Participants

Humans aged 18 years and over scheduled for elective surgery.

Intervention

Preoperative medical consultations by an internal medicine physician or generalist for elective surgical patients. The assessment may take place in any setting, such as on a ward or in an outpatient clinic.

Comparator

Preoperative assessment by an anaesthetist, other existing preoperative assessment process or no preoperative medical consultation.

Outcomes

- ▶ Convalescence (length of hospital stay);
- ▶ Perioperative morbidity and mortality (same-day admissions, surgical cancellations, complications, mortality);
- ▶ Cost/resource use (cost-effectiveness analyses, cost-savings, resource use);
- ▶ Quality of life (generic or disease-specific quality-of-life survey instruments, patient satisfaction).

Two reviewers (CP, JK) independently screened all titles and abstracts to determine eligibility. Full texts were retrieved for potentially relevant articles. Disagreements were resolved through discussion.

Data extraction and quality assessment

Data were extracted by one reviewer (CP) and checked by a second (JK) using standardised data extraction tables that were developed a priori.

The evidence presented in the included studies were classified according to the National Health and Medical Research Council (NHMRC) Evidence Hierarchy.⁵ Study quality was assessed using the Cochrane Collaboration's tool for assessing risk of bias in RCTs (chapter 8,⁶ table 8.5a) and in non-randomised studies (chapter 13,⁶ table 13.2a). All studies were assessed based on the four main sources of systematic bias in studies of the effects of healthcare, namely selection bias, performance bias, detection bias and attrition bias. Discrepancies were resolved through a consensus process.

Data synthesis and analysis

The heterogeneity of the interventions and the variability of outcome measures precluded meta-analysis. The outcome data from the studies were therefore reported narratively. Differences between intervention and control groups for each outcome measure were reported as difference in means, OR or risk ratio.

RESULTS

Of the 128 citations screened for eligibility, 4 met the inclusion criteria; 1 RCT and three non-randomised comparative studies (1 prospective and 2 retrospective). [Figure 1](#) provides a summary of the search results and study selection.

Quality assessment

The quality of the available evidence was poor. [Table 1](#) summarises the risk of bias assessments for the included studies. The one RCT⁷ described their randomisation process but did not state their method of allocation concealment. Outcome assessments were not blinded but interobserver and intraobserver reliability tests were performed with 100% agreement reported from both tests. Blinding of investigators and patients was not possible due to the nature of the intervention. There were no losses to follow-up. The external validity of this RCT is uncertain as the study setting differed to the

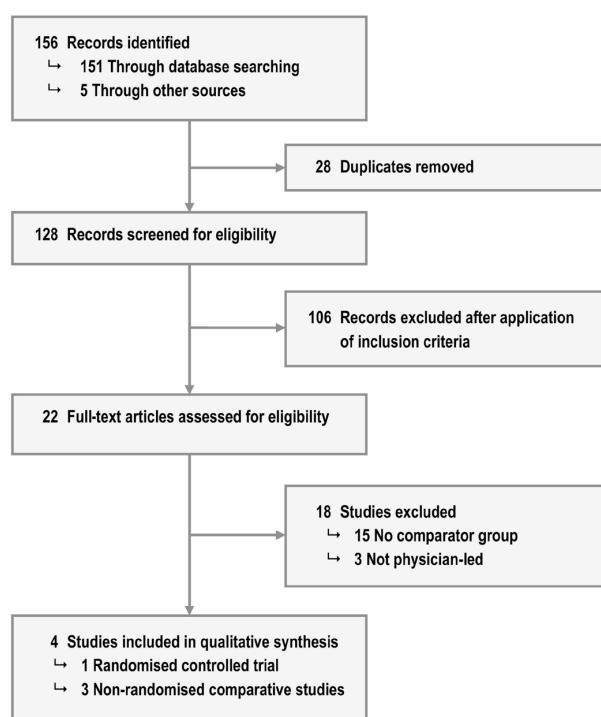


Figure 1 Summary of search results and study selection.

non-experimental setting, for example, the time between admission and surgery was more restrictive in the study.

Two non-randomised studies used concurrent controls, but alternative methods for patient allocation were used. Auerbach *et al*⁸ included patients prospectively via the Center for Medicare and Medicaid Services criteria, randomly selecting medical records of patients for the public reporting of data regarding adherence to surgical site infection processes. Katz *et al*⁹ collected retrospective data on all consecutive patients in their specified study periods. Auerbach *et al*⁸ used propensity scores as weights to control for selection bias but only the discriminative power of the propensity score model was reported and not whether covariate balance was achieved. Katz *et al*⁹ reported significant differences between the medical consultation and no consultation group for age, ASA status, type of surgery and gender, but did not adjust for these differences in their outcome analysis. The remaining non-randomised study used a pre-intervention/postintervention design and included all retrospective patients in the specified time periods.¹⁰ Vazirani *et al*¹⁰ used regression models with age, gender, time period (pre or post) and the American Society of Anesthesiologists (ASA) classification as covariates to adjust for differences between groups.

Due to the non-randomised comparative study design, outcome assessments were not blinded so there is the potential for error and bias in the collection and interpretation of information. Two studies retained

all patients^{8 10} and the remaining reported losses to follow-up of around 8%.

Description of included studies

For the RCT, the mean ages of the patients were 65.3 years for the intervention group and 65.7 years for the comparator group. There were no significant differences between groups for number of medications on admission, cardiac risk index category and ASA score. Patients in the comparator group could still receive a preoperative medical consultation, if necessary, but only as an inpatient (ie, only after admission for surgery), compared with the intervention group who attended an outpatient clinic within 3 weeks of surgery (figure 2). A range of surgical procedures across multiple specialties were included, with no significant differences in the proportion of patients in each surgical service.

For the non-randomised comparative studies, patients in the comparator group in one study⁸ received consultation from an internist on days other than the intervention or from another specialty but the actual timing of the consultation was not reported (table 2). Comparator groups in the remaining studies received either preoperative anaesthetic assessment only or did not receive any preoperative medical consultation, although no further details were reported (table 2). The timing of the preoperative medical consultation in the intervention groups differed across the three studies (figure 2). Age ranged from a mean 61.4 years to a mean 70.1 years in the intervention group and a median 58 years to a mean 67.3 years in the comparator group. A range of surgical procedures across multiple specialties were included. Two of the studies focused on clinical outcome measures and the other focused on reviewing the medical consultation process (eg, reason for consultation, consultants' recommendations).

Effectiveness of intervention

Table 3 provides a summary of the effectiveness of preoperative medical consultations by an internal medicine physician for a range of outcomes.

Surgical cancellations

Randomised controlled trial

A similar proportion of patients in each group did not undergo surgery (24.4% for a medical consultation within 3 weeks and 23.5% for a medical consultation after admission but before surgery). Of the surgical cancellations that occurred after the admission for surgery, the patients who received a medical consultation after admission (control group) had a higher proportion of cancellations (6.6% higher, 95% CI 0.5% to 12.7%).

Non-randomised comparative studies

One non-randomised comparative study reported on surgical cancellations.¹⁰ There were no significant differences in the number of surgical cancellations between patients who received an anaesthetic consultation and those who received a medical consultation.

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**Table 1** Assessment of risk of bias in included studies

Source of bias	Macpherson and Lofgren ⁷	Auerbach <i>et al</i> ⁸	Katz <i>et al</i> ⁹	Vazirani <i>et al</i> ¹⁰
Selection bias				
Randomisation (RCT)	Permuted blocks of size 2 and 4, stratified by quartiles of anticipated LoS	–	–	–
Allocation concealment (RCT)	Not reported	–	–	–
Control for confounders (NRS)	–	Patients sampled at random; propensity score weighting	Consecutive patients	Regression methods
External validity (RCT and NRS)	Uncertain as study setting was more restrictive than a non-experimental setting	Potential unobserved confounding	Potential unobserved confounding	Potential unobserved confounding
Performance bias				
Blinding of participants and/or investigators (RCT)	No	–	–	–
Measurement of exposure (NRS)	–	No blinding but 5% of medical record abstractions were reviewed for data validity	No blinding	No blinding
Detection bias				
Blinded outcome assessment (RCT and NRS)	No blinding but 100% interobserver and intraobserver agreement*	Not reported	Not reported	Not reported
Attrition bias				
Completeness of follow-up (RCT and NRS)	Yes	Yes	35 (8.3%) patients with missing medical records	Yes

Ellipses indicate not applicable.

*A researcher re-abstracted length of stay data on 10 randomly selected records, and a physician not associated with the study abstracted length of stay from the same 10 records.

LoS, length of stay; NRS, non-randomised studies; RCT, randomised controlled trials.

Length of hospital stay

Randomised controlled trial

Across all patients, the preoperative length of stay was reduced in the intervention group (1.3-day reduction, 95% CI –1.8 to –0.8), but there was no significant difference between the intervention and control groups for the postoperative and overall length of stay.

Non-randomised comparative studies

Length of stay was reported in two of the non-randomised comparative studies.^{8 10} After adjustment for observed potential confounding, a medical consultation on or around the day of surgery compared with a medical or other specialty consultation in two or more days before surgery resulted in a 13% increase in length of stay (95% CI 2% to 26%).⁸ There were no significant differences in overall length of stay between the medical and anaesthetic consultations but patients who were ASA 3 or higher had a significantly shorter length of stay with a medical consultation.¹⁰

Costs

Randomised controlled trial

The RCT did not report on costs.

Non-randomised comparative studies

Only one non-randomised comparative study reported on costs.⁸ There was a 24% increase in costs for patients who received a medical consultation on or around the day of surgery compared with those who received a medical or other specialty consultation in two or more days before surgery, with increases ranging from 14% to 36%.

Postoperative complications

Randomised controlled trial

The RCT did not report on postoperative complications.

Non-randomised comparative studies

The odds of complications after postoperative day 2 for patients receiving a medical consultation on or around the day of surgery was 1.51 times greater than for patients receiving a medical or other specialty consultation in two or more days before surgery (95% CI 0.98 to 2.32).⁸

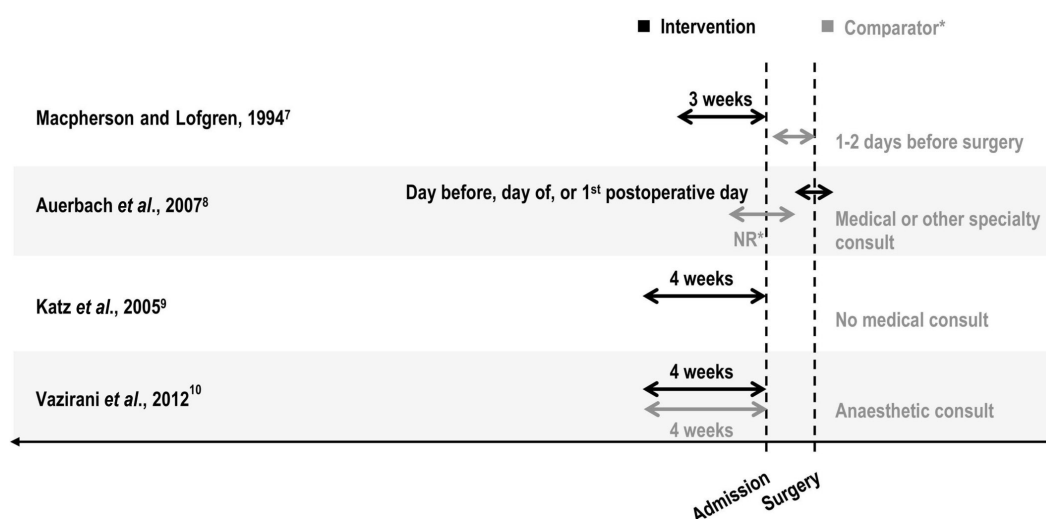


Figure 2 The timing of the preoperative medical consultation in each included study. *Macpherson and Lofgren⁷ compared preadmission medical consultations (outpatient clinic) to postadmission preoperative medical consultations (inpatient) and Auerbach *et al*⁸ compared a medical consultation on the day before, day of or day after surgery with a medical or other specialty consultation on days other than the intervention (ie, two or more days before surgery).

Suspected infection, cardiac, pulmonary and other medical complications were the most commonly reported complications.

Mortality

Randomised controlled trial

The RCT did not report on mortality.

Non-randomised comparative studies

The likelihood of death in patients who received a medical consult was significantly lower (69% less likely) than those who received an anaesthetic consult.¹⁰

Patient satisfaction

Randomised controlled trial

No significant differences in quality of life and quality of care measures at 2 months postrandomisation were reported between patients who received a medical consultation in the 3 weeks prior to admission, and following admission.

Non-randomised comparative studies

None of the non-randomised comparative studies reported on patient satisfaction.

Review of the medical consultation process

In the non-randomised study of preoperative assessment in the 4 weeks prior to admission,⁹ medical records were reviewed to determine the characteristics of the medical consultations. The specialty of the requesting physician and the reason for medical consultation could not be determined for the majority of the consultations (51% and 64%, respectively). Of the remaining, requests for a medical consultation were either from surgeons (46%) or other internists or family practitioners (3%), and the main reasons for requesting a medical consultation

were for clearance (19%) or evaluation (14%). Other reasons included risk assessment (0.7%) and re-assessment (0.7%). Patients' diagnoses were listed in 83% of the consultations, with 3% diagnosing a medical condition not previously identified in the admitting history. In terms of recommendations, no recommendations were reported in 43% of the consultations, 34% 'cleared' the patient for surgery and 20% provided a risk assessment such as 'minimal increased risk' or 'no increased risk'. Of the 178 preoperative, intraoperative and postoperative recommendations made, documentation in the medical records indicated that 73% were followed, 9% were not followed and in 18% it could not be determined.

DISCUSSION

The effectiveness of preoperative medical consultation is uncertain due to a lack of high-level comparative evidence. The one RCT⁷ identified reported medical consultations in an outpatient setting were effective in reducing surgical cancellations following admission for surgery compared with medical consultations in an inpatient setting. The RCT also reported a small reduction in length of stay for patients who received preadmission preoperative medical consultations, noting that the active control (inpatient medical consultations) may have reduced the effect size relative to a non-active control. The observational studies reported mixed results regarding length of stay^{8 10} and mortality,^{9 10} and increased costs⁸ and postoperative complications⁸ in patients who received preoperative medical consultations, but these results must be interpreted with caution due to the potential for bias and confounding.



Table 2 Characteristics of included studies					
Study and setting	Study type	Population	Intervention	Comparator	n (patients)
Macpherson and Lofgren ⁷ Pennsylvania, USA	Level II, randomised controlled trial	>50 years of age, referred from a surgeon, lived within 100 miles of study hospital The most common procedures included upper airway endoscopy under general anaesthetic for head and neck cancer, hip and knee arthroplasty, cataract extraction, transurethral resection of the prostate, and laminectomy	Medical preoperative evaluation clinic (outpatient) Consultation provided by internist or third-year internal medicine resident supervised by attending internist	Internal medicine evaluation, if necessary (inpatient) Consultation provided by internist or third-year internal medicine resident supervised by attending internist	176 (intervention) 179 (comparator)
Auerbach <i>et al</i> ⁸ California, USA	Level III 2, prospective observational cohort study with concurrent controls	>18 years of age, underwent one of the following surgeries (emergency or elective): colon surgery, cardiac bypass or valve procedures, hip or knee arthroplasty, hysterectomy, vascular surgery	Medical consultation on day before, day of or first day after surgery Consultation provided by attending physician, and fellow (for subspecialty services, eg, cardiology) or third-year internal medicine resident	Medical consultation on days other than intervention or from non-internal medicine services Consultation provided by internist or other specialist	117 (intervention) 1165 (comparator)
Katz <i>et al</i> ⁹ New York, USA	Level III 2, retrospective observational cohort study with concurrent controls	>50 years of age, underwent elective non-cardiac surgery	Medical consultation (as noted in patients' medical records) Consultation provided by internist or family practitioner	No medical consultation noted in patients' medical records No other comparator details reported	138* (intervention) 249 (comparator)
Vazirani <i>et al</i> ¹⁰ California, USA	Level III 3, pre-post retrospective comparative study	All patients in the Veterans Health Administration database covering the following surgical specialties: ophthalmology, orthopaedics, urology, general surgery	Hospitalist-run preoperative clinic (outpatient) Consultation provided by mid-level providers with hospitalist oversight	Preoperative anaesthetic clinic (outpatient) Consultation provided by mid-level providers with anaesthesiologist oversight	2565 (intervention) 2658 (comparator)

*146 consultations.

**Table 3** Summary of effectiveness of physician-led preoperative assessment by outcome

Outcome and study	Intervention	Comparator	Difference*
Length of stay (days)			
Macpherson and Lofgren ⁷ (mean)			
All patients			
Preadmission for surgery	1.6	2.9	-1.3 (-0.8 to -1.8)
Admission for surgery	3.6	3.0	0.6 (-0.6 to 1.8)
Total	5.5	6.0	-0.5 (-2.0 to 1.1)
Patients who had surgery			
Preadmission for surgery	1.9	3.0	-1.1 (-0.5 to -1.6)
Admission for surgery	4.8	3.9	0.9 (-0.6 to 2.4)
Total	7.1	7.0	0.1 (-1.7 to 2.0)
Auerbach <i>et al</i> ⁸ (median, IQR)			
Before adjustment	10 (7-18)	6 (4-9)	87% (63% to 115%)†
After adjustment	NR	NR	13% (2% to 26%)†
Vazirani <i>et al</i> ¹⁰			
Mean (SD)	5.28 (9.24)	9.87 (25.4)	NR
ASA classification			
No disturbance	NR	NR	-1.31 (SE 5.90), P=0.82
Mild	NR	NR	-2.52 (SE 1.39), P=0.07
Severe	NR	NR	-4.22 (SE 0.96), P<0.01
Life-threatening	NR	NR	-19.70 (SE 3.81), P<0.01
Costs (USD)			
Auerbach <i>et al</i> ⁸ (median)			
Before adjustment	1 55 020 (101 473-292 951)	74 237 (53 824-126 927)	116% (88% to 148%)†
After adjustment	NR	NR	24% (14% to 36%)†
Postoperative complications			
Auerbach <i>et al</i> ⁸ (n, %)			
Before adjustment	60 (51.3)	322 (27.6)	OR 2.76 (1.88 to 4.04)
After adjustment	NR	NR	OR 1.51 (0.98 to 2.32)
Mortality			
Katz <i>et al</i> ⁹ (n, %)			
Unexpected ICU/death	2 (1.4)	4 (1.6)	P=0.9046
Vazirani <i>et al</i> ¹⁰ (n, %)			
	4 (0.4)	14 (1.3)	OR 0.31 (0.10 to 0.99)
Surgical cancellations			
Macpherson and Lofgren ⁷ (n, %)			
During admission	10 (5.7)	22 (12.3)	-6.6% (-0.5% to -12.7%)
Did not undergo surgery	43 (24.4)	42 (23.5)	NR
Vazirani <i>et al</i> ¹⁰ (n, %)			
Total	368 (14.3)	400 (15.0)	NR
Medically avoidable‡	18 (4.9)	34 (8.5)	P=0.065
Patient satisfaction			
Macpherson and Lofgren ⁷			
MOS SF-22 (higher score indicates better health)			
Health perceptions	38.8	33.1	NS
Pain	55.3	59.8	NS
Physical function	45.7	44.1	NS

Continued

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Table 3 Continued

Outcome and study	Intervention	Comparator	Difference*
Social function	62.3	61.2	NS
Mental health	63.0	58.0	NS
Questionnaire adapted from RAND§ (%)			
Satisfaction with care	73	66	NS
Dissatisfaction with care	39	47	NS
Rated care as very good or excellent	64	54	NS
Rated care as better than most or best	62	54	NS
Overall, very or extremely satisfied	66	58	NS

*Difference reported as mean difference (95% CI of the difference) unless otherwise specified.

†Cost and length of stay data were log transformed to normalise data with percentage differences attributable to consultation calculated using the following equation: $100 \times (e^{\beta} - 1)$.

‡As opposed to unavoidable, patient-related causes.

§Patient satisfaction questionnaire adapted from RAND.

ASA, American Society of Anesthesiologists; ICU, intensive care unit; MOS SF-22, Medical Outcomes Study Short Form-22; NR, not reported; NS, not significant, actual P value not reported; USD, United States Dollar.

Design limitations in included studies

As well as differences in the comparator arms, the reviewed studies varied with respect to the timing and delivery of the preoperative medical consultation, which precluded the pooling of results. One study evaluated the effect of medical consultations on the day before or day of surgery,⁸ while differences in the timing of preadmission consultations may be driven by varying waiting times across forms of elective surgery (eg, cancer vs non-cancer procedures) and geographical locations. In general, it might be hypothesised that consultations undertaken close to the date of surgery provide less time for optimisation. A recent review of guidelines pertaining to preoperative medical management suggested that consultations may be most beneficial when sought at least 4 weeks prior to elective surgery, and when there is a clear understanding of the planned procedure and its associated risks.¹¹

The form of preoperative medical consult also varied across the included studies, with minimal detail from each of the studies on the actual services provided as part of the intervention. It was not clear in any of the included studies if the consultant providing the intervention was also involved in the postoperative care of the patient. A one-off consult with recommendations but no patient follow-up may be less effective than a coordinated approach to shared decision making between specialists and physicians for perioperative management. Katz *et al*⁹ provided some insight into the reasons for requesting a consult, but were limited by the information documented in the medical records.

The comanagement concept of surgeons managing a patient's surgery and surgery-related issues and the internal medicine physician or geriatrician managing a patient's medical conditions is rational.¹² The results of

the review do not confirm nor reject the hypothesis that preoperative medical consultation provides important benefits. The findings suggest that there is significant uncertainty around the overall effect of such services, as well as illustrating the variation in the design and implementation of preoperative assessment.

The role of the general internist compared with other subspecialists

Internationally, the subspecialist providing the preoperative medical consultation will vary. Anaesthetists have a different focus and expertise by providing safe anaesthesia and specific perioperative management,^{13 14} which complements the role of the general internist who assesses and optimises the patient's modifiable comorbidities. Despite a great deal of overlap between geriatrics and general internal medicine, the focus of a comprehensive geriatric assessment (CGA) may differ to a preoperative medical consultation in some surgical populations. A CGA intervention that focuses on the assessment component only will differ to the focus of a general internist who will assess the patient and recommend specific management plans to optimise modifiable risk factors for adverse postoperative outcomes.¹⁵ For this reason, studies involving a preoperative medical consultation by subspecialists other than the general internist as the intervention were excluded.

Recommendations for improvements in clinical practice and research design

Currently, there are no clear recommendations regarding the selection of patients who require medical consultation.¹⁶ Given limited resources, patients at high risk of morbidity and mortality should be prioritised for a medical consultation but substantial practice variation



exists.¹⁷ The decision to refer a patient for preoperative consultation is at the discretion of the treating surgeon and influenced by the surgeon's personal preference for the intervention, patient preference, patient characteristics and medical history. Auerbach *et al*⁸ reported increases in postoperative complications with a medical consult but the consultations may have been requested for an impending or suspected complication, which would make it difficult to discern whether a consult reduced the risk of complications. Thus, confounding by indication is a major source of bias in the non-randomised comparative studies.¹⁸ Auerbach *et al*⁸ used propensity scores as weights to adjust for confounding but the authors indicated that patterns of consultation and other unmeasured confounding factors in the patient's medical history or illness may have biased their results. A key potential confounder that may not be adequately represented in the reported studies is frailty, which has been shown to be a predictor of surgical morbidity and mortality, and may also be an important factor in the decision to refer for preoperative medical consultation.^{19–21}

Well-designed and conducted RCTs can remove potential confounding, but issues remain around the feasibility of such trials and the generalisability of the findings. Having a no-consultation arm in the trial for a patient identified as high risk would be a major challenge, and strict trial conditions cannot be easily translated into clinical practice. In the RCT in this review, patients in the comparator group could still receive a preoperative medical consultation as an inpatient, if necessary, and the strict trial conditions on the timing between admission and surgery may not reflect the application of the intervention in routine clinical practice.

Evidence directly linking preoperative interventions with a reduction in perioperative risk are lacking. Given the multidisciplinary care of patients in a hospital setting, it is difficult to assess whether one particular aspect of care provided directly impacts on a particular outcome. The design of services applied to date is heterogeneous, but the consolidation of existing evidence has identified potential elements of preoperative assessment that may contribute to better outcomes, for example, eligibility criteria for referral, and the timing and process of assessment. In the absence of robust evidence, preoperative medical consultations are likely to remain ad hoc in terms of implementation and design. Qualitative data may provide an in-depth understanding of the processes of care and the perceived value of preoperative consultation. Future research should aim to clearly describe the level of involvement of the internal medicine physician in the surgical decision-making process and their relationship with the surgical team. A better understanding of the mechanisms of preoperative medical consultations and the complex decision-making processes involved may help explain the relationship between medical consultations and outcomes. Further research is also required to determine the characteristics of patients who would benefit most from medical consultation.

CONCLUSION

Preoperative medical consultations for patients with complex care requirements and in poor health is an intuitive health service development. To date, such services appear to have been developed and implemented on a limited and ad hoc basis, resulting in varied service designs and a lack of evidence on the value of preoperative assessment. With an ageing population and increasing rates of chronic disease, the management of high-risk surgical patients is likely to become an increasingly important issue. The available evidence suggests a positive effect of preoperative medical consultation with a general internist compared with standard care, but more conclusive evidence may be needed to persuade hospitals to fund such a service. Alternative forms of preoperative assessment may also need to be considered, such as comprehensive geriatric assessment, and there may be scope to optimise the value of such services by closer consideration of referral criteria and the timing of preoperative assessment. Providing continuity of multidisciplinary care from the decision to operate through to rehabilitation and recovery is certainly logical and intuitive. However, further research is required to inform the value, and the optimal design and implementation of coordinated involvement of physicians and surgeons in the provision of care for high-risk surgical patients. A standardised approach to perioperative decision-making processes should be developed with a clear protocol or guideline for the assessment and management of surgical patients.

Contributors All authors (CP, CG, RF, JK) contributed substantially to the conception and design of the study; and the acquisition, analysis and interpretation of data. CP drafted the work and all authors (CP, CG, RF, JK) provided critical revision for important intellectual content. All authors (CP, CG, RF, JK) approve of the final version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated or resolved.

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Competing interests CLG is a consultant physician in the High Risk Clinic at the Royal Adelaide Hospital and Queen Elizabeth Hospital. The remaining authors declare no conflict of interest.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data used in the analysis were extracted from peer-reviewed publications. No additional unpublished data were generated or collected in the study.

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Effectiveness of preoperative medical consultations by internal medicine physicians: a systematic review

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4.3.1 Online supplementary material

Appendix 1. Search strategies

Search strategy for **Centre for Reviews and Dissemination**

#1 MeSH descriptor: [preoperative care] explode all trees

#2 MeSH descriptor: [referral and consultation] explode all trees

#3 (#1 AND #2)

Search strategy for **PubMed**

#1 preoperative[All Fields]

#2 medical[All Fields]

#3 (“referral and consultation”[MeSH Terms] OR (“referral”[All Fields] AND “consultation”[All Fields]) OR “referral and consultation”[All Fields] OR “consultation”[All Fields])

#4 (“surgical procedures, elective”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “elective”[All Fields]) OR “elective surgical procedures”[All Fields] OR (“elective”[All Fields] AND “surgery”[All Fields]) OR “elective surgery”[All Fields])

#5 (#1 AND #2 AND #3 AND #4)

#6 preoperative[Title]

#7 “medical consultation”[Title]

#8 (#6 AND #7)

#9 “preoperative evaluation”[All Fields]

#10 “internal medicine”[All Fields]

#11 (#9 AND #10)

#12 (“Hospitalists”[MeSH] OR “internal medicine”[MeSH]) AND “preoperative evaluation”[All Fields]

Search strategy for **EMBASE (Elsevier)**

#1 ‘preoperative care’/exp OR ‘preoperative care’

#2 ‘elective surgery’/exp OR ‘elective surgery’

#3 ‘referral and consultation’/exp OR ‘referral and consultation’

#4 (#1 AND #2 AND #3)

Search strategy for **CINAHL (EBSCO host)**

S1 MW 'preoperative care'

S2 MW 'elective surgery'

S3 MW medical OR MW 'referral and consultation'

S4 (S1 AND S2 AND S3)

Search strategy for **Current Contents Connect (Web of Science)**

#1 TOPIC: 'preoperative care'

#2 TOPIC: 'elective surgery'

#3 TOPIC: 'referral and consultation'

#4 (#1 AND #2 AND #3)

Search strategy for **MEDLINE (Ovid)**

#1 exp "preoperative care"/

#2 exp "surgical procedures, elective"/

#3 exp "referral and consultation"/

#4 (#1 AND #2 AND #3)

Part III

Evaluation

Chapter 5

Evaluation of preoperative assessment and management

5.1 Preface

This chapter describes the evaluation of the costs and effects of an outpatient clinic providing physician-led preoperative assessment and management in Adelaide, South Australia. The article, published in the *Journal of Evaluation in Clinical Practice*, details the propensity-based approaches, including a recently introduced covariate balancing methodology, used to control for confounding in a retrospective observational dataset. The focus of the analysis was to estimate the costs and effects of the physician-led clinic using a mixed retrospective and prospective observational study design. The application of alternative propensity-based approaches to a large sample of retrospective data, supplemented with a smaller sample of prospective data, informed a pragmatic approach to reducing potential observed confounding and assessing the potential for unmeasured confounding in the evaluation.

5.2 Costs and effects of preoperative assessment and management

5.2.1 Statement of authorship

Title of paper: A Comparison of Propensity Score Based Approaches to Health Service Evaluation: a Case Study of a Preoperative Physician-led Clinic for High-Risk Surgical Patients.

Publication status: Published

Publication details: PHAM C, GIBB C, MITTINTY M, FITRIDGE R, MARSHALL V, KARNON J. A Comparison of Propensity Score Based Approaches to Health Service Evaluation: a Case Study of a Preoperative Physician-led Clinic for High-Risk Surgical Patients. *Journal of Evaluation in Clinical Practice* 2016; **22**(5): 761-770. DOI: 10.1111/jep.12537

Name of principal author (Candidate): Clarabelle T Pham

Contribution to the paper: Conception and design, acquisition of data, analysis and interpretation of data, drafted the article and critical revisions, and acted as corresponding author.

Overall percentage: 85%

This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.

Signed:

Date: 30/01/2019

Co-author contributions

By signing the statement of authorship, each author certifies that:

- i. the candidate’s stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate’s stated contribution.

Name of co-author: Catherine L Gibb

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Murthy N Mittinty

Contribution to the paper: Conception and design, analysis and interpretation of data, and revised it critically for important intellectual content.

Signed:

Date: 23/01/2019

Name of co-author: Robert A Fitridge

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Villis R Marshall

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

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Date: 17/01/2019

Name of co-author: Jonathan D Karnon

Contribution to the paper: Conception and design, acquisition of data, interpretation of data, and revised it critically for important intellectual content.

Signed:

Date: 30/01/2019

5.2.2 Publication

Journal of Evaluation in Clinical Practice
International Journal of Public Health Policy and Health Services Research



Journal of Evaluation in Clinical Practice ISSN1365-2753

A comparison of propensity score-based approaches to health service evaluation: a case study of a preoperative physician-led clinic for high-risk surgical patients

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Keywords

evaluation, health services research, health care, medical research, multimorbidity

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Abstract

Rationale, aims and objectives A physician-led clinic for the preoperative optimization and management of high-risk surgical patients was implemented in a South Australian public hospital in 2008. This study aimed to estimate the costs and effects of the clinic using a mixed retrospective and prospective observational study design.

Method Alternative propensity score estimation methods were applied to retrospective routinely collected administrative and clinical data, using weighted and matched cohorts. Supplementary survey-based prospective data were collected to inform the analysis of the retrospective data and reduce potential unmeasured confounding.

Results Using weighted cohorts, clinic patients had a significantly longer mean length of stay and higher mean cost. With the matched cohorts, reducing the calliper width resulted in a shorter mean length of stay in the clinic group, but the costs remained significantly higher. The prospective data indicated potential unmeasured confounding in all analyses other than in the most tightly matched cohorts.

Conclusions The application of alternative propensity-based approaches to a large sample of retrospective data, supplemented with a smaller sample of prospective data, informed a pragmatic approach to reducing potential observed and unmeasured confounding in an evaluation of a physician-led preoperative clinic. The need to generate tightly matched cohorts to reduce the potential for unmeasured confounding indicates that significant uncertainty remains around the effects of the clinic. This study illustrates the value of mixed retrospective and prospective observational study designs but also underlines the need to prospectively plan for the evaluation of costs and effects alongside the implementation of significant service innovations.

Introduction

Advances in medical technology and public health initiatives have increased life expectancy. However, the consequences in terms of the health and medical needs of an ageing population are a global issue for health care providers and health care systems worldwide. More than 80% of Australians aged 65 years and over have three or more co-morbidities [1]. In the USA, 62% of the population aged between 65 and 74 years and 81% aged 85 years and over have two or more co-morbidities [2], with similar numbers reported in the UK [3]. In surgical patients, co-morbidities affect the rate and extent of post-surgical recovery, resulting in higher health service costs and poorer patient outcomes [4]. Targeted

preoperative management of potentially modifiable co-morbidities may improve postoperative outcomes [5–8]. A high-risk clinic for the preoperative medical optimization and management of high-risk surgical patients has been operating in a South Australian public hospital since 2008, but the costs and consequences of the clinic have not been formally evaluated. Evaluation is required to justify the continuation of the clinic, as well as to inform the potential value of expanding preoperative management to other facilities.

The aim of this paper is to assess the value of a mixed retrospective and prospective study design for the evaluation of an existing health service, which provides an empirical assessment of a potential unmeasured confounder. The study also compares the

application of alternative propensity score-based approaches to the retrospective data with respect to minimizing potential observed confounding.

Methods

The retrospective study aimed to analyse the costs and consequences of a preoperative clinic for high-risk surgical patients (compared with no preoperative clinic) using alternative propensity-based methods to adjust for potential observed confounders. A supplementary prospective study of quality of life in patients attending and not attending the high-risk clinic informed the likelihood of unmeasured confounding in the retrospective study.

Retrospective study

Setting. A cost–consequence analysis was performed using a retrospective cohort of patients scheduled for elective surgery between January 2008 and December 2011 at the Royal Adelaide Hospital (RAH).

Patients were referred to the high-risk clinic ('clinic') at the discretion of the surgical consultant or anaesthesiologist around the time of the decision to undergo surgery (no formal referral pathway was defined). All patients scheduled for elective surgery were seen by the preoperative anaesthetic service approximately 1 week before surgery, where anaesthesiologists provided standard preoperative care.

In the high-risk clinic, a consultant physician and nurse, who both specialized in the provision of medical optimization and management of high-risk patients, assessed patients in an outpatient setting prior to surgery and through to recovery and rehabilitation in the postoperative period. There were four clinics per week with an average of 24 patients seen per week (16 new patients and 8 patients with follow-up visits). All referrals were triaged according to surgical priority, with patients awaiting curative surgery for malignancy prioritized over those awaiting non-life saving elective surgery.

Patients who were not referred to the clinic either proceeded to surgery without further specialist consultation or were referred, at the surgeon's discretion, to a specialist for management of a specific condition (e.g. cardiologist and nephrologist). Patients may not have been referred to the clinic for a variety of reasons, such as further management was not required, the surgeon was not aware of the clinic and its services, and the surgeon's preference was to refer to a specialist for management of a specific condition (e.g. cardiologist and nephrologist).

Participants. Eligibility criteria for the analysis of the clinic included patients who were aged 18 years and over at the time of referral and who were scheduled for one of five elective surgical procedures [transurethral resection of the prostate (TURP); total hip or knee replacements (THR, TKR); and surgery for abdominal aortic aneurysm (AAA), head and neck cancer (HNC) and colorectal cancer (CRC)]. The selected procedures account for approximately two-thirds of the patient population referred to the clinic. In cases where a patient had several eligible procedures, the

procedure associated with a referral to the high-risk clinic was coded as the index event; otherwise, the first procedure was coded.

Data sources. Detailed patient and clinical information on all public and private hospital separations were extracted from hospital and state-level data systems. Data from the patient who completed Preoperative Assessment Patient Questionnaire were extracted from patient records, which provided additional information on patients' health status, existing condition(s) and current medication(s). Laboratory test results were obtained from the Red Cross Blood Service and South Australian Pathology, and patient-level inpatient cost estimates were provided by the Department of Health. The high-risk clinic database provided data on patients who were referred to the clinic, including the number and dates of clinic appointments.

The primary measure of outcome was length of stay (LoS), with secondary outcomes including postoperative complications, total inpatient costs (for the index separation) and 12-month mortality. Costs for running the clinic, based on staff salaries, were calculated for new and follow-up appointments and added to inpatient costs for each clinic patient.

Data analysis. The observational data were analysed using a two-step process:

- 1 Propensity score estimation to adjust for observed confounding (model for treatment) [9].
- 2 Regression analyses to examine the association between patients who attended the clinic and surgical outcomes (models for outcomes).

Covariables. Covariables that could potentially influence whether a patient was referred to the clinic were selected a priori and were based on clinical consultation and previous studies [10,11]. Covariables included patient demographics, surgery-related factors, whether the patient had a fall in the previous 12 months, patient's physical function and nine medical comorbidities targeted by the high-risk clinic with the greatest potential to be modified: ischaemic heart disease, congestive heart failure, stroke, diabetes mellitus, renal impairment, anaemia, dementia including Alzheimer's disease, asthma or chronic obstructive pulmonary disease, and primary hypertension (Table 1) [12]. The number of days since the clinic was established was also included as a covariable to account for changes in surgical and medical treatment and management.

Propensity score estimation. Propensity scores were initially estimated using standard logistic regression and boosted logistic regression. Logistic regression focuses on finding parameter estimates that maximize the fit of the data (maximum likelihood estimation) rather than maximize the covariate balance, which should occur if the model is correctly specified [13]. Boosted logistic regression improves on the standard by using a data-adaptive algorithm, which accommodates for various types of covariates (continuous, nominal and ordinal), and a non-parametric model to reduce the risk of model misspecification errors [14]. Despite the improvement in the propensity score models from standard to boosted, both approaches failed to achieve covariate balance with

Table 1 Patient characteristics, pre-propensity and post-propensity score weighting

Characteristic	Unweighted					Propensity weighted			
	Clinic (n = 121)	Control (n = 700)	Standardized difference	Variance ratio	P-value	Control	Standardized difference	Variance ratio	P-value
Age (mean years)	73.6	69.2	0.41	0.75	0.00	73.5	0.01	0.96	0.95
Female	37.2	38.4	-0.03	0.99	0.80	37.2	0.00	1.00	0.99
Surgical procedure				0.98	0.69			1.00	1.00
Abdominal aortic aneurysm	7.4	9.1	-0.06	0.83	0.54	7.7	-0.01	0.97	0.93
Transurethral resection of prostate	9.1	8.9	0.01	1.04	0.93	9.1	0.00	1.01	0.99
Total knee replacement	22.3	22.7	-0.01	1.00	0.92	22.1	0.01	1.01	0.96
Total hip replacement	22.3	27.0	-0.11	0.89	0.28	22.5	0.00	1.00	0.97
Head and neck cancer surgery	16.5	12.0	0.14	1.32	0.17	16.2	0.01	1.02	0.94
Colorectal cancer surgery	22.3	20.3	0.05	1.08	0.61	22.5	0.00	1.00	0.98
Surgical severity				0.98	0.79			1.00	1.00
Mild	20.7	19.1	0.04	1.07	0.70	20.7	0.00	1.01	0.99
Moderate	76.9	77.3	-0.01	1.02	0.92	76.7	0.00	1.00	0.98
Significant	2.5	3.6	-0.06	0.70	0.54	2.6	0.00	0.97	0.96
Urgency category				0.95	0.35			1.01	1.00
Within 30 days	48.8	44.3	0.09	1.02	0.75	48.7	0.00	1.01	0.99
Within 90 days	18.2	15.7	0.07	1.13	0.95	18.5	-0.01	0.99	0.95
Within 1 year	33.1	40.0	-0.14	0.93	0.58	32.9	0.00	1.01	0.97
SEIFA (mean score)	959.7	968.0	-0.11	0.84	0.25	960.2	-0.01	0.74	0.95
BMI (mean score)	29.5	28.5	0.17	1.15	0.09	29.4	0.02	0.73	0.89
Smoking status				0.96	0.85			1.02	0.99
Never	39.7	38.1	0.03	1.02	0.75	38.8	0.02	1.01	0.88
Former	48.8	48.4	0.01	1.01	0.95	49.7	-0.02	1.01	0.88
Current	11.6	13.4	-0.05	0.89	0.58	11.5	0.00	1.01	0.99
Marital status				1.11	0.18			1.03	1.00
Never married	10.7	11.1	-0.01	0.97	0.90	10.4	0.01	1.03	0.92
Married/ <i>de facto</i>	51.2	60.1	-0.18	1.05	0.07	51.9	-0.01	1.01	0.91
Widowed	19.0	15.1	0.11	1.20	0.28	19.3	-0.01	0.99	0.95
Divorced	16.5	10.1	0.20	1.53	0.04	15.8	0.02	1.04	0.88
Separated	2.5	3.4	-0.05	0.73	0.59	2.5	0.00	0.99	0.97
Medical co-morbidities									
Ischemic heart disease	66.1	32.0	0.71	1.03	0.00	65.4	0.02	1.00	0.89
Congestive heart failure	5.0	0.7	0.37	6.74	0.00	4.6	0.03	1.08	0.91
Stroke	19.0	6.0	0.48	2.74	0.00	17.9	0.04	1.05	0.83
Diabetes mellitus	33.1	20.1	0.31	1.39	0.00	32.1	0.02	1.02	0.87
Renal impairment	34.7	16.7	0.46	1.64	0.00	34.6	0.00	1.01	0.98
Anaemia	40.5	26.4	0.31	1.25	0.00	40.1	0.01	1.01	0.94
Dementia including Alzheimer's	3.3	0.6	0.28	5.76	0.01	3.0	0.03	1.11	0.91
Asthma/COPD	44.6	30.6	0.30	1.17	0.00	44.7	0.00	1.00	0.99
Hypertension	16.5	7.1	0.34	2.09	0.00	15.5	0.04	1.06	0.83
Fall in previous 12 months	5.8	2.3	0.21	2.43	0.03	4.8	0.06	1.18	0.73
Able to walk around house	57.9	70.0	-0.26	1.17	0.01	58.2	-0.01	1.01	0.96
Able to walk upstairs	37.2	50.9	-0.27	0.94	0.01	37.1	0.00	1.01	0.98
Physical disabilities	38.8	25.4	0.30	3.71	0.00	38.1	0.02	1.01	0.90
Artificial joints/implants	20.7	25.6	-0.11	0.87	0.25	20.7	0.00	1.01	1.00
Days since clinic was established (mean)*	1127.9	1048.3	0.23	0.82	0.02	1126.3	0.00	0.76	0.97

Data are presented as percentages of each group unless otherwise specified.

BMI, body mass index; SEIFA, socioeconomic indexes for areas; ENT, ears, nose and throat; COPD, chronic obstructive pulmonary disease.

*The number of days since the high-risk clinic was established on 1 January 2008.

standardized differences of >10% between the clinic and control groups in 14 and 10 of the 24 covariables for the standard and boosted logistic regressions, respectively.

The covariate balancing propensity score (CBPS) method [15] is an alternative approach that replaces the maximum likelihood

estimation in the logistic regression with a non-parametric method of moments estimation that uses the entire distribution of baseline covariates, an important factor when dealing with skewed data. The fundamental aim of CBPS is to estimate the propensity score that preserves the property of balancing covariates. The CBPS

estimation method can also yield robust estimates of treatment effects, even when both the outcome and propensity score models are misspecified and does so at the cost of some likelihood. This method focuses on minimizing the imbalance of covariates when calculating the parameter estimates and was able to balance all 24 covariables, with standardized differences and variance ratios for covariables between the clinic and control groups all <10% and <2.0, respectively.

The sensitivity of treatment effect estimates was tested using two propensity score methods: weighting using the propensity score [16] and matching on the propensity score [17]. With weighting, overall estimates of the average treatment effect on the treated (ATT) were calculated based on the CBPSs. With matching, patients attending and not attending the clinic were matched (1:1) on the predicted propensity of being referred to the clinic. The nearest neighbour matching method without replacement was used with callipers set to 0.0001, 0.001 and 0.01, respectively. This approach pairs clinic with control patients such that the difference in probabilities between the matched patients differs by a maximum at most a fixed distance (the calliper width). An optimal calliper width of 20% of the standard deviation of the predicted propensity scores has been proposed [18], but the resulting calliper width of 0.035 was considered too wide, resulting in clinically significant differences in covariables between the matched clinic and control patients. A calliper of 0.0001 generated highly similar matches but produced too few matched patients (23 patients). Thus, calliper widths of 0.001 and 0.01 were applied to provide a range of estimates given the variance–bias trade-off. One-to-one matching (over 1:N matching) was used as it provides similar observations to construct the counterfactuals and thus reduce bias. This reduction in bias comes at a cost of a decrease in precision, but the reduction of bias was considered the dominant issue in this analysis.

Propensity score methods were performed using Stata [19] and the R statistical programming language [20]. Stata's 'pscore' command was used for the standard logistic regression. In R, the 'twang' package [21] was used for the boosted logistic regression and the 'CBPS' package [22] for the CBPS method. Matching was performed in Stata using the 'psmatch2' command with the probabilities from the CBPS method imported from R.

Outcome analyses. Propensity-weighted regression methods, using ATT weights derived from the CBPS estimation, tested for associations between outcomes and clinic patients. For count data (LoS, total inpatient costs and number of postoperative complications), negative binomial regressions were used to account for the over-dispersion. Logistic regression was used for the binary outcome of 12-month mortality. Non-parametric bootstrapping (1000 iterations) was then applied to estimate the 95% confidence intervals (CI). Paired *t*-tests for count data and the McNemar test for binary data were used to compare outcomes after propensity score matching.

Results are presented as ATT with 95% CI. Costs are reported in Australian Dollars (AUD). *P*-values of less than 0.05 were considered statistically significant. Regression analyses and bootstrapping were performed using the R statistical programming language [20].

Supplementary prospective study

Setting. The aim of this supplementary study was to collect prospective health-related quality of life (HRQOL) data on a cohort of patients listed for surgery, to test for potential unmeasured confounding due to the use of retrospective data for the main analysis. Patients listed for elective surgery between June 2012 and October 2013 at the RAH were identified via hospital elective surgery waiting lists.

Participants. Identified patients were eligible if they were aged 18 years and over and listed for at least one of the selected elective surgical procedures (TURP, THR, TKR, AAA, HNC and CRC).

Data collection and analysis. Eligible patients were sent a survey including the EuroQOL five-dimension questionnaire (EQ-5D-5L) [23] and a set of additional co-morbidity questions, via postal mail. The EQ-5D-5L is the new, updated version of one of the most widely used health status instruments (the EQ-5D) and comprises five questions, each with five levels, representing five health domains: pain, mood, mobility, self-care and daily activities [24]. Data from the Preoperative Assessment Patient Questionnaire were also collected.

The EQ-5D profiles were transformed, using the value set for the UK, into weighted health state index scores, ranging from –0.594 (worst health state) to 1.00 (best health state) [25].

The CBPS estimation method, as described in the main study analyses, was used on this prospective dataset. Regression using generalized linear modelling was used to test the association between health state index scores and clinic patients. Non-parametric bootstrapping (1000 iterations) was then applied to estimate the 95% CI. Results are presented as ATT with 95% CI. *P*-values of less than 0.05 were considered statistically significant. Regression analyses and bootstrapping were performed using the R statistical programming language [20].

Ethics approval for the main and sub-study was granted by the South Australian Department of Health Human Research Ethics Committee (HREC Protocol No. 490/01/2015) and the Royal Adelaide Hospital Research Ethics Committee (RAH Approval No. 120225/120225a).

Results

Retrospective study

Of the 943 eligible patients, 821 patients had complete-case data and 122 patients had data missing for at least one of the covariables of interest. Body mass index and socioeconomic indexes for areas score had the highest proportions of missing data.

Of the 821 patients, 121 (14.7%) were in the clinic group and 700 (85.3%) were in the control group, with total joint replacements making up the majority of the selected elective procedures.

Table 1 details the characteristics of the control and clinic patients pre-propensity and post-propensity score weighting. Compared with control patients, clinic patients were significantly more likely to be older, have a higher body mass index, have modifiable co-morbidities targeted by the clinic, a fall in the previous 12 months and physical disabilities. Clinic patients were also

significantly less likely to be able to walk around the house and/or upstairs. After weighting, there were no significant differences between the two groups for all the covariables, with standardized differences of <10% and variance ratios of <2.0 for all 24 covariables indicating negligible differences and support of the assumption of balance between the two groups [26]. The percentage of overlap between the clinic and control propensity score distributions was 94% (Fig. 1).

High-risk clinic. The 121 patients referred to the clinic had a mean 1.6 clinic appointments prior to their elective surgical procedure.

Surgery was cancelled after admission for none of the clinic patients and seven of the control patients. Of these seven control patients, TURP surgery was cancelled in three patients at a total cost of \$9149, CRC surgery in two patients at a total cost of \$1539, HNC surgery in one patient at a cost of \$445 and TKR surgery in one patient at a cost of \$708. The total cost that could have potentially been avoided for the seven admissions with cancelled surgery was \$11 841.

Propensity-weighted regression

Length of stay and costs. Table 2 presents the results from the weighted regression analyses for LoS and costs. Across all procedures, patients attending the clinic had a significantly longer mean LoS (9.1 days versus 7.75 days) and significantly higher mean costs (\$22 512 versus \$17 210). For the non-cancer procedures, there were no significant differences in LoS and costs between the two groups, although the mean differences in LoS and costs were reduced compared with all procedures. For the cancers, both CRC and HNC clinic patients had longer LoS and higher costs (Table 3).

Complications and 12-month mortality. For all procedures and non-cancer procedures, clinic patients had a higher mean number of complications although these differences were not

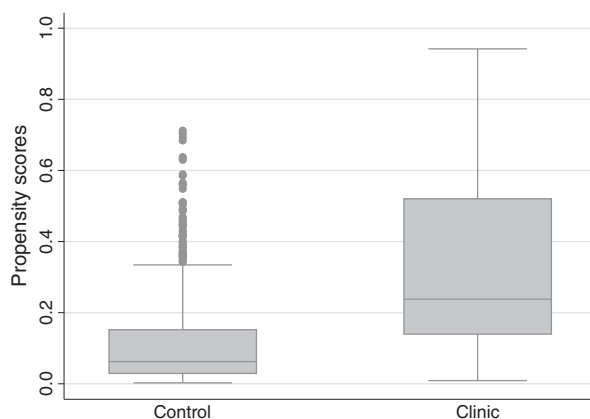


Figure 1 Distributions of propensity scores for clinic and control groups indicating degree of overlap.

significant (Table 2). By procedure, TURP and CRC had fewer mean complications in the clinic group compared with control (Table 3).

The proportion of patients dying within 12 months was higher in the clinic group for all procedures and non-cancer procedures. Higher proportions of clinic patients died within 12 months for AAA, TURP and THR (Table 3). For the cancer procedures, the proportion of death within 12 months was slightly lower for HNC and higher for CRC in clinic patients.

Propensity score matching

Length of stay and costs. For all procedures, reducing the calliper width reduced the mean difference in LoS between the clinic and control groups, but the costs remained significantly higher for the clinic patients. For the non-cancer procedures, the more restrictive calliper resulted in a shorter mean LoS in clinic patients (Tables 2 and 3). For the cancer procedures, matching reduced the mean differences in LoS and costs for HNC, but CRC clinic patients had a significantly longer mean LoS and significantly higher mean costs (Table 3).

Complications and 12-month mortality. The more restrictive calliper resulted in lower mean numbers of complications in clinic patients for the non-cancer procedures and all procedures and the largest differences in favour of the clinic (Tables 2 and 3).

Results on the proportion of patients dying within 12 months for all procedures and non-cancer procedures were consistent with the regression results (Table 2). For all procedures, 12 clinic and 8 control patients died with the 0.01 calliper matching, and seven clinic and four control patients died with the 0.001 calliper matching.

Supplementary prospective study

Of the 645 questionnaires that were sent to eligible patients, 408 (63%) were returned with 22 only partially completed (some EQ-5D dimensions were missing responses). Of the 386 (60%) fully completed questionnaires, 51 (13%) were in the clinic group and 335 (87%) were in the control group. Total joint replacements again accounted for the majority (53%) of the selected elective procedures.

The mean unweighted index score for the clinic group was significantly lower than the control group (0.452 versus 0.551, 95% CI $-0.19, -0.01$).

Using regression analysis to control for differences in other baseline characteristics (i.e. the variables included in the retrospective evaluation), patients attending the clinic had a significantly lower mean index score than control patients (0.452 versus 0.548, 95% CI $-0.188, -0.010$) (Table 4), across all procedures. For the non-cancer procedures, results from the matching were consistent with the regression findings, with a lower mean index score in clinic patients. However, the inclusion of cancer procedures (all procedures) resulted in clinic patients reporting higher mean index scores with the more restrictive calliper. The index scores by procedure for the matched cohorts are not presented as subgroup analysis resulted in very small numbers.

Table 2 Aggregate outcomes for unweighted data and after propensity score weighting and matching

Outcomes	Unweighted*				Weighted				Matched				
	Clinic		Control		ATT	95% CI	n [‡]	ATT	95% CI	0.01 calliper		0.001 calliper	
	Mean (SD)	n	Mean (SD)	n						n [‡]	ATT	95% CI	n [‡]
Length of stay (days)													
Non-cancer procedures only	7.45 (4.53)	548	6.46 (5.11)	548	0.46	-0.91, 1.74	56	0.71	-0.94, 2.36	35	-0.68	-2.98, 1.63	
All procedures	9.10 (5.73)	821	7.19 (5.87)	821	1.35	0.19, 2.57	96	0.87	-0.99, 2.73	69	0.47	-1.74, 2.68	
Costs (AUD)													
Non-cancer procedures only	19669 (11 783)	548	18531 (13 141)	548	772	-2189, 4429	56	-2124	-6897, 2648	35	44	-4246, 4334	
All procedures	22512 (15 951)	821	17782 (13 191)	821	5302	2433, 8334	96	6043	2537, 9550	69	5804	883, 10 724	
Number of complications													
Non-cancer procedures only	1.45 (2.35)	548	1.03 (1.94)	548	0.22	-0.41, 0.98	56	0.39	-0.40, 1.19	35	-0.11	-1.11, 0.88	
All procedures	1.48 (2.48)	821	0.99 (1.93)	821	0.16	-0.29, 0.75	96	-0.28	-0.95, 0.39	69	-0.41	-1.18, 0.37	
12-month mortality (%)													
Non-cancer procedures only	10.81 (31.26)	548	3.80 (19.13)	548	5.98	-1.84, 14.63	56	3.57	-9.24, 16.39	35	5.71	-10.73, 22.16	
All procedures	12.40 (33.09)	821	6.29 (24.29)	821	4.06	-2.87, 11.39	96	4.17	-5.50, 13.83	69	4.35	-6.47, 15.16	

Negative ATT values indicate shorter length of stay, lower costs and fewer complications or deaths within 12 months for clinic patients.

CBPS, covariate balancing propensity score; ATT, average treatment effect on the treated (calculated as weighted mean outcome for clinic minus weighted mean outcome for control); 95% CI, 95% confidence interval.

*Reported as mean (standard deviation).

[‡]Total number of patients in the weighted cohort.

[‡]Number of patients in each group.

Table 3 Outcomes by procedure for unweighted data and after propensity score weighting and matching

Outcomes	Unweighted*			Weighted				Matched			
	Clinic	Control	n [†]	ATT	95% CI	n [†]	ATT	0.01 calliper		0.001 calliper	
								n [†]	95% CI	n [†]	95% CI
Length of stay (days)											
AAA	6.57 (6.07)	8.34 (8.74)	73	-1.69	-5.95, 2.95	8	-2.64	-9.89, 4.61	6	-2.44	-4.06, -0.83
TURP	3.05 (1.98)	3.07 (2.00)	73	-1.31	-1.16, 1.41	9	-7.47	-15.03, 0.09	7	-9.21	-19.05, 0.62
TKR	7.03 (2.44)	6.56 (4.95)	186	0.05	-2.55, 1.94	20	-1.94	-5.26, 1.39	13	-1.08	-4.25, 2.10
THR	9.96 (4.86)	6.84 (3.60)	216	2.34	-0.71, 4.61	22	2.70	-0.54, 5.93	16	0.84	-3.74, 5.41
HNC	8.90 (5.82)	7.11 (7.30)	104	2.92	-1.97, 5.07	13	-0.02	-5.61, 5.57	11	1.11	-5.00, 7.22
CRC	13.79 (6.22)	9.69 (6.63)	169	2.68	-2.17, 6.31	24	6.32	2.45, 10.20	16	6.25	0.85, 11.65
Costs (AUD)											
AAA	31 276 (16 813)	35 301 (28 132)	73	-978	-11 614, 9664	8	15 917	1414, 30 420	6	10 713	-4528, 25 955
TURP	6250 (3087)	5474 (2291)	73	744	-1024, 2708	9	-13 682	-19 947, -7417	7	-13 682	-19 947, -7417
TKR	16 977 (4247)	17 180 (7895)	186	-682	-5084, 2303	20	-1118	-4690, 2454	13	1609	-4400, 7618
THR	23 960 (11 474)	19 063 (4926)	216	4550	-726, 10 204	22	7791	4286, 11 296	16	5977	2824, 9129
HNC	24 233 (17 465)	17 884 (19 230)	104	10 280	-2386, 15 636	13	6241	-7378, 19 859	11	5617	-18 880, 30 114
CRC	29 091 (22 215)	14 812 (6988)	169	13 835	5981, 22 383	24	13 552	4167, 22 938	16	15 075	2155, 27 995
Number of complications											
AAA	2.89 (4.46)	2.25 (3.55)	73	0.70	-2.28, 3.76	8	0.75	-3.41, 4.91	6	0.67	-0.91, 2.25
TURP	0.82 (1.25)	0.48 (1.04)	73	-0.37	-0.40, 1.17	9	-1.44	-4.08, 1.19	7	-1.86	-5.42, 1.70
TKR	0.93 (1.57)	0.72 (1.39)	186	0.31	-0.64, 1.03	20	-1.30	-2.71, 0.11	13	-1.23	-3.04, 0.58
THR	1.74 (2.25)	1.04 (1.61)	216	0.23	-0.75, 1.54	22	0.41	-0.77, 1.58	16	-0.19	-1.76, 1.38
HNC	0.95 (1.43)	0.51 (1.42)	104	0.30	-0.35, 1.16	13	-0.08	-1.83, 1.68	11	0.73	-0.84, 2.29
CRC	1.96 (3.32)	1.15 (2.14)	169	-0.08	-0.32, 0.89	24	-0.08	-1.62, 1.46	16	-0.50	-2.75, 1.75
12-month mortality (%)											
AAA	22.22 (44.10)	7.81 (27.05)	73	14.00	-10.45, 47.10	8	13.00	-22.92, 47.92	6	16.67	-29.82, 63.15
TURP	27.27 (46.71)	8.06 (27.45)	73	9.90	-7.69, 47.38	9	22.22	-16.05, 60.49	7	14.29	-25.92, 54.49
TKR	0.00 (0.00)	1.26 (11.18)	186	-0.41	-3.45, 0.00	20	-15.00	-35.65, 6.65	13	-7.69	-29.87, 14.49
THR	11.11 (32.03)	3.17 (17.58)	216	8.15	-16.82, 22.05	22	9.09	-7.47, 26.65	16	0.00	-6.25, 6.25
HNC	20.00 (41.04)	19.05 (39.50)	104	-0.95	-19.44, 24.59	13	15.38	-21.28, 52.05	11	18.18	-24.89, 61.25
CRC	11.11 (32.03)	7.04 (25.68)	169	2.26	-13.79, 19.34	24	0.00	-24.17, 24.17	16	0.00	-30.75, 30.75

Negative ATT values indicate shorter length of stay, lower costs and fewer complications or deaths within 12 months for clinic patients.

CBPS, covariate balancing propensity score; ATT, average treatment effect on the treated (calculated as weighted mean outcome for clinic minus weighted mean outcome for control); 95% CI, 95% confidence interval; AAA, abdominal aortic aneurysm; TURP, transurethral resection of prostate; TKR, total knee replacement; THR, total hip replacement; HNC, head and neck cancer; CRC, colorectal cancer.

*Reported as mean (standard deviation).

[†]Total number of patients in the weighted cohort.

*Number of patients in each group.

Table 4 Differences in health state index scores for unweighted data and after propensity score weighting and matching

Health-related quality of life	Unweighted*		Weighted			Matched					
	Clinic	Control	<i>n</i> [†]	ATT	95% CI	0.01 calliper			0.001 calliper		
						<i>n</i> [‡]	ATT	95% CI	<i>n</i> [‡]	ATT	95% CI
All procedures	0.452 (0.306)	0.551 (0.315)	382	-0.096	-0.188, -0.010	37	-0.042	-0.189, 0.105	19	0.009	-0.202, 0.219
Non-cancer procedures only	0.625 (0.279)	0.735 (0.244)	176	-0.147	-0.302, 0.021	9	-0.086	-0.322, 0.150	3	-0.036	-0.604, 0.532
By procedure											
AAA	0.656 (0.417)	0.662 (0.267)	44	-0.062	-0.482, 0.367	—	—	—	—	—	—
TURP	0.623 (0.304)	0.757 (0.248)	17	-0.087	-0.544, 0.095	—	—	—	—	—	—
TKR	0.570 (0.245)	0.757 (0.209)	43	-0.074	-0.453, 0.043	—	—	—	—	—	—
THR	0.655 (0.195)	0.787 (0.231)	72	-0.162	-0.383, 0.120	—	—	—	—	—	—
HNC	0.404 (0.203)	0.448 (0.239)	106	-0.070	-0.191, 0.135	—	—	—	—	—	—
CRC	0.209 (0.356)	0.328 (0.299)	100	-0.140	-0.388, 0.279	—	—	—	—	—	—

Negative ATT values indicate lower health state index scores in clinic patients. Health state index scores for each procedure in the matching cohorts are not presented as the sample sizes after subgroup analysis are too small.

CBPS, covariate balancing propensity score; ATT, average treatment effect on the treated (calculated as weighted mean outcome for clinic minus weighted mean outcome for control); 95% CI, 95% confidence interval; AAA, abdominal aortic aneurysm; TURP, transurethral resection of prostate; TKR, total knee replacement; THR, total hip replacement; HNC, head and neck cancer; CRC, colorectal cancer.

*Reported as mean (standard deviation).

[†]Total number of patients in the weighted cohort.

[‡]Number of patients in each group.

Discussion

This study has reported a mixed retrospective and prospective evaluation of a new hospital service – a physician-led preoperative clinic for high-risk patients scheduled for elective surgery. The aim of the clinic is to optimize medical co-morbidities in patients in preparation for elective surgery and coordinate postoperative care. The service was implemented incrementally, without a formal referral pathway or evaluation plan. As the service expanded, hospital managers requested evidence of the value of the clinic to support continued investment in the service.

The rationale for a retrospective evaluation of the high-risk clinic included the availability of a wide range of data sources and patient-level variables that could be used to control for potential confounding using appropriate statistical methods; the absence of a formal referral pathway suggested that not all high-risk patients would be referred to the clinic (increasing the likelihood of an appropriate control group for comparison); and the extended timeframe required to conduct a comprehensive prospective evaluation.

The results of the retrospective analyses varied according to the methods used to control for observed potential confounding. The propensity-weighted regression methods found that patients who attended the high-risk clinic had increased LoS and costs compared with control patients. Using propensity-based matching, especially with narrower calliper widths, differences in LoS and complications were reduced, and in some cases, outcomes were improved in clinic patients, although costs remained significantly higher. The high degree of overlap (common support) between the clinic and control groups (94%) justified the inclusion of weighting as a potentially valid approach for this comparative analysis. The subsequent analyses suggested that weighting was not as robust as the matched analyses but was a relevant option because of the benefits of maintaining a larger sample size. Matching on the propensity score closely matched cases and controls in

terms of their baseline characteristics, but the sample sizes were substantially reduced.

The observed increase in inpatient costs may be partly due to the labelling effect of the clinic, that is, clinic patients are labelled as being high risk, which results in additional attention and resource use over the inpatient episode. Mean 12-month mortality remained higher in the clinic group in the matched analysis (seven deaths in the clinic group versus four deaths in the control group). There is no rationale for a negative clinic effect on 12-month mortality, and so these results may reflect random variation (the finding was not statistically significant) or indicate remaining unobserved potential confounding.

Previous studies of preoperative medical optimization include a randomized controlled trial that reported a decrease in LoS (0.5-day decrease, 95% CI -2.0 to 1.1) in patients who received medical preoperative evaluation in an outpatient setting (within 3 weeks of surgery) [27]. Other observational studies have reported longer lengths of stay [10,11], higher costs [10] and higher risks of death at 30 days and 1 year [11] in patients who received preoperative medical assessment. Auerbach *et al.* [10] used propensity scores as weights to adjust for confounding, but the authors indicated that patterns of consultation and other unmeasured confounding factors in the patient's medical history or illness may have biased their results. Further, only the discriminative power of the propensity score model was mentioned and not whether covariate balance was achieved. Wijesundera and colleagues [11] also indicated that their data sources may have lacked sufficient detail for adequate risk adjustment using propensity score matching.

In this study, we collected a wider range of baseline covariates than previous observational studies in an attempt to better adjust for potential confounding factors. We compared alternative propensity score-based approaches to analysing observational data, including the recently proposed CBPS methodology. The CBPS method has been shown to improve the robustness of propensity

score models in terms of balancing covariates and reducing bias [13]. Propensity scores are estimated such that both covariate balance and prediction of treatment assignment are maximized with both model fitting and balance checking implemented simultaneously [15]. This is an improvement on the existing methods (e.g. standard logistic regression and boosted logistic regression) that estimate the probability of treatment assignment and assume automated covariate balancing. In our study, standard and boosted logistic regression approaches failed to achieve covariate balance, whilst the CBPS method achieved balance between a highly complex and sicker patient intervention group and a less complex control group.

The study design also included a supplementary prospective survey that collected additional baseline information as patients were listed for elective surgery, to identify differences between clinic and non-clinic patients who were not captured by the available retrospective data. Preoperative quality of life was identified as a potential unobserved confounder, which has previously been shown to be significantly associated with postoperative morbidity and hospital readmission [28] and could provide an early indicator for patients at risk of complications [29,30] and death [31] after surgery. To test for the presence of unobserved confounding, HRQOL data were collected from elective surgery patients prospectively. After adjustment for the covariables included in the retrospective analysis, the weighted analysis showed the clinic group to have significantly lower mean HRQOL index scores. However, differences in HRQOL were reduced in the matched analyses, especially with the more restrictive 0.001 calliper matching. This result suggests that the retrospective analyses using the 0.001 calliper matching may provide unbiased estimates of the effect of the clinic. The results from the 0.001 calliper matching showed positive mean effects on LoS and complications for patients undergoing non-cancer procedures, with statistically significant improvements within specific procedure groups.

The prospective data were collected via postal survey, which may have reduced the sensitivity with which potential confounders were measured. One such potential confounder is frailty, which has been shown to be a predictor of surgical morbidity and mortality and may impact greatly on whether a patient is referred for preoperative medical consultation [32–34]. The available data could inform a frailty index, describing the accumulation of deficits [35], but data to inform an objective measure of frailty were lacking (e.g. weight loss, exhaustion, weakness, slowness and low levels of activity) [36].

Other limitations of the analyses include the sample size. Using a weighted cohort, we were able to preserve the full sample of 121 clinic patients and draw on a control group of 700 patients. However, given the heterogeneity of the patient population and the treatment effects, and the sensitivity of the weighted estimates to extreme observations, the number of clinic patients since the inception of the high-risk clinic may not have been large enough to detect any significant differences. For the more restricted calliper matching, the sample sizes were substantially reduced as not all of the clinic patients could be matched to similar control patients.

Clearly, some form of randomized controlled trial is the preferred study design for the evaluation of such interventions, but in the absence of resources and buy-in to undertake an experimental study, can sufficiently robust data be collected and analysed to overcome the limitations observed in this study?

Further evaluation might be usefully expanded to include hospitals in which the preoperative clinic has not been implemented, in order to provide greater covariate balance between the intervention and control groups. The need to collect prospective data precludes the use of a conventional pretest/posttest study with a contemporaneous control study design, but procedure-specific differences in outcomes for cohorts matched to clinic and control patients at the study hospital could inform an adapted pretest/posttest approach.

In conclusion, patients referred for preoperative medical optimization have complex care requirements and are often in poorer health compared with the general surgical population. The application of alternative propensity-based approaches to a large sample of retrospective data, supplemented with a smaller sample of prospective data, informed a pragmatic approach to reducing potential observed and unobserved confounding in an evaluation of a physician-led preoperative clinic. The physician-led high-risk clinic reduced the frequency of unnecessary admissions and cancellations, but significant uncertainty remains around the effect of the clinic on LoS, complications, costs and post-discharge mortality. This study illustrates the value of mixed retrospective prospective observational study designs but also underlines the need to prospectively plan for the evaluation of costs and effects alongside the implementation of significant service innovations.

Acknowledgements

This study was supported by a National Health and Medical Research Council Project Grant APP1025140. The authors thank Dr John Field for his statistical contribution and advice; Graeme Tucker, Tina Hardin and Phil Battista for the provision and linkage of data; Margaret Clark for the provision of additional clinical and patient data; and unit secretaries, nurses and medical records staff at the Royal Adelaide Hospital for their support with accessing files for data collection. We also thank all the participants in the quality-of-life questionnaire.

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5.2.3 Erratum

The authors would like to apologize for the error that was published in the article:

Pham C, Gibb C, Mittinty M, Fitridge R, Marshall V, Karnon J. A Comparison of Propensity Score Based Approaches to Health Service Evaluation: a Case Study of a Preoperative Physician-led Clinic for High-Risk Surgical Patients. *Journal of Evaluation in Clinical Practice* 2016; 22(5): 761-770.

An error was detected in the code and the number of covariables with standardized differences of >10% between clinic and control groups for the standard and boosted logistic regressions is incorrect. The corrected section of this article is printed below:

Page 762, right column, last paragraph, last sentence:

The propensity score models did not improve from standard to boosted. Both approaches failed to achieve covariate balance with standardized differences of >10% between the clinic and control groups for 2 and 13 covariables in the standard and boosted logistic regressions, respectively. Given that the aim of boosted logistic regression is to minimize the prediction error, the increase in the number of unbalanced covariables suggested that this approach was inappropriate for confounder adjustment in this dataset (Friedman 2001).

Friedman JH. Greedy function approximation: a gradient boosting machine. *Annals of Statistics* 2001; 29(5): 1189-1232.

5.3 Data sources

5.3.1 Preoperative Assessment Patient Questionnaire

A retrospective casenote review was conducted to collect additional co-morbidity data on the control patients to match the level of detail recorded in the clinic database on clinic patients. All patients scheduled for elective surgery at the Royal Adelaide Hospital receive a booking pack containing forms that must be completed and

returned, one of which is a preoperative assessment patient questionnaire (PAPQ) (Figure 5.1). Additional information on the patient's health status, existing condition(s) and current medication(s) are collected via this questionnaire that is placed in the patient's medical records as a reference but the data is not entered into the electronic database. Data from the PAPQ were manually extracted from medical case records within the medical records department at the Royal Adelaide Hospital.

5.3.2 Surgical severity

The Johns Hopkins Surgical Risk Classification System (JHSRCS) was used as an indicator of surgical severity, a covariable in the propensity score estimation, for the range of elective surgical procedures included in the analysis (Table 5.1). This classification system is based on a combination of factors that contribute to the risk of surgery, including invasiveness, associated blood loss and fluid shift, entry into specific body areas (e.g. intrathoracic and intracranial), postoperative anatomic and physiologic alterations, and the need for postoperative intensive care monitoring.

5.3.3 Health-related quality of life

Health-related quality of life (HRQOL) data was collected using the EuroQOL five-dimension questionnaire (EQ-5D) (EuroQol Group 1990). The EQ-5D-5L is the updated version of the EQ-5D, one of the most widely used health status instruments, and comprises five questions, each with five levels, representing five health domains: pain, mood, mobility, self-care and daily activities (Herdman *et al.* 2011). Further detailed questions on the patient's medical co-morbidities were included in the additional questionnaire to determine whether additional information on the severity of such co-morbidities could improve the characterisation of clinic patients. Figure 5.2 details the research questionnaire that was sent to patients for completion.

Figure 5.1: The Preoperative Assessment Patient Questionnaire.

<p>PRE-OPERATIVE ASSESSMENT PATIENT QUESTIONNAIRE</p> <p style="text-align: center;">TQEH <input type="checkbox"/> RAH <input type="checkbox"/></p>	<p style="text-align: center;">PATIENT LABEL</p> <p>Unit Record No.: _____</p> <p>Surname: _____</p> <p>Given Names: _____</p> <p>Date of Birth: _____ Sex: _____</p>																																	
<p>PLEASE TICK RELEVANT BOX AND ANSWER ALL QUESTIONS (on all 4 pages)</p>																																		
<p>YES NO</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you have any allergies to medications, foods, or skin sensitivities?</p>																																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">Allergy to (please list)</th> <th style="width: 50%; text-align: center;">Reaction (what happens to you)</th> </tr> </thead> <tbody> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </tbody> </table>		Allergy to (please list)	Reaction (what happens to you)																															
Allergy to (please list)	Reaction (what happens to you)																																	
<p><input type="checkbox"/> <input type="checkbox"/> Do you take any medications/drugs? Please list ALL medications and tablets, including inhalers, eyedrops, drugs that are not prescribed, herbal medications, recreational drugs, etc.</p>																																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">Name of medication</th> <th style="width: 20%; text-align: center;">How much? (dose)</th> <th style="width: 30%; text-align: center;">How many times per day?</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>		Name of medication	How much? (dose)	How many times per day?																														
Name of medication	How much? (dose)	How many times per day?																																
<p><input type="checkbox"/> <input type="checkbox"/> Have you had an anaesthetic before? If yes, when was the last one?.....</p>																																		
<p><input type="checkbox"/> <input type="checkbox"/> Have you had any problems with anaesthetics? Details:</p> <p>.....</p>																																		
<p><input type="checkbox"/> <input type="checkbox"/> Have you any blood relatives who have had problems with anaesthetics? Details:.....</p> <p>.....</p>																																		
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Operation Date/Year	Type of Operation	Which Hospital?																																

PRE-OPERATIVE ASSESSMENT - PATIENT QUESTIONNAIRE MR 48.3

<p>PRE-OPERATIVE ASSESSMENT PATIENT QUESTIONNAIRE</p> <p>TQEH <input type="checkbox"/> RAH <input type="checkbox"/></p>	<p>PATIENT LABEL</p> <p>Unit Record No.: _____</p> <p>Surname: _____</p> <p>Given Names: _____</p> <p>Date of Birth: _____ Sex: _____</p>
<p>Can you normally walk without stopping?</p> <p>YES NO</p> <p><input type="checkbox"/> <input type="checkbox"/> Around the house only</p> <p><input type="checkbox"/> <input type="checkbox"/> Upstairs</p> <p style="padding-left: 40px;">half a flight of stairs <input type="checkbox"/></p> <p style="padding-left: 40px;">one flight of stairs <input type="checkbox"/></p> <p style="padding-left: 40px;">two flights of stairs (one floor) <input type="checkbox"/></p> <p style="text-align: right;">What stops you from walking further (eg. chest pain, arthritis, pain, etc)?</p> <p style="text-align: right;">.....</p> <p style="text-align: right;">.....</p> <p>Do you have, or have you ever had (If YES, please give details):</p> <p>YES NO</p> <p><input type="checkbox"/> <input type="checkbox"/> High blood pressure? For how long?</p> <p><input type="checkbox"/> <input type="checkbox"/> Chest pains or tightness <input type="checkbox"/> or angina <input type="checkbox"/>? When? How often?</p> <p><input type="checkbox"/> <input type="checkbox"/> A heart attack? When?</p> <p><input type="checkbox"/> <input type="checkbox"/> Heart bypass <input type="checkbox"/> angioplasty (balloon) <input type="checkbox"/> stent <input type="checkbox"/>? Details:.....</p> <p>.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Artificial heart valve? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Heart pacemaker <input type="checkbox"/> other heart devices <input type="checkbox"/>? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Heart murmur? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Frequent palpitations? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Any other heart problems? Details:</p> <p>.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Any heart investigations (tests)? Details:</p> <p>.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Asthma <input type="checkbox"/> or wheezing <input type="checkbox"/>? When? How often?</p> <p><input type="checkbox"/> <input type="checkbox"/> If yes, have you ever been in hospital for your asthma? When?</p> <p><input type="checkbox"/> <input type="checkbox"/> Chronic bronchitis <input type="checkbox"/> or emphysema <input type="checkbox"/>? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Persistent cough or produce phlegm? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you use a puffer, inhaler, nebulizer (eg. Ventolin)? How often?</p> <p><input type="checkbox"/> <input type="checkbox"/> Troublesome shortness of breath? When do you get this?.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Any problems with breathing at night? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Any problems with heavy snoring? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Sleep apnoea? If yes, do you have any treatment for it? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Other lung, chest or breathing problems? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> An admission to hospital for lung or breathing problems? Details:</p> <p>.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Diabetes? If yes, please tick:</p> <p style="padding-left: 20px;">insulin controlled <input type="checkbox"/> and / or diabetic tablets controlled <input type="checkbox"/> diet controlled <input type="checkbox"/></p> <p style="padding-left: 20px;">What are your usual blood sugar levels?</p> <p><input type="checkbox"/> <input type="checkbox"/> Strokes <input type="checkbox"/> or mini strokes (TIAs) <input type="checkbox"/>? When was your last one?.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Blackouts <input type="checkbox"/> Funny turns <input type="checkbox"/> Giddy spells <input type="checkbox"/> How often?.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Convulsions or fits? When was the last one?</p> <p><input type="checkbox"/> <input type="checkbox"/> Heartburn <input type="checkbox"/> Reflux <input type="checkbox"/> Acid in mouth <input type="checkbox"/> Hiatus hernia <input type="checkbox"/>? Details:.....</p>	

<p>PRE-OPERATIVE ASSESSMENT PATIENT QUESTIONNAIRE</p> <p>TQEH <input type="checkbox"/> RAH <input type="checkbox"/></p>	<p>PATIENT LABEL</p> <p>Unit Record No.: _____</p> <p>Surname: _____</p> <p>Given Names: _____</p> <p>Date of Birth: _____ Sex: _____</p>																		
<p>Do you have, or have you ever had (If YES, please give details):</p> <p>YES NO</p> <p><input type="checkbox"/> <input type="checkbox"/> Kidney disease? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Liver disease or jaundice? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Thyroid disease? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Rheumatoid arthritis? Which joints?</p> <p><input type="checkbox"/> <input type="checkbox"/> Muscular disease or weakness in the arms or legs? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Bleeding or bruising problems? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Other blood disorders or anaemia? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Blood clots? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Reason to believe you have been exposed to HIV?</p> <p><input type="checkbox"/> <input type="checkbox"/> Hepatitis B <input type="checkbox"/> Hepatitis C <input type="checkbox"/> Other Hepatitis <input type="checkbox"/>?</p> <p><input type="checkbox"/> <input type="checkbox"/> Psychiatric treatment <input type="checkbox"/> or any mental health problems <input type="checkbox"/>? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Any other serious illnesses not mentioned above (eg. cancer, TB, rheumatic fever, polio, multiple sclerosis)? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Any hereditary diseases we should know about (eg. muscular dystrophy, thalassaemia, sickle cell)? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Females, is there any possibility you may be pregnant?</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you been compressed air diving (SCUBA) in the last 48 hours?</p> <p><input type="checkbox"/> <input type="checkbox"/> Physical disabilities? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Artificial joints or other implants? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> What is your approximate weight? (kg) or stones pounds</p> <p><input type="checkbox"/> <input type="checkbox"/> What is your approximate height? (cm) or feet inches</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you had a hospital admission for any health problems (excluding operations) in the last 5 years? If yes, please list below:</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 20%;">Admission Date/Year</th> <th style="width: 40%;">Details of Illness</th> <th style="width: 40%;">Which Hospital?</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>		Admission Date/Year	Details of Illness	Which Hospital?															
Admission Date/Year	Details of Illness	Which Hospital?																	

<p style="text-align: center;">PRE-OPERATIVE ASSESSMENT PATIENT QUESTIONNAIRE</p> <p style="text-align: center;">TQEH <input type="checkbox"/> RAH <input type="checkbox"/></p>	<p style="text-align: center;">PATIENT LABEL</p> <p>Unit Record No.: _____</p> <p>Surname: _____</p> <p>Given Names: _____</p> <p>Date of Birth: _____ Sex: _____</p>
<p>YES NO</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you seen a medical specialist in the past 5 years? When? What for?</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you seen your GP for any serious illnesses in the last 2 years? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you taken any blood thinners (such as aspirin, clopidogrel, warfarin, heparin) in the last 7 days? Details:</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you ever been prescribed prednisolone, cortisone or steroids? When?..... What for?</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you had a recent chest infection? When?.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you ever smoked? If yes, how many cigarettes/day? For how many years?</p> <p><input type="checkbox"/> <input type="checkbox"/> Are you still smoking? If not, when did you stop?</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you drink alcohol? How much? glasses per day <input type="checkbox"/> or week <input type="checkbox"/> of</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you used recreational drugs, including marijuana? What? When last used?</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you have loose <input type="checkbox"/> chipped <input type="checkbox"/> capped/crowned <input type="checkbox"/> teeth?</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you have dentures? Upper <input type="checkbox"/> - partial <input type="checkbox"/> full <input type="checkbox"/> Lower <input type="checkbox"/> - partial <input type="checkbox"/> full <input type="checkbox"/></p> <p><input type="checkbox"/> <input type="checkbox"/> Do you have any neck stiffness <input type="checkbox"/> or difficulty opening your mouth <input type="checkbox"/>? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Do you have any questions or concerns about the anaesthetic that you would like to discuss before you sign your anaesthetic consent form? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Are there any religious or cultural issues which you think are important for us to know or you would like to discuss? Details:.....</p> <p><input type="checkbox"/> <input type="checkbox"/> Have you completed this questionnaire yourself?</p> <p>Signature: Date:</p> <p>Please print your Name:</p> <p>If NO, name of person completing questionnaire and relationship to patient: Signature: Date:</p> <p>Please print your Name: Relationship:.....</p> <p>Nurse reviewing patient questionnaire: Signature: Date:</p> <p>Please print Name:</p>	

Table 5.1: Johns Hopkins Surgical Risk Classification System (JHSRCS).

JHSRCS status	Description	Study surgical procedures
1 (minimal risk)	Non-invasive procedure with minimal blood loss and minimal risk to the patient independent of medical conditions and anaesthesia	
2 (mild risk)	Procedures limited in their nature, usually with minimal to mild blood loss and only mild associated risk to the patient independent of medical conditions and anaesthesia	Transurethral resection of prostate Endovascular/endoluminal AAA repair (Vascular) Panendoscopy + biopsy (HNC) Parotidectomy (HNC) Transoral robotic resection (HNC) Cricopharyngeal myotomy (HNC)
3 (moderate risk)	More invasive procedures and/or those involving moderate blood loss with moderate risk to the patient independent of medical conditions and anaesthesia	Neck dissection (HNC) Glossectomy (HNC) Pharyngectomy (HNC) Total hip replacement (Orthopaedic) Total knee replacement (Orthopaedic) Laparoscopic assisted hemicolectomy (CRC) Laparoscopic assisted anterior resection (CRC) Laparoscopic assisted loop ileostomy (CRC) Open hemicolectomy (CRC) Open anterior resection (CRC) Sigmoidectomy (CRC) Hartmann's procedure (CRC) Subtotal/total colectomy (CRC) Proctocolectomy (CRC)
4 (significant risk)	Procedures posing significant risk to the patient independent of medical conditions and anaesthesia	Open AAA repair (Vascular)

AAA, abdominal aortic aneurysm; CRC, colorectal cancer surgery; HNC, head and neck cancer surgery.

Figure 5.2: The EQ-5D 5 level version (EQ-5D-5L) and additional questions on the patient's medical co-morbidities.



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Surname: _____

Given Names: _____

Date of Birth: _____

RESEARCH QUESTIONNAIRE

Under each heading, please tick the **ONE** box that best describes your health **TODAY**:

1. MOBILITY

- I have no problems in walking about
 I have slight problems in walking about
 I have moderate problems in walking about
 I have severe problems in walking about
 I am unable to walk about

2. SELF-CARE

- I have no problems washing or dressing myself
 I have slight problems washing or dressing myself
 I have moderate problems washing or dressing myself
 I have severe problems washing or dressing myself
 I am unable to wash or dress myself

3. USUAL ACTIVITIES (e.g. work, study, housework, family or leisure activities)

- I have no problems doing my usual activities
 I have slight problems doing my usual activities
 I have moderate problems doing my usual activities
 I have severe problems doing my usual activities
 I am unable to do my usual activities

4. PAIN / DISCOMFORT

- I have no pain or discomfort
 I have slight pain or discomfort
 I have moderate pain or discomfort
 I have severe pain or discomfort
 I have extreme pain or discomfort

5. ANXIETY / DEPRESSION

- I am not anxious or depressed
 I am slightly anxious or depressed
 I am moderately anxious or depressed
 I am severely anxious or depressed
 I am extremely anxious or depressed

We may be asking you the **above questions** again in **6 and 12 months** to see if your quality of life has improved.

Please provide your **telephone number**: ()

- I **do not** wish to be contacted at 6 and 12 months



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Department of Health

RESEARCH QUESTIONNAIRE

PLEASE **TICK** RELEVANT BOX AND ANSWER **ALL** QUESTIONS

YES NO

- Do you have a **regular GP** you go to? Details:
- How **often** do you see your **GP**?
- Have you ever had **high cholesterol**? Details:
- Have you ever had a **blood clot** in your **legs** or **lungs**? When?
- Did you need **warfarin**? Details:
- Do you have difficulty **breathing** when you **lie flat**? Details:
- How many pillows do you sleep on?
- Does your **breathing** ever **wake you up** when you are **sleeping**? Details:
- Have you ever been told you have **dementia**? Details:
- Do **you** have **concerns** about your **memory**?
- Has **anyone else** been **concerned** about your **memory**? Details:
- Have you ever had **heart failure** or **fluid build up** in your **lungs**? Details:
- Did you need to go to **hospital** because of fluid?
- Do you have **problems eating** because of your **teeth**?
- Have you had a **blood transfusion** in the **last 6 months**? Details:
- Have you had **iron tablets** in the **last 12 months**? Details:
- If you have **diabetes**, is your **doctor happy** with your **blood sugar** control?
- Have you had a **stroke(s)**? If yes, did it affect your **arms** **legs** **speech** **vision** ?
- Before your stroke(s)**, were you **right-handed** or **left-handed** ? Details:
- Did the stroke(s) affect the **right-side** or **left-side** of your **body**? Details:

5.4 Propensity score methodology

Propensity score estimation using the standard logistic regression and boosted logistic regression were tested prior to the CBPS method in the final analysis. The standard logistic regression and boosted logistic regression are based on two moments (mean and variance) and assumes automated covariate balancing (Wyss *et al.* 2014). The CBPS method, a doubly robust approach, differs from and outperforms the standard regression methods (using generalized linear models with maximum likelihood estimation) by using a generalized method of moments framework that uses the entire distribution of baseline covariates; an important factor when dealing with skewed data (as was the case with this dataset) (Imai and Ratkovic 2014).

The two standard regression methods failed to achieve covariate balance, the results of which are documented below.

5.4.1 Standard logistic regression

For standard logistic regression, the ‘glm’ command and the ‘logit’ link function were used in R statistical programming language (R Core Team 2013).

Table 5.2 details the characteristics of the clinic and control patients pre-propensity and post-propensity score weighting using standard logistic regression for propensity score estimation. The percentage of overlap between the clinic and control propensity score distribution was 97% (Figure 5.3) and the variance ratios were <2.0 for all 24 covariables after weighting. However, this method failed to achieve covariate balance with standardised differences of $>10\%$ between the clinic and control patients for SEIFA score and smoking status after propensity score weighting.

5.4.2 Boosted logistic regression

For the generalised boosted regression, the ‘twang’ package (Ridgeway *et al.* 2013) was used in R statistical programming language (R Core Team 2013).

Table 5.3 details the characteristics of the control and clinic patients pre-propensity and post-propensity score weighting using boosted logistic regression for propensity score estimation. This method failed to achieve covariate balance with standardised differences of $>10\%$ between the clinic and control patients for SEIFA score, BMI, marital status, ischaemic heart disease, congestive heart failure, stroke, renal

Table 5.2: Patient characteristics and balance diagnostics using standard logistic regression for propensity score estimation.

Characteristic	Unweighted					Propensity weighted			
	Clinic (n=121)	Control (n=700)	Standardised difference	Variance ratio	P-value	Control	Standardised difference	Variance ratio	P-value
Age (mean years)	73.6	69.2	0.47	0.75	0.00	73.6	0.00	0.94	1.00
Female	37.2	38.4	-0.03	0.99	0.80	37.3	-0.00	1.01	0.99
Surgical procedure				0.98	0.69			1.01	0.99
Abdominal aortic aneurysm	7.4	9.1	-0.07	0.83	0.54	7.6	-0.01	0.99	0.96
Transurethral resection of prostate	9.1	8.9	0.01	1.03	0.93	10.5	-0.05	0.89	0.73
Total knee replacement	22.3	22.7	-0.01	0.99	0.92	19.5	0.07	1.11	0.54
Total hip replacement	22.3	27.0	-0.11	0.89	0.28	20.8	0.04	1.06	0.74
Head and neck cancer surgery	16.5	12.0	0.12	1.32	0.17	17.4	-0.02	0.97	0.85
Colorectal cancer surgery	22.3	20.3	0.05	1.08	0.61	24.3	-0.05	0.95	0.72
Surgical severity				0.98	0.79			0.92	0.76
Mild	20.7	19.1	0.04	1.07	0.70	24.6	-0.10	0.89	0.47
Moderate	76.9	77.3	-0.01	1.02	0.92	73.3	0.08	0.92	0.52
Significant	2.5	3.6	-0.07	0.71	0.54	2.1	0.02	1.18	0.80
Urgency category				0.95	0.35			1.01	0.99
Within 30 days	48.8	44.3	0.09	1.02	0.36	48.1	0.01	1.01	0.92
Within 90 days	18.2	15.7	0.06	1.13	0.50	18.4	-0.01	1.00	0.96
Within 1 year	33.1	40.0	-0.15	0.93	0.15	33.5	-0.01	1.00	0.95
SEIFA (mean score)	959.7	968.0	-0.12	0.84	0.22	966.8	-0.10	0.77	0.42
BMI (mean score)	29.5	28.5	0.16	1.15	0.11	29.2	0.06	0.81	0.64
Smoking status				0.96	0.85			1.12	0.64
Never	39.7	38.1	0.03	1.02	0.75	36.3	0.07	1.04	0.56
Former	48.8	48.4	0.01	1.01	0.95	54.1	-0.11	1.01	0.38
Current	11.6	13.4	-0.06	0.89	0.58	9.6	0.06	1.18	0.55
Marital status				1.11	0.18			1.05	0.96
Never married	10.7	11.1	-0.01	0.98	0.90	8.4	0.08	1.26	0.45
Married/De facto	51.2	60.1	-0.18	1.05	0.07	51.7	-0.01	1.01	0.94
Widowed	19.0	15.1	0.10	1.21	0.28	20.5	-0.04	0.95	0.77
Divorced	16.5	10.1	0.17	1.52	0.04	17.1	-0.02	0.98	0.91
Separated	2.5	3.4	-0.06	0.74	0.59	2.4	0.01	1.04	0.96
Medical co-morbidities									
Ischaemic heart disease	66.1	32.0	0.72	1.04	0.00	66.3	0.00	1.01	0.98
Congestive heart failure	5.0	0.7	0.20	6.69	0.03	7.0	-0.09	0.73	0.65
Stroke	19.0	6.0	0.33	2.75	0.00	21.2	-0.06	0.93	0.71
Diabetes mellitus	33.1	20.1	0.27	1.39	0.01	34.0	-0.02	0.99	0.87
Renal impairment	34.7	16.7	0.38	1.64	0.00	35.6	-0.02	1.00	0.89
Anaemia	40.5	26.4	0.29	1.25	0.00	44.0	-0.07	0.98	0.57
Dementia including Alzheimer's	3.3	0.6	0.15	5.66	0.10	1.8	0.08	1.83	0.46
Asthma/COPD	44.6	30.6	0.28	1.17	0.00	44.3	0.01	1.01	0.96
Hypertension	16.5	7.1	0.25	2.09	0.01	14.7	0.05	1.11	0.70
Fall in previous 12 months	5.8	2.3	0.15	2.46	0.11	4.4	0.06	1.31	0.60
Able to walk around house	57.9	70.0	-0.25	1.17	0.01	58.5	-0.01	1.01	0.92
Able to walk upstairs	37.2	50.9	-0.28	0.94	0.00	37.5	-0.01	1.00	0.97
Physical disabilities	38.8	25.4	0.27	1.26	0.01	41.0	-0.04	0.99	0.73
Artificial joints/implants	20.7	25.6	-0.12	0.87	0.22	19.1	0.04	1.07	0.74
Days since clinic was established (mean)*	1127.9	1048.3	0.25	0.82	0.01	1130.8	-0.01	0.76	0.95

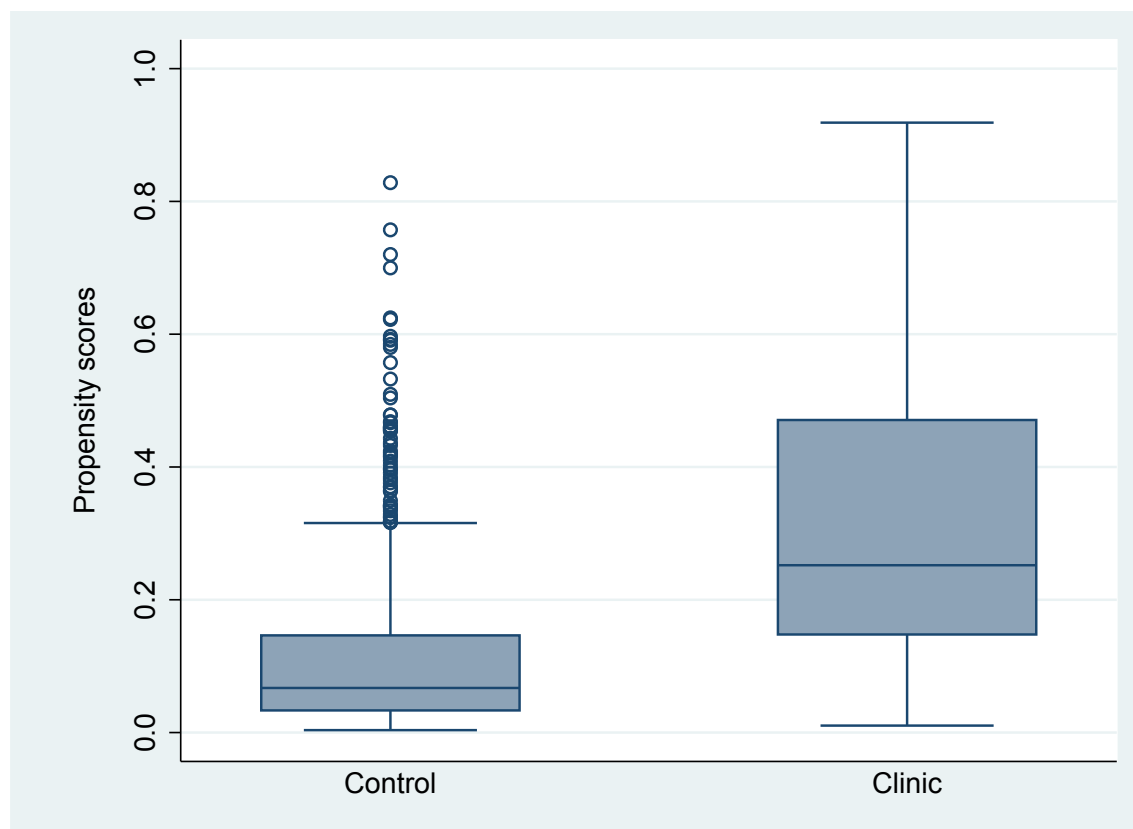


Figure 5.3: Distributions of propensity scores with standard logistic regression for clinic and control groups indicating degree of overlap.

impairment, dementia including Alzheimer’s disease, hypertension, fall in the previous 12 months, able to walk around the house, able to walk upstairs, and physical disabilities after propensity score weighting. Congestive heart failure and dementia including Alzheimer’s disease had variance ratios of >2.0 after weighting.

The percentage of overlap between the clinic and control propensity score distribution was 57% (Figure 5.4).

Additional comments from the reviewer suggested three other methods for addressing the imbalance between treatment and control groups: stratification/ subclassification, coarsened exact matching, and the doubly robust estimator introduced by Robins (2000). Responses to these suggestions are detailed below.

- Due to the high degree of overlap with the covariate balancing propensity score (CBPS) method, stratification/subclassification was not considered. The authors are satisfied with the CBPS method, which generates propensity score estimates by selecting parameter values that maximise the resulting covari-

Table 5.3: Patient characteristics and balance diagnostics using boosted logistic regression for propensity score estimation.

Characteristic	Unweighted					Propensity weighted			
	Clinic (n=121)	Control (n=700)	Standardised difference	Variance ratio	P-value	Control	Standardised difference	Variance ratio	P-value
Age (mean years)	73.6	69.2	0.47	0.75	0.00	73.0	0.07	0.96	0.53
Female	37.2	38.4	-0.03	0.99	0.80	38.1	-0.02	1.00	0.86
Surgical procedure				0.98	0.69			0.97	0.96
Abdominal aortic aneurysm	7.4	9.1	-0.07	0.83	0.54	8.6	-0.04	0.88	0.69
Transurethral resection of prostate	9.1	8.9	0.01	1.03	0.93	10.1	-0.03	0.92	0.76
Total knee replacement	22.3	22.7	-0.01	0.99	0.92	21.5	0.02	1.04	0.85
Total hip replacement	22.3	27.0	-0.11	0.89	0.28	25.1	-0.07	0.93	0.56
Head and neck cancer surgery	16.5	12.0	0.12	1.32	0.17	13.4	0.08	1.20	0.43
Colorectal cancer surgery	22.3	20.3	0.05	1.08	0.61	21.4	0.02	1.04	0.84
Surgical severity				0.98	0.79			0.89	0.75
Mild	20.7	19.1	0.04	1.07	0.70	22.2	-0.04	0.95	0.73
Moderate	76.9	77.3	-0.01	1.02	0.92	74.1	0.07	0.93	0.56
Significant	2.5	3.6	-0.07	0.71	0.54	3.7	-0.08	0.68	0.53
Urgency category				0.95	0.35			0.99	0.81
Within 30 days	48.8	44.3	0.09	1.02	0.36	45.8	0.06	1.01	0.58
Within 90 days	18.2	15.7	0.06	1.13	0.50	18.0	0.00	1.01	0.98
Within 1 year	33.1	40.0	-0.15	0.93	0.15	36.2	-0.07	0.97	0.54
SEIFA (mean score)	959.7	968.0	-0.12	0.84	0.22	968.9	-0.14	0.94	0.22
BMI (mean score)	29.5	28.5	0.16	1.15	0.11	28.8	0.12	1.03	0.27
Smoking status				0.96	0.85			1.10	0.76
Never	39.7	38.1	0.03	1.02	0.75	38.2	0.03	1.02	0.78
Former	48.8	48.4	0.01	1.01	0.95	52.1	-0.07	1.01	0.54
Current	11.6	13.4	-0.06	0.89	0.58	9.7	0.06	1.17	0.55
Marital status				1.11	0.18			1.23	0.50
Never married	10.7	11.1	-0.01	0.98	0.90	7.8	0.10	1.34	0.31
Married/De facto	51.2	60.1	-0.18	1.05	0.07	58.5	-0.15	1.04	0.18
Widowed	19.0	15.1	0.10	1.21	0.28	19.7	-0.02	0.98	0.87
Divorced	16.5	10.1	0.17	1.52	0.04	11.6	0.13	1.35	0.17
Separated	2.5	3.4	-0.06	0.74	0.59	2.3	0.01	1.07	0.92
Medical co-morbidities									
Ischaemic heart disease	66.1	32.0	0.72	1.04	0.00	57.1	0.19	0.92	0.08
Congestive heart failure	5.0	0.7	0.20	6.69	0.03	2.0	0.14	2.42	0.19
Stroke	19.0	6.0	0.33	2.75	0.00	14.0	0.13	1.29	0.25
Diabetes mellitus	33.1	20.1	0.27	1.39	0.01	29.5	0.08	1.07	0.50
Renal impairment	34.7	16.7	0.38	1.64	0.00	28.1	0.14	1.13	0.22
Anaemia	40.5	26.4	0.29	1.25	0.00	39.1	0.03	1.02	0.79
Dementia including Alzheimer's	3.3	0.6	0.15	5.66	0.10	0.5	0.16	6.56	0.09
Asthma/COPD	44.6	30.6	0.28	1.17	0.00	40.5	0.08	1.03	0.45
Hypertension	16.5	7.1	0.25	2.09	0.01	10.9	0.15	1.43	0.19
Fall in previous 12 months	5.8	2.3	0.15	2.46	0.11	3.0	0.12	1.90	0.22
Able to walk around house	57.9	70.0	-0.25	1.17	0.01	65.0	-0.14	1.08	0.19
Able to walk upstairs	37.2	50.9	-0.28	0.94	0.00	42.5	-0.11	0.96	0.31
Physical disabilities	38.8	25.4	0.27	1.26	0.01	30.8	0.16	1.12	0.13
Artificial joints/implants	20.7	25.6	-0.12	0.87	0.22	20.5	0.00	1.01	0.97
Days since clinic was established (mean)*	1127.9	1048.3	0.25	0.82	0.01	1098.9	0.09	1.03	0.39

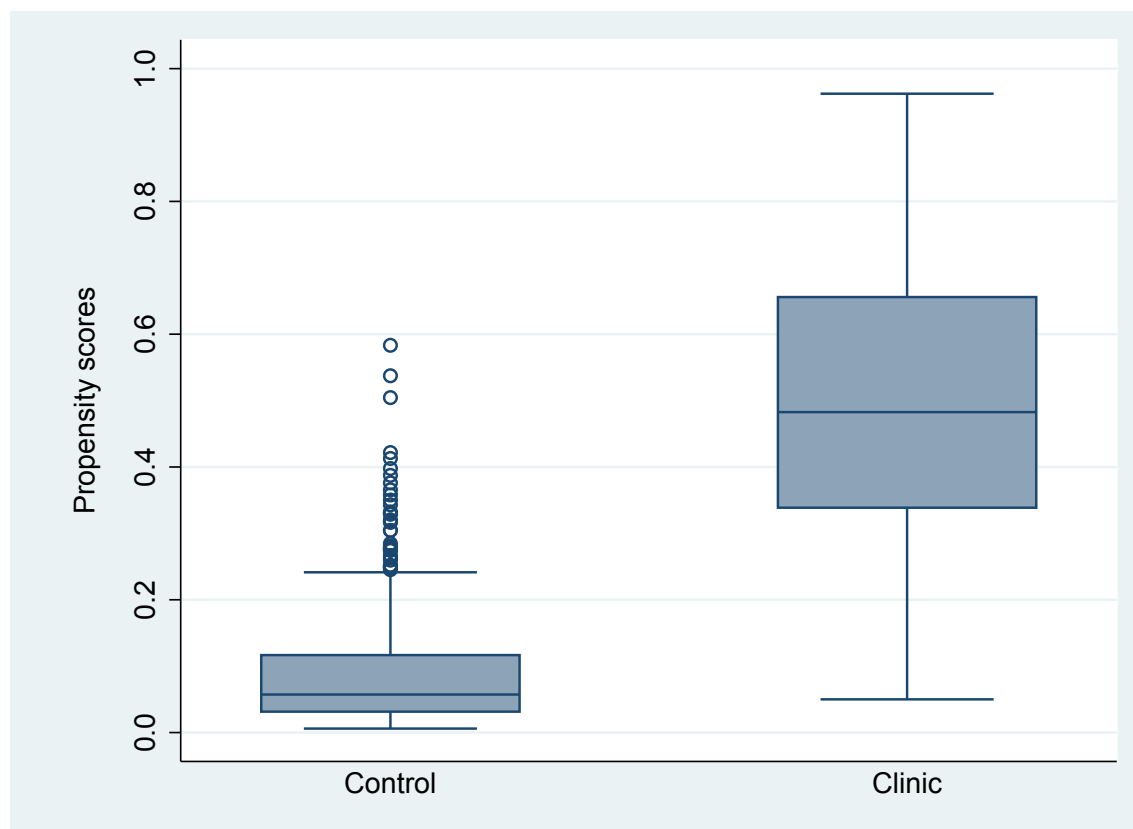


Figure 5.4: Distributions of propensity scores with boosted logistic regression for clinic and control groups indicating degree of overlap.

ate balance, regardless of modelling assumptions. This minimises the potential misspecification of a parametric propensity score model, a common issue with other propensity score estimation methods. Previous analyses have also suggested that propensity score matching is more effective at dealing with systematic differences in baseline characteristics between treatment and control subjects than stratification on the propensity score (Austin and Mamdani 2006, Austin *et al.* 2007, Austin 2009).

- Coarsened exact matching (CEM) aims to reduce the imbalance between treatment and control groups without estimating the propensity score (King *et al.* 2011). CEM assigns a level of imbalance *ex ante* and then fixes any residual imbalances by temporarily coarsening each covariable (King *et al.* 2011). The authors' aim was to achieve balance between the treatment and control groups to improve the propensity score estimation for use in the outcome models. Thus, the CBPS method was used as it enables the robust and efficient

estimation of the propensity score by directly incorporating the key covariate balancing property of the propensity score (Imai and Ratkovic 2014).

- Kang and Schafer (2007) tested the doubly robust estimator of Robins (2000) and found that it provided a consistent estimate of the treatment effect as long as the outcome model or the propensity score model was correct. However, when both models were slightly misspecified, the performance of the doubly robust estimator deteriorated. The CBPS estimation method can yield robust estimates of treatment effects, even when both the outcome and propensity score models are misspecified (Imai and Ratkovic 2014). Imai and Ratkovic (2014) reported that the CBPS achieved better covariate balance than the standard logistic regression method when both the outcome and propensity score models were correctly specified, and when both models are misspecified, the CBPS improved the covariate balance with some loss of likelihood.

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Chapter 6

Quality of life

6.1 Introduction

One of the main goals of elective surgery is to improve health-related quality of life (QoL) for the patient. However, QoL outcome measures, commonly used to inform the estimation of quality adjusted life years (QALYs) in cost-effectiveness analyses, are not currently routinely collected within the study hospital.

In cancer patients, patient-reported preoperative QoL scores have been used as predictors of postoperative complications (Bingener *et al.* 2015, Doll *et al.* 2014), hospital readmission (Doll *et al.* 2014) and overall survival (Sloan *et al.* 2012, Von Gruenigen *et al.* 2012, Velanovich 2011).

This study is an extension of the supplementary prospective study exploring quality of life as a potentially unmeasured confounder, as part of an evaluation of the high-risk clinic (see Chapter 5.2). Preoperative QoL, measured at the time the patient was placed on the surgery waiting list, was identified as a potential unmeasured confounder with the clinic group reporting significantly lower mean QoL index scores than the control group (Pham *et al.* 2016). QoL data has the potential to improve the characterisation of complex patients referred to the high-risk clinic and could be an early indicator of operative risk and postoperative morbidity and mortality.

The aims of this study were to determine whether health-related QoL was an additional indicator of high risk in a patient, and compare changes in QoL before and after surgery in patients attending and not attending the high-risk clinic.

6.2 Methods

6.2.1 Patient recruitment

Prospective patients listed for elective surgery between June 2012 and October 2013 at the RAH were identified via hospital elective surgery waiting lists. Identified patients were eligible if they were aged 18 years and over and listed for at least one of the following selected elective surgical procedures: transurethral resection of the prostate, total hip or knee replacement, abdominal aortic aneurysm repair, head and neck cancer surgery and colorectal cancer surgery.

Patients were originally recruited via an opt-in strategy, with an information sheet and questionnaire added to the elective surgical admission booking pack (containing standard RAH forms that all patients must complete in order to proceed to surgery). It was anticipated that patients would complete the questionnaire while in the waiting room of the outpatient clinic but the response rate using this strategy was very poor with only two of the 39 eligible patients returning the baseline questionnaire. The distribution of the questionnaire was then changed to target eligible patients with a personalised letter, sent via postal mail, inviting them to participate in the study. Questionnaires were sent to patients attending and not attending the high-risk clinic.

Patients were referred to the high-risk clinic ('clinic') at the discretion of the surgical consultant or anaesthetist around the time of the decision to undergo surgery. Patients who were not referred to the clinic ('control') either proceeded to surgery without further sub-specialist consultation or were referred, at the surgical consultant's discretion, to a sub-specialist for management of a specific condition (e.g. cardiologist, nephrologist).

6.2.2 Data collection

Eligible patients were asked to complete the EuroQOL five dimension questionnaire (EQ-5D) (EuroQol Group 1990) and a set of additional co-morbidity questions at baseline (see Chapter 5.3.3). Patients who completed the baseline questionnaire and did not opt-out of recontact were asked to complete the EQ-5D questionnaire again at six and 12 months.

The EQ-5D-5L was chosen as it gives more weight to physical functioning, as opposed to the social functioning in the SF-6D (van Stel and Buskens 2006). The physical functioning component was considered to be more relevant than the social functioning in this study, as the high-risk clinic intervention has a greater focus on managing the physical aspects of the patient.

Data from the patient-completed PAPQ (see Chapter 5.3.1) were extracted from the elective surgical admission booking packs via weekly visits to the surgical units at the RAH. Detailed patient and clinical information, including the hospital admission for the selected surgical procedure and whether the patient was referred to the high-risk clinic, were extracted from the hospital database.

In circumstances where a patient ticked ‘I am extremely anxious or depressed’ in the EQ-5D-5L, the researcher informed the Consultant Physician involved in the study who sent a letter to the patient with recommendations to seek further help and a Beyond Blue pamphlet.

6.2.3 Statistical analyses

The CBPS estimation method, as described in Pham *et al.* (2016) (see Chapter 5.2), was used for propensity score estimation to adjust for potential observed confounding and balance selected patient characteristics across treatment groups. Covariables that could potentially influence whether a patient was referred to the clinic were selected *a priori* and were based on the covariables used in the previous analysis (Pham *et al.* 2016) (see Chapter 5.2). Covariables included patient demographics, surgery-related factors, patient’s physical function and nine medical co-morbidities targeted by the high-risk clinic with the greatest potential to be modified: ischaemic heart disease, congestive heart failure, stroke, diabetes mellitus, renal impairment, anaemia, dementia including Alzheimer’s disease, asthma or chronic obstructive pulmonary disease, and primary hypertension. Table 6.1 details the characteristics of the control and clinic patients pre-propensity and post-propensity score weighting. Due to the small sample size, the CBPS estimation method was unable to balance all 19 covariables, with standardised differences of >10% between clinic and control groups remaining in six of the covariables.

Regression using generalised linear modelling was used to test the association between health state index scores and clinic patients before and after surgery. The

six covariables with standardised differences of $>10\%$ were included as independent variables in the regression model. Non-parametric bootstrapping (1,000 iterations) was then applied to estimate the 95% CI. Results are presented as means or mean differences with 95% CI. Negative mean differences indicate lower health state index scores in clinic patients. The CBPS estimation method using the ‘CBPS’ package (Ratkovic and Imai 2014), regression analyses and bootstrapping were performed using R statistical programming language (R Core Team 2013).

Analyses of health state index scores before and after surgery for clinic and control patients were performed due to the variation in the timing of responses to the EQ-5D. The timing of surgery was dependent on the type and urgency of the surgical procedure and the length of the waiting list, so for patients who completed the EQ-5D at all three time points, surgery could have occurred between baseline and six months or between six and 12 months. For such cases, the first EQ-5D measured after surgery was used in the analysis. Patients who only completed the EQ-5D at one follow-up time point, either six or 12 months, and had surgery between baseline and follow-up were included in the before and after analyses.

The EQ-5D profiles were transformed, using the value set for the United Kingdom¹, into weighted health state index scores, ranging from -0.594 (worst health state) to 1.00 (best health state) (EuroQol Group 2012). When interpreting the impact of changes in the index scores, a minimally important difference value of 0.074 was used (Walters and Brazier 2005). In order to detect a 0.074 difference in index scores at 80% power and a significance level of 0.05, 244 patients were needed in each treatment group.

Ethics approval was granted by the South Australian Department of Health Human Research Ethics Committee (HREC Protocol No. 490/01/2015) and the Royal Adelaide Hospital Research Ethics Committee (RAH Approval No. 120225/120225a).

6.3 Results

Of the 645 eligible patients who were sent questionnaires, 386 (60%) returned completed baseline questionnaires (Figure 6.1). Of the 386 patients with a baseline EQ-5D measure, 183 (47%) were included in the before and after analyses with 131

¹an EQ-5D value set for Australia is not yet available

patients completing the EQ-5D at all 3 time points and 52 patients either completing the baseline and 6-month EQ-5D (26 patients) or the baseline and 12-month EQ-5D (26 patients). Patients were mainly excluded from the analyses if they did not wish to be recontacted or if they had their surgical procedure, predominantly for head and neck cancer and abdominal aortic aneurysm repair, before returning their baseline EQ-5D measure (Figure 6.1).

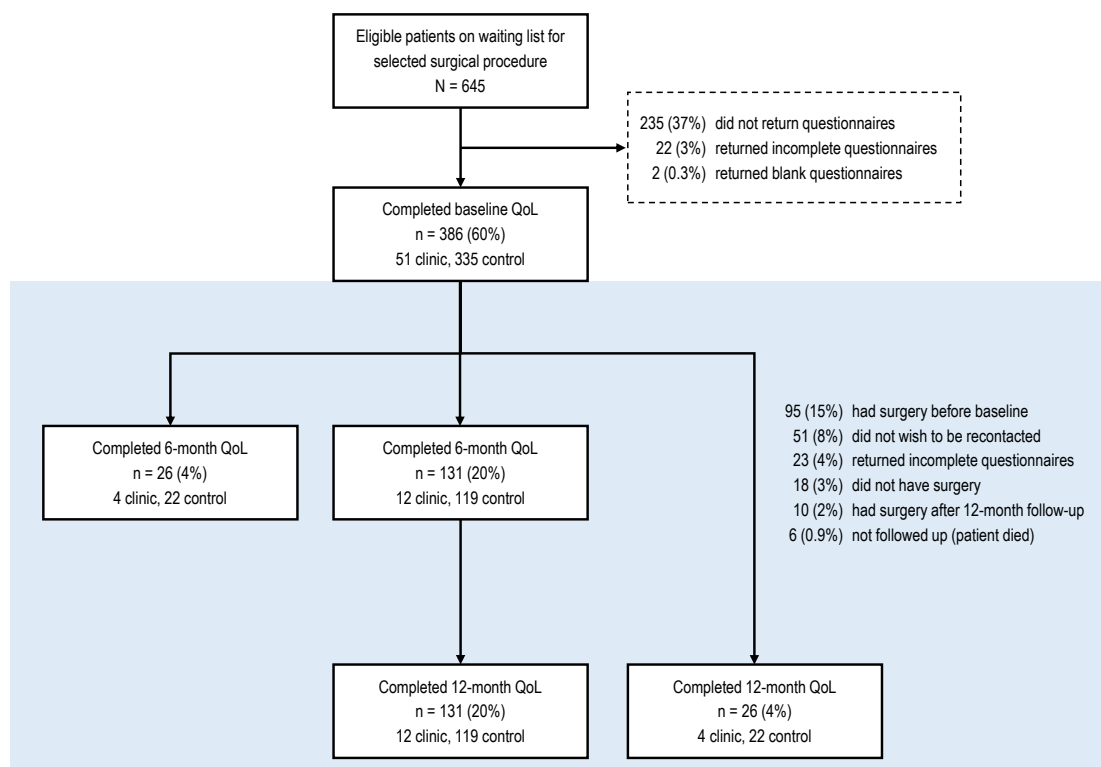


Figure 6.1: Flowchart of patient recruitment. The number of patients lost to follow-up and the reasons for exclusion could occur anywhere between the baseline and 12-month questionnaires (area shaded in blue).

Table 6.1 details the characteristics of the 163 control and 20 clinic patients pre-propensity and post-propensity score weighting. Total joint replacements accounted for the majority (65%) of the selected surgical procedures. Compared with control patients, clinic patients tended to be older, female, have modifiable co-morbidities targeted by the clinic and physical disabilities. Fewer clinic patients were able to walk around the house and/or upstairs.

The mean unweighted index scores for the clinic group was significantly lower

Table 6.1: Patient characteristics and balance diagnostics for quality of life data.

Characteristic	Unweighted			Propensity weighted	
	Clinic (n=20)	Control (n=163)	Standardised difference	Control	Standardised difference
Age (mean years)	75.6	69.4	0.78	74.2	0.12
Female	63.2	50.3	0.13	56.2	0.04
Surgical procedure					
Abdominal aortic aneurysm	5.3	2.8	0.03	5.7	-0.01
Transurethral resection of prostate	0.0	10.3	-0.10	0.0	0.00
Total knee replacement	47.4	31.7	0.16	39.4	0.11
Total hip replacement	36.8	36.6	0.00	44.8	-0.09
Head and neck cancer surgery	0.0	0.7	-0.01	0.0	0.00
Colorectal cancer surgery	10.5	17.9	-0.07	10.1	-0.01
Urgency category					
Within 30 days	21.1	11.0	0.10	15.8	0.04
Within 90 days	0.0	17.9	-0.18	0.0	0.00
Within 1 year	78.9	62.8	0.16	84.2	-0.04
Deferred	0.0	8.3	-0.08	0.0	0.00
BMI (mean score)	29.2	30.0	-0.16	29.0	0.06
Smoking status					
Never	31.6	42.8	-0.11	14.2	0.17
Former	57.9	50.3	0.08	74.7	-0.16
Current	10.5	6.9	0.04	11.1	-0.01
Medical co-morbidities					
Ischaemic heart disease	73.7	24.1	0.50	62.8	0.11
Congestive heart failure	31.6	10.3	0.21	28.1	0.02
Stroke	10.5	3.4	0.07	8.3	0.03
Diabetes mellitus	31.6	13.1	0.18	20.4	0.12
Renal impairment	5.3	3.4	0.02	8.3	-0.03
Anaemia	36.8	16.6	0.20	20.9	0.16
Dementia including Alzheimer's	15.8	22.1	-0.06	19.9	-0.04
Asthma/COPD	36.8	30.3	0.07	37.2	-0.02
Hypertension	84.2	58.6	0.26	91.3	-0.05
Able to walk around house	36.8	62.1	-0.25	47.7	-0.09
Able to walk upstairs	21.1	35.2	-0.14	22.3	-0.02
Physical disabilities	42.1	24.1	0.18	37.2	0.07
Artificial joints/implants	31.6	28.3	0.03	32.6	0.00

than the control group before surgery (0.371 versus 0.515, mean difference -0.144, 95% CI -0.287, -0.001) with a smaller difference in unweighted index scores after surgery (0.597 versus 0.696, mean difference -0.099, 95% CI -0.213, 0.015).

After weighting, there were no significant differences in the mean index scores between the clinic and control groups before surgery (weighted mean difference -0.059, 95% CI -0.151, 0.100) and after surgery (weighted mean difference -0.083, 95% CI -0.196, 0.082) (Figure 6.2). Both groups reported higher mean index scores (improved quality of life) after surgery. There were also no significant differences in the magnitude of quality of life improvement for the clinic and control groups (weighted mean difference -0.028, 95% CI -0.203, 0.146). Of the 163 control patients, 91 (56%) had an improvement of at least 0.074 in their EQ-5D score after surgery, 23 (14%) reported a deterioration of greater than 0.074 in their EQ-5D score, and 49 (30%) reported no or small changes in their EQ-5D score. Of the 20 clinic patients, 12 reported an improvement of at least 0.074, 5 reported a deterioration of greater than 0.074, and 3 reported no or small changes in their EQ-5D score after surgery.

6.4 Discussion

Due to the small sample of usable preoperative and postoperative QoL measures, it was not possible to draw any meaningful conclusions from the data.

The available data suggests that clinic patients have a lower mean preoperative QoL index score than control patients and similar magnitudes of improvement in QoL in each group after surgery. The lower mean preoperative and postoperative index scores in clinic patients compared with control remained after weighting, suggesting that QoL could potentially be an additional indicator of high risk in a patient.

The CBPS method for propensity score estimation was unable to balance 6 of the 19 covariables indicating that the control group in this sample could not be matched (at the group level) to the complex, high-risk clinic group. A mean preoperative QoL index score of 0.371 in clinic patients is among the lowest reported in the published literature, with similar mean preoperative EQ-5D index scores reported in lumbar spinal stenosis patients (0.36) (Jansson *et al.* 2009) and in people with depression

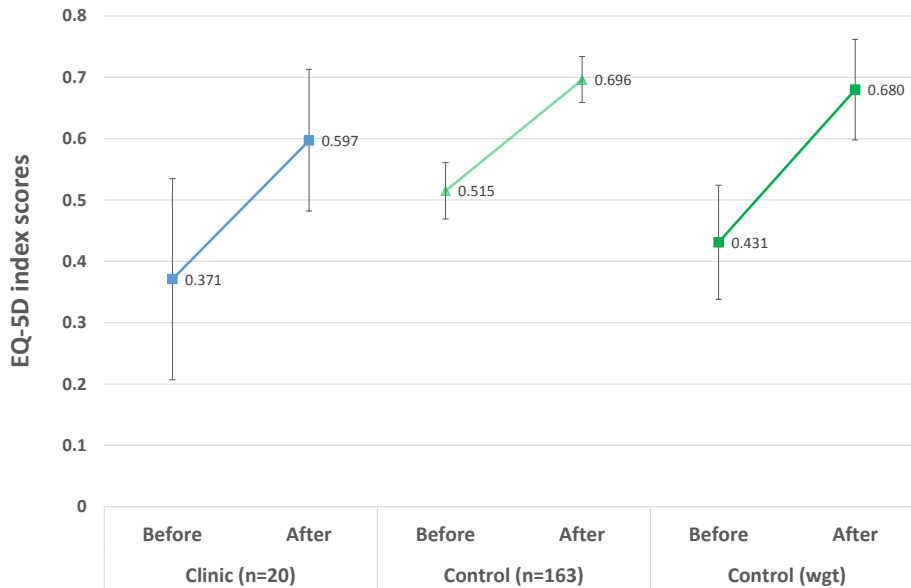


Figure 6.2: EQ-5D index scores before and after surgery for the clinic group and unweighted and weighted control group.

(0.38) (Burström *et al.* 2001). The mean preoperative QoL index score in the control patients of 0.431 is similar to QoL index scores of stroke patients (0.44) (Burström *et al.* 2001). The lower mean preoperative QoL index score in clinic patients suggests that preoperative QoL could improve the characterisation of clinic patients.

In this small sample of patients, we found that health-related quality of life improves after elective surgery in both clinic and control patients. Further research should focus on identifying an appropriate control group, with the potential use of the preoperative QoL index score, to match the highly complex and sicker clinic patient subset. In this study, there were difficulties with identifying a relevant, contemporary control group in the hospital that established the high-risk clinic. Patients managed in other similar hospitals could be used as a control group but the differences in clinical pathways and care delivery models may affect QoL and must be considered. Given the challenges with using an observational dataset on this cohort of complex patients, a full cost-effectiveness analysis was considered to be of limited value. A qualitative component focusing on the validation of the findings

from this quantitative evaluation was deemed to be of greater value and is detailed in the following chapter (Chapter 7).

6.5 Acknowledgements

We would like to thank the patients who participated in this study and the unit secretaries at the Royal Adelaide Hospital for their support with accessing files for data collection.

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Chapter 7

Assessing the validity of the evaluation findings

7.1 Preface

This chapter presents the qualitative component undertaken to assess the validity of the findings from the quantitative evaluation of the clinic in Chapter 5. This explanatory study explores the reasons for and expectations of referral to the high-risk clinic, validates the baseline covariates used in the evaluation, assesses the potential for unmeasured confounding, and assesses whether the value of the high-risk clinic was appropriately captured in the outcomes used in the evaluation.

7.2 Statement of authorship

Title of paper: Supporting Surgeons in Patient-Centered Complex Decision Making: a Qualitative Analysis of the Impact of a Perioperative Physician Clinic.

Publication status: Submitted

Publication details: Pham C, Gibb C, Fitridge R, Karnon J, Hoon E.

Name of principal author (Candidate): Clarabelle Pham

Contribution to the paper: Conception and design, interviewed participants, transcribed data, analysis and interpretation of data, drafted the article and critical revisions, and acted as corresponding author.

Overall percentage: 85%

This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.

Signed:

Date: 30/01/2019

Co-author contributions

By signing the statement of authorship, each author certifies that:

- i. the candidate's stated contribution to the publication is accurate (as detailed above);
- ii. permission is granted for the candidate to include the publication in the thesis; and
- iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of co-author: Catherine Gibb

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Robert Fitridge

Contribution to the paper: Conception and design, interpretation of data, and revised it critically for important clinical content.

Signed:

Date: 15/01/2019

Name of co-author: Jonathan Karnon

Contribution to the paper: Conception and design, analysis and interpretation of data, and revised it critically for important intellectual content.

Signed:

Date: 30/01/2019

Name of co-author: Elizabeth Hoon

Contribution to the paper: Conception and design, analysis and interpretation of data, and revised it critically for important intellectual content.

Signed:

Date: 30/01/2019

7.3 Manuscript

7.3.1 Structured abstract

Background

Patients with co-morbidities can be referred to a physician-led high-risk clinic prior to elective surgery at the discretion of the surgical consultant, but the factors that influence this referral are not well understood. The aims of this study were to understand the factors that influence a surgeon's decision to refer a patient to the clinic, and how the clinic impacts on the management of complex patients.

Methods

Theoretical thematic analysis was used to analyze transcribed semi-structured interviews with seven surgical consultants who were eligible to refer patients to the clinic.

Results

When discussing the factors that influence a referral to the clinic, all participants initially described the optimization of co-morbidities and would then discuss with examples the challenges with managing complex patients and communicating the risks involved with having surgery. When discussing the role of the clinic, two related sub-themes were dominant and focused on the management of risk in complex patients. The participants valued the involvement of the clinic in the decision-making and communication of risks to the patient.

Conclusions

The integration of the high-risk clinic in this study appears to offer additional value in supporting the decision-making process for the surgical team and patient beyond the clinical outcomes. The factors that influence a surgeon's decision to refer a patient to the clinic appear to be driven by the aim to manage the uncertainty and risk to the patient regarding surgery and it was seen as a strategy for managing difficult and complex cases. Further research is required to explore the perspectives

of the patient and other medical professionals collaborating with the clinic and guide the optimal use of the high-risk clinic.

7.3.2 Introduction

The decision of whether to operate on a patient can be complex. For patients who are young and fit with no other medical co-morbidities, the decision to proceed with surgery is relatively straight-forward. In contrast, the decision to operate on a patient who is frail and/or has multiple medical co-morbidities can be challenging, and could potentially involve a large degree of uncertainty due to the increased risk of morbidity and mortality during the perioperative period (Kuwabara *et al.* 2008, Librero *et al.* 1999).

A set of potentially modifiable co-morbidities have been identified to be associated with increased length of hospital stay and postoperative complications (Pham *et al.* 2014). Patients with poorly controlled modifiable co-morbidities can be referred for medical optimization prior to elective surgery at the discretion of the surgical consultant, but the factors that influence this referral are not well understood (Pham *et al.* 2017). Further, there has been minimal detail published on the actual services provided as part of the medical optimization of patients and its design and implementation has been heterogeneous to date (Pham *et al.* 2017).

The number of patients with multiple co-morbidities increases with an aging population. Outpatient clinics, such as the Perioperative High Risk Clinic at the Royal Adelaide Hospital in South Australia, have been established to co-manage complex patients by targeting, managing and optimizing their modifiable medical co-morbidities. A recent evaluation of this clinic (Pham *et al.* 2016) was found to reduce the frequency of unnecessary admissions for and cancellations of surgery but there was significant uncertainty around the effect of the clinic on clinical outcomes and costs. The evaluation suggested that there may be additional unmeasured factors to the identified modifiable medical co-morbidities that contribute to patient complexity (Pham *et al.* 2014), thus influencing referral to the clinic and patient outcomes.

This explanatory study was designed to provide an in-depth examination of the surgeons' perceptions of referral practices to the clinic and thereby illuminate the findings of the clinic evaluation. Factors related to the referral of patients for med-

ical optimization identified by the surgeons but not captured by the available data would indicate the potential presence of unmeasured confounding in the clinic evaluation. Additionally, the surgeons' perceptions of the clinic would inform whether the value of the clinic was appropriately captured in the outcomes used in the clinic evaluation. The aims of this study were to understand the factors that influence a surgeon's decision to refer a patient to the clinic, and how the clinic impacts on the management of complex patients.

7.3.3 Methods

Research design

This explanatory sequential study design (Klassen *et al.* 2012) was part of a larger mixed methods study evaluating the assessment and management of high-risk patients provided by an outpatient Perioperative High Risk Clinic ("the clinic"). The qualitative data collected was used to explain and build on the findings of the quantitative evaluation of the services provided by the clinic.

Taking a realist epistemological approach, theoretical thematic analysis was used to analyze the collected data (Braun and Clarke 2006). There was a focus on themes to help explain the complexity of the patient population referred to the clinic and provide insight into the context, subjective attitudes and behaviors that govern the surgeons' decision making processes in assessing and managing complex surgical patients.

Setting and participants

Semi-structured interviews were conducted in person with surgical consultants from five specialties at the Royal Adelaide Hospital and The Queen Elizabeth Hospital, Adelaide, South Australia. Participants were recruited with an invitation letter via post or electronic mail and followed up with a telephone call. Surgical consultants who were eligible to refer patients to the clinic were invited to participate in the interests of obtaining a range of perspectives on the clinic. Sampling was purposive with the aim of achieving data saturation.

Data collection

The interviews were conducted by one of the authors (CP), a researcher with no clinical relationship with patients or staff of the clinic but who had recently completed the quantitative evaluation of the clinic, between March and July 2014. One-to-one interviews were held in either the surgical consultant's private office or a quiet office/room in the hospital ward. Prior to being interviewed, participants received an information sheet and completed a consent form.

The study team developed an interview guide and compiled interview and probing questions focusing on the reasons for and expectations of referral to the clinic, and the level of involvement of the clinic in the surgical decision making process and the delivery of clinical care to patients. The questions and prompts in the guide were developed by the project investigators (academic researchers, the clinic physician and a surgeon) and piloted on selected surgeons to test the appropriateness and flow of questions. For the interview guide, see Appendix 7.4.1.

All interviews were audio recorded and transcribed by either the interviewer, or a professional transcription service and reviewed by the interviewer to ensure accuracy.

Data analysis

Themes were identified at a semantic level focusing on the explicit, stated meaning of the data (Braun and Clarke 2006). CP initially coded all transcripts and EH reviewed and coded selected transcripts. CP and EH examined the consistency of the coded text and explored and refined the emerging themes. All authors contributed to the final selection of themes and their interpretation in relation to the overall research questions.

NVivo 10 for Windows (QSR International Pty Ltd.) was used to transcribe, code and manage data.

Ethics approval to conduct the study was granted by the South Australian Department of Health Human Research Ethics Committee (HREC Protocol No. 490/01/2015) and the Royal Adelaide Hospital Research Ethics Committee (RAH Approval No. 120225/120225a). Written informed consent was obtained from each participant, including permission to audio-record the interviews and use anonymized

quotes.

7.3.4 Findings

General characteristics

Of the 27 invitations sent, 7 surgical consultants agreed to participate (one of whom referred patients infrequently to the clinic). The reasons for non-participation were not known. The duration of the interviews ranged from 10 to 34 minutes (mean 23 minutes). Interviewees were predominantly male, with surgical experience ranging from 11 to 31 years, indicating that all had quite extensive experience on which to draw upon in the interview. The surgical specialties included vascular surgery; colorectal surgery; orthopedic surgery; ear, nose and throat surgery; and general and hepatobiliary surgery. For participants who frequently referred patients to the clinic, data saturation of themes was achieved.

Two main themes were readily identified and explored in this analysis: factors that influence a surgeon's decision to refer a patient to the clinic, and the role of the clinic in assessing and managing complex patients.

Theme 1:

Factors that influence a surgeon's decision to refer a patient to the clinic

In discussing how they assessed and determined whether a patient should be referred to the clinic, participants generally identified at least two of the following factors. All participants initially described the optimization of co-morbidities and would then elaborate with discussion of exemplar patient cases to demonstrate the challenges with managing complex patients and communicating the risks involved with having surgery.

(a) Optimization of co-morbidities

All participants, including the participant who referred patients infrequently, mentioned the optimization of co-morbidities as one of their main expectations when referring a complex patient to the clinic and felt that it complemented the care they provided.

“I see the role of it as **identification of patients who have a higher risk of morbidity and mortality** related to the [...] surgical treatment of their disease, which are largely cancer diseases, and after identification of their risk, then to **optimize their care to reduce that risk** to the lowest possible level for surgery.”

(Participant 3)

And

“... their **medical issues are examined or delineated and any further investigation** that might be warranted is undertaken, medications may be changed [...] and in the process, though I see the optimization probably more as the role, it **gives the patient further insight into what sort of medical risks are involved and potential implications**. So it adds to the **informed decision making process for consent**.”

(Participant 2)

And

“I expect probably a more **thorough assessment from a medical disease point of view**, an optimization of their conditions whether it’s an adjustment of their inhalers or their cardiac medications or whatever. Some more streamlined **advice on what they should be doing with their medications in the perioperative period**.”

(Participant 5)

The assessment and review of current medical conditions and medication management in complex patients appears to be the main reason for referral to the clinic. The focus on the impact of such medical conditions on surgical risk was seen to add to the decision making process and to improve patient informed consent.

(b) Management of factors other than co-morbidities

Beyond the checklist of potentially modifiable co-morbidities that can be optimized by the clinic, there appeared to be unmeasured factors that contributed to the surgeon’s decision to refer, such as a patient’s physiological reserve and resilience.

When discussing the decision to refer a complex patient to the clinic, all participants referred to clinical experience and judgment in discussing how they assessed increased risks and uncertainty during and after surgery.

“... we don't use an algorithm to decide, it's just an **experiential thing** and so I think of patients as oh my goodness they're going to be quite difficult to look after afterwards, I think we should get some help beforehand. You just look at them and go you're going to break if I touch you. It's a resilience thing in a way. **We talk about psychology but it's a physical resilience to see how much reserve do you think they're going to have.** Therefore **if it's very low then you need to make sure that everything goes absolutely perfectly** otherwise it's going to be a disaster.”

(Participant 4)

And

“I think it's **identifying patients that have a low reserve** so while they might not have identifiable medical problems you recognise that they are patients that potentially don't do well after the operation and I suppose that we accept that any major surgery takes someone down a level of functioning so if someone's only just functioning that's going to be significant. I suppose **with fragility, we look at how they cope with everyday function as a sort of measure of how robust they are.**”

(Participant 2)

And

“So just going to the waiting room, **walking them in, sitting them down, getting them up onto the bed.** I mean if it's hard work to get them up onto the bed, you need to crow bar them onto the bed or whatever, a bit of a red flag will go up. **How far they can walk or activities of daily living,** if it's quite challenging.”

(Participant 1)

And

“You get a pretty good idea of frailty in the first 90 seconds when they walk into the room, really. It’s just sort of clinical acumen, I suppose. That probably sounds a bit snobby. But you can just tell - if you sat on a bus and looked at the old people on the bus, you’d think, well, she looks pretty good for 70 and the man looks like he needs help to sit down or to stand up.”

(Participant 6)

As the previous quotes highlight, there was variance in how participants discussed their use of clinical experience and judgement; however, these assessments commonly focused on the physical dimensions of reserve and fragility. One participant described the combination of physical and cognitive characteristics that could also prompt a referral to the clinic, suggesting informal checks for indicators of frailty.

“Strength of handshake, mobility, cognitive ability at answering questions, focusing properly, how they interact with their family. All those things I think all add up to bizarrely an increased operative risk which we somehow try and translate into needing to see a specialist about that beforehand.”

(Participant 4)

There appears to be a stronger focus on the patient’s physical characteristics by observing their ability to perform usual activities than the cognitive and psychosocial functioning, but difficulties with both the physical and cognitive aspects were seen to increase the operative risk.

Despite participants commonly describing the informal checks for some of the indicators of frailty, none identified the use of a quantitative measure.

(c) A strategy for managing difficult and complex cases

Given the complexity of the patient and the uncertainty regarding surgical risk, some participants viewed the clinic as a means to provide an independent, second opinion on whether the patient should proceed with surgery.

“But as I say, having that **second set of eyes or third-party assessment** [...] because **it’s very difficult where a patient’s come along with an expectation that they need something done**. They generally expect that we’re going to see them and say, right, well, yes, away we go. **If you try to tell them that maybe, really, it’s not the best thing to do, I think it’s very useful to have a third party who’s clearly disconnected from the surgical clinic** and say, look, you’re actually not - do you really want to do this? Do you realise this is a bit risky?”

(Participant 6)

And

“...I mean probably **the most common reason I use the clinic is for the patients to understand the risk involved in surgery**. So patients I don’t particularly want to operate on, for me that’s the ideal situation. The patient says why can’t you do this [...] why is it risky? So they go and see [the clinic physician] and then [the clinic physician] tells them. **It helps put the thing in perspective for them.**”

(Participant 7)

These examples highlight how the referral for a second opinion not only provides an additional clinical assessment but also a strategy to manage the expectations of patients, particularly in communicating the risks with surgery.

(d) Holistic assessment and care of the patient

Referral to the clinic is currently ad hoc and largely at the discretion of the surgeon. Prior to the establishment of the clinic, surgeons would refer patients to sub-specialists, such as the cardiologist and nephrologist. One participant in this study continued with this practice and very rarely referred patients to the clinic.

“...I’ve been around for a long time and used to operating on **high-risk patients without having someone review them**, so we’ve got a pretty good understanding of what risks are involved. A pretty good understanding of who needs to have something done [...] **Often if patients need an operation then there’s not much that the high-risk**

clinic can do. I mean if things are - medical conditions are not treated optimally then that's a role for the high-risk clinic. I don't really need a high-risk clinic to tell me this patient might have an infarct, they might have a stroke when I'm doing an operation, to prevent it [...] They've by and large seen other people. Other people manage those things, if everything seems to be controlled. If you can't correct something then they either have to have the operation or they don't."

(Participant 7)

This participant distinguished the surgical from the medical and perceived the clinic to have a role in reviewing medical conditions that were not well managed, but this participant did not require this additional clinic review to supplement their surgical practice. In contrast, those who referred patients to the clinic frequently viewed it as a means to provide a snapshot of the overall health of a patient with multiple medical co-morbidities, as opposed to stand-alone reports from other sub-specialists.

"...these patients, they've usually been cigarette smokers or possibly alcoholics as well, and so related to their lifestyle choices they often have co-morbidity issues related to that, such as issues of cardiac/pulmonary disease sometimes renal disease, diabetes and when people have more than one area of problem, this is when the problem occurs. **The time to get patients in to see each individual clinic, getting a report from each clinic, and trying to coalesce the importance of each of these co-morbidities into one single answer is really what the problem was. So we see the benefit of the high-risk clinic as the coalescence of the risks of all of their co-morbidity and giving us an overall idea about the patient.**"

(Participant 3)

And

"...it's also a bit more holistic so **rather than looking at each individual medical problem that a specialist might see someone for, we've got someone who integrates the whole thing, which is very beneficial.**"

(Participant 2)

And

“... the high-risk clinic is able to access the various bits of information or plug these people into clinics to get extra bits done that we can't. **Before this clinic started, if I saw someone who had a cardiac history, I'd say to them, well, we can do your operation but you have to go and see the cardiologist first.** So then they'd go and they'd sit in the queue for the cardiac clinic, which might be forever. Or they'd see the registrar who'd never seen them before and things - and it'd just - so **this really pulls together all the bits.**”

(Participant 6)

And

“I think a lot of specialists just compartmentalize - I'll worry about the heart and the respiratory guy will just worry about the lungs and you'll see that quite a lot that **no-one puts it all together.** So I think that's important -. **It's an integration of all the different disease processes going on.**”

(Participant 1)

The holistic assessment of the patient provided by the clinic was described by many participants as a consolidation of all the relevant patient factors that support their clinical decision making processes and streamlines patient care, a service not provided elsewhere. It was thought that the medically-focused role of the clinic physician complemented their role allowing them to focus on the surgery. However, this perceived value was not held by all participants, which may explain the continued ad hoc nature of patient referrals to the clinic.

Theme 2:

The role of the clinic in assessing and managing complex patients

When discussing the role of the clinic, two related sub-themes were dominant and focused on the management of risk in complex patients. The participants emphasized the risks for both patients and surgeons and that the involvement of the clinic in the decision making process and communication of risks, particularly in predicting how the patient would cope post-surgery, was valued by surgeons.

(a) Informing and assuring the patient

The clinic provided additional detail on the risks to the patient and the potential implications of surgery, and was perceived to be beneficial to patients who were concerned and hesitant about having surgery.

“It’s useful for us but I think it’s also **useful for the patient, knowing what’s expected, how they’re going to be managed postoperatively to try and minimise their risk** of pneumonia, etc. [...] I see the optimization probably more as the role, it **gives the patient further insight into what sort of medical risks are involved and potential implications**. So it adds to the informed decision making process for consent.”

(Participant 2)

It also appeared to be beneficial for patients who were adamant about undergoing surgery despite having a high risk of morbidity and mortality.

“I think for those that need it, **a more clear indication of risk** that they’re putting themselves at. **We can only tell them so much about the complications of hip replacement, but if they’ve got other illnesses their risk of mortality and other perioperative morbidities** I think it would be important to be assessed as well.”

(Participant 5)

The above example also describes the separation of roles with the surgeon discussing the potential complications of the surgical procedure and the clinic physician providing supplementary information on the potential complications as a result of the patient’s medical conditions. This reinforces the focus on adding to the decision making process and informed patient consent and appeared to provide a form of assurance for the patient.

“Now the way that I’d probably view it most importantly though is that **from the patient’s point of view, they are often worried and scared, they view their outcome as being uncertain** [...] they’re worried that they’re going to die, not from the cancer but from the impact of

having an operation [...] **If [the clinic physician] says to the patient, “I think that you are fit to go through this type of procedure”, they feel confident about that.** Patients often have a traumatic time psychologically, going through management of cancer, the diagnosis and treatment of it, but [if] everybody that’s around them that works in that team [is confident], they feel happier with that.”

(Participant 3)

(b) Assuring the surgeon

Descriptions of the relationship between the surgical team and the clinic revealed that there was ongoing communication and involvement in the management of the patient between the two parties throughout the surgical period, and not just a one-off consultation. This appeared to provide a form of assurance for the surgeon and the surgical team.

“I think communication between the high-risk clinic staff and the referring surgeon is important because there can be discussion about how important a procedure is relatively to treating the patient conservatively [...] Often [the clinic physician will] ring me up and say, “can we wait 3 or 4 weeks, I’ll get these tests done and I’ll start a meeting, [...] is it safe to do that?” Usually there’s quite good communication.”

(Participant 1)

And

“I find it useful when [the clinic physician] rings me to say that this is a real issue or there’s a patient that is a bit outside the norm or their risk is going to be unacceptably high that that personal contact has been useful because it makes sure that is recognised and acted upon.”

(Participant 2)

And

“I think it’s useful for everyone who’s involved because if there’s some concern on the day that they come into theatre, the anaesthetist will say,

well, yes, he's been to the high-risk clinic, he's a bit crumbly, but they seem to have sorted it. I think it gives the anesthetist a bit more reassurance as well."

(Participant 6)

For some specialties, the clinic physician was seen as a member of the surgical team and one who had expertise to medically manage the patient in preparation for surgery.

"[the clinic physician is] an embedded part of our unit, which is critical. [...] it's not just a referral to a clinic but it's an embedding of a physician within the unit who gives us expert opinion on those areas [...] [the clinic physician] probably has more expertise than any other physician in the hospital who doesn't see our patients regularly. [the clinic physician is] a specialist physician for surgeons. [the clinic physician] knows more about surgery than most physicians."

(Participant 3)

And

"[the clinic physician] comes to our radiology meetings so [the clinic physician is] part of the unit [...] often if I talk to [the clinic physician] I say, "well ideally we should an open because the anatomy's not favourable but if they're really high-risk we may change to doing endoluminal even though the long-term results aren't as good". **I think it's useful to have that discussion in complicated cases or cases which are certainly not that straight forward.** And it goes both ways, us letting [the clinic physician] know what the scoop is and [the clinic physician] maybe saying, "you need this, this and this and you can have an open""

(Participant 1)

The clinic was perceived to be beneficial for both the patient and surgeon and helped in determining the most appropriate treatment pathway, especially for complex cases.

(c) Supporting postoperative management

Management of the patient also extended to the postoperative period, with the clinic physician providing recommendations for postoperative care of the patient and the perioperative involvement of clinic nurses (as part of the clinic team) ensuring consistency of care and appropriate postoperative follow-up.

“[the clinic’s] role to me now is optimizing patient care and time of surgery with preoperative care but also perioperative care with the perioperative physician team. So I think it’s only fair to get people involved in looking after people postoperatively only if they’ve had a role in preoperatively.”

(Participant 4)

The postoperative management provided by the clinic physician and team not only focuses on the potential medical complications after surgery but extends to managing the patient’s expectations regarding care and assistance after they are discharged from hospital, as described in the following quote:

“I guess there’s two things, one is if there is an intervention required for example they need a coronary stent or something like that, then that’s kind of a no-brainer, but if there are issues that maybe require convalescence afterwards, high risk of confusion afterwards, those sorts of things that’s useful advice but you have to take into account that that doesn’t usually affect necessarily decision making for the procedure. But there are a reasonable number of patients that are just coping at home and if they do have a major procedure then they’ll probably never get home again and that’s important because a lot of patients want their independence and have no concept that a major intervention may end up with them going to a care facility on a permanent basis not just for some convalescence.”

(Participant 1)

All participants acknowledged the importance of the clinic’s involvement in the postoperative management of their patients. However, the clinic physician’s recommendations for postoperative care were viewed to be for the benefit of the medical

and nursing staff who were involved with the day-to-day care of the patient in the postoperative period.

7.3.5 Discussion

This explanatory study aimed to assess the validity of findings from a recent evaluation of an outpatient Perioperative High Risk Clinic that optimizes surgical patients with a high risk of morbidity and mortality by targeting and managing their modifiable medical co-morbidities (Pham *et al.* 2016). This study focused on identifying factors that influence a surgeon's decision to refer a patient to the clinic and the impact of the clinic on the management of complex patients.

The validity of the evaluation findings

The recent evaluation of the clinic (Pham *et al.* 2016) controlled for potential confounding by using a range of patient-level factors that could potentially influence whether a patient was referred to the clinic. Factors were limited by the routinely collected data available and included patient demographics, surgery-related factors, patient's physical function (using proxy measures such as the ability to walk around the house and upstairs) and the modifiable medical co-morbidities targeted for optimization by the clinic. The results varied depending on the method used to control for differences in observed potential confounders suggesting that the inclusion of other unmeasured confounding factors would improve the characterization of the complexity of patients referred to the clinic.

Findings from this study suggest a high likelihood of unmeasured confounding in the quantitative evaluation of the clinic and additional relevant outcomes that could be collected to describe the perceived value of the clinic. The presence of potentially modifiable co-morbidities that increase the risk of morbidity and mortality in patients was confirmed to be the initial indicator for a clinic referral for optimization, thereby supporting the covariables used in the quantitative evaluation to control for confounding. However, unmeasured factors such as the surgeon's subjective clinical assessment of the patient and the informal use of frailty indicators also appeared to influence whether a patient was deemed to be complex and requiring additional management and treatment. This is consistent with previous studies

(Wijeysundera *et al.* 2012, Thilen *et al.* 2013) reporting that associations between preoperative consultation and the presence of medical co-morbidities only explained a small proportion of the substantial variation in referral patterns for consultation. This small study provides further insight into other possible sources of variation in such referral patterns.

Participants within this study described consideration of the patient's physiological reserve and resilience, indicated mainly by physical characteristics such as the ability to walk from the waiting room to the consult room, strength of handshake, and general physical function, as contributing factors to their decision to refer a patient to the clinic. Cognitive and psychosocial functioning were considered but were not the main focus for the participants. The clinic includes a mini-mental state examination for cognitive impairment and the likelihood of postoperative delirium as part of the medical assessment, which appears to complement this aspect of patient care for the participants. Frailty and quality of life measures, not routinely collected in clinical data, could potentially enhance the quantitative evaluation by improving the characterization of clinic patients. However, other aspects of the surgeon's subjective assessment, such as clinical judgment, are difficult to quantify and their influence on the reasons and thresholds for referral warrant consideration.

Clinical decision making is a complex process (Minick and Harvey 2003), dependent on the surgeon's clinical judgment in conjunction with evidence-based practice to provide quality patient care (Pearson 2013, Newell *et al.* 1972) and the patient's anatomy, physiology and well-being (Crebbin *et al.* 2013). Clinical judgment has been described to involve critical thinking, reflective practice, problem solving, judgement, ethical values and professional accountability (Standing 2005). With the accumulation of data from various clinical experiences, this judgment could be interpreted as a cognitive process involving pattern recognition that draws upon the interpretation of clinical evidence within the experience, understanding and prior knowledge of the practitioner (Francis 2009) and differentiates the novice from the expert practitioner (Benner and Tanner 1987). Unfortunately, there are no reliable and validated measures of clinical judgment (Minick and Harvey 2003) but further research could acknowledge that variation exists and focus on how thought processes of the expert practitioner, such as the types of questions asked of the patient and the forward reasoning, determine the most appropriate treatment pathway (Willi-

ams 2017). This could inform and improve the shared decision making process and provision of patient-centered care.

The perceived value of the clinic

Participants described additional value in the form of an overall assessment of the current health status of a patient, and the benefits of an integrated approach regarding assurances to both the patient and the surgeon beyond the clinical outcomes measured in the quantitative evaluation.

Clinical outcome data, such as surgical cancellations, length of hospital stay, postoperative complications, mortality and quality of life, are important to demonstrate the cost-effectiveness of preoperative medical consultations but the additional perceived value of the clinic may not be adequately captured in such clinical outcome measures (Pham *et al.* 2016). The reduction in uncertainty and the discussions regarding risk and expectations post-surgery, elements of value evident in this study, warrant consideration when assessing the value of health care interventions such as the high-risk clinic. However, how to best measure and include such elements of value and other patient-reported outcomes into cost-effectiveness analysis remains a subject of debate (Lakdawalla *et al.* 2018).

The surgeon and clinic physician relationship has also not been well described in previous studies (Pham *et al.* 2017), making it difficult to determine whether the clinic physician provided a stand-alone consultation with no postoperative patient follow-up or an integrated approach to patient care between the surgeon and clinic physician. The clinic physician in this study was considered a member of the surgical teams with expertise on the medical management of patients in preparation for surgery. There was ongoing communication and active involvement in the management of the patient between the surgeon and the clinic physician throughout the surgical period. Participants valued the role of the clinic in providing additional information and the opportunity for further discussion of the risks and potential implications with surgery to help with the management of patient expectations after surgery. Good communication has the potential to improve overall patient care coordination and the patient experience (Rosenstein 2012).

In this study, we have explored the surgeon's perspectives of the clinic as it is the surgeon who authorizes the referral of a patient for preoperative assessment

and management. The small sample of participants limits the generalizability of the findings to other clinics providing a similar service. The lack of participation by clinicians choosing not to use the clinic is also a limit to the study. The assurances provided to both the patient and the surgeon through the assessment and management of risk and uncertainty regarding surgery should be explored through further qualitative interviews or validated shared decision making questionnaires. Additional perspectives from the patients, the clinic team and other medical professionals collaborating with the clinic would also provide further insight into the aspects of care that provide additional value.

Decisions to invest in services such as those provided by the clinic are driven by their impact on the costs and health benefits. The development, validation and evaluation of a checklist, based on the key factors identified through qualitative and quantitative evaluations, could guide the assessment and selection of patients who would benefit most from such services and enable a robust evaluation of the clinic. Ensuring the optimal use of such services, as opposed to the ad hoc nature of the current referral process, would improve the effectiveness of existing clinics and inform the implementation of clinics at other hospitals.

Conclusions

The integration of the preoperative medical consultative service provided by the clinic in this study appears to offer additional value in supporting the decision-making process for the surgical team and patient beyond the clinical outcomes. The factors that influence a surgeon's decision to refer a patient to the clinic appear to be driven by the aim to manage the uncertainty and risk to the patient regarding surgery and it was seen as a strategy for managing difficult and complex cases. The current ad hoc nature of determining which patient to refer to the clinic, as described by the participants in this study, may explain the variations in the clinical outcome measures from the quantitative evaluation, and suggest a high likelihood of unmeasured confounding, with frailty and quality of life measures not captured in current routinely collected hospital data. Further research is required to explore the perspectives of the patient, the clinic team and other medical professionals collaborating with the clinic and guide the optimal use of the preoperative medical consultative service. This will inform improvements to the design, implementation

and evaluation of preoperative medical assessment and management.

7.3.6 Acknowledgements

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7.4 Appendices

7.4.1 Appendix 1. Interview guide

Preoperative medical assessment and management

- Provide information sheet
- Obtain informed consent (2 copies)
 - Confidentiality - all data de-identified
 - Permission to audio record this discussion
 - Please feel free to ask any questions during the interview
- Ask whether the participant would like to be sent a transcript of the interview for them to check and make further comments if necessary

The focus of this discussion will be on the perioperative high-risk clinic at the RAH. Findings from our quantitative analyses on the impact of the clinic on certain outcomes (LoS, mortality, and complications) are not what we expected.

We thought surgeons would be the best people to speak with as you have the expertise to help us explore what we might be missing from our analyses.

We would like to explore your perspectives of the clinic and give you the opportunity to reflect on current practice.

Ref ID: _____

Date: _____ / _____ / _____

Start time: _____ AM / PM

End time: _____ AM / PM

Specialty:

- Urology
- Orthopaedic
- Vascular
- ENT
- Colorectal

A. ABOUT YOU

- What is your current position at the RAH/TQEH?
- What year were you awarded FRACS?
- How long have you been working at the RAH/TQEH?
- How many other consultants are there currently in your specialty?

B. THE PREOPERATIVE HIGH RISK CLINIC

This interview focuses on patients scheduled for elective surgery and the process from GP referral to admission for surgery, and the involvement of the perioperative high-risk clinic in the management of complex patients with multiple medical co-morbidities.

- Q1. Could you please describe your understanding of the role of the high-risk clinic?**

Probing questions:

- Do you know about the physician-led preoperative high-risk clinic?
- How did you first hear about it?
- Do you refer patients to the clinic?
If yes, how often? How many patients per week on average?
If no, skip to **section F-G**
- What prompted you to begin referring?

- Q2. Do you think the clinic complements what you do?**

- Q3. When you refer patients to the high-risk clinic, what do you expect to be done?**

Probing questions:

- Is it more about risk management or benefit to the patient?
- What impact do you think the medical consult has? Reduce the likelihood of having peri- and post-operative complications? Long-term benefits post-discharge?

C. DECIDING REFERRAL

- Q4. How do you determine whether the patient should see a physician or other specialist?**

Probing questions:

- Is it about the availability of specialists? Or when there are multiple issues and not sure which condition needs attention?
- Before the clinic was established, who did you refer to for medical optimisation?

D. DETERMINING ELIGIBLE PATIENTS

- Q5. Over the last 12 months, what would be your main reason for referring a patient to the high-risk clinic?**
- Q6. What are the key factors you use to determine whether a patient should be referred to the high-risk clinic?**

Probing questions:

- Do you use specific clinical measures?
- How about cognitive and psychosocial factors?
- Preliminary analysis of quality of life data suggests that self-care and usual activities are predictive factors for clinic referral. Do you think this might be a useful in your decision making?

E. MEDICAL CONSULT

- Q7. The clinic provides a list of recommendations, how do you deal with them?**

Probing questions:

- Do you find them useful? If no, how could they be improved?
- There can be numerous recommendations for some patients, in these instances how do you prioritise?
- If you focus on surgical recommendations only, what happens to the other recommendations?
- When you check on the patient postoperatively, do you refer back to these recommendations?

F. DISTRIBUTION/COMMUNICATION OF REFERRAL GUIDELINE

- Q8. Have you seen this referral guideline? (see Chapter 7.4.2)**

Probing questions:

- Do you think it is useful/helpful? Why or why not?
- Do you think the communication could be improved? How? Dissemination?

G. LOW/NO REFERRAL FOR PREOPERATIVE MEDICAL CONSULTATION

- Q2. May I ask why you do not refer?**

Probing questions:

- Could you explain why you think it's not useful/effective?
- Do you think it does not address a particular need?

- Q3. What do you do instead? How do you manage complex patients with multiple co-morbidities?**

Probing questions:

- How do you prioritise management of co-morbidities?
- How do you manage the complexities of these needs?
- What do you think might address the needs of these complex patients better?

7.4.2 Appendix 2. Referral guidelines

Guidelines for referral to the physician-led Perioperative High Risk Clinic

The Perioperative High Risk Clinic (POHR) provides physician-led assessment of patients being worked up towards elective surgery. The assessment aims to diagnose and optimise medical conditions which may impact on the surgical outcome of these patients. This will include liaison with the General Practitioner to try and improve longer term medical care, and advice to interns to guide appropriate postoperative medical management, and may include advice on risk: benefit of proceeding with the planned surgical procedure.

Patients seen in the POHR will be supported after surgery by the perioperative clinical practice consultant.

Any patient that is felt to be likely to benefit from preoperative physician-led assessment will be seen in the POHR clinic.

All referrals will be triaged according to surgical priority (i.e. patients awaiting curative surgery for malignancy will be prioritised over patients awaiting non-life saving elective surgery).

Referrals will be accepted from any and all medical practitioners.

Medical co-morbidities that may be targets for optimisation prior to elective surgery include:

CARDIAC

- Symptomatic angina or cardiac failure

- Previous cardiac history with no recent cardiac follow up

- Hypertension

- History of CVA, MI or CCF

- Advice regarding antiplatelet agents

- Previous drug eluting stent insertion

PULMONARY

Shortness of breath on exertion

Recalcitrant smoking

COPD/asthma

RENAL

Any degree of renal dysfunction may be associated with increased risk of perioperative morbidity and mortality

THROMBOEMBOLIC

Advice regarding anticoagulation particularly warfarin

DIABETES

Poorly controlled diabetes

Significant diabetic end organ damage

ANAEMIA

For further information or to discuss potential referrals please contact either:

Dr Katy Gibb ext 22074

CPC Colette Burford SD 1618

Part IV

Conclusions and recommendations

Chapter 8

Conclusions and recommendations

The aims of this research were to evaluate the preoperative assessment and management services provided by the physician-led high-risk clinic, and provide recommendations for improvement. It is anticipated that the findings from this evaluation will guide the identification of elective surgical patients who would benefit most from preoperative physician-led medical optimisation, and provide clarity on the collaborative care provided by the high-risk clinic and surgical teams in managing complex patients. The principal findings, contributions and recommendations for further research are presented in this concluding chapter.

8.1 Principal findings

The clinical rationale

A set of potentially modifiable co-morbidities in elective surgical patients are associated with increased length of hospital stay and postoperative complications (Chapter 3). The nine potentially modifiable co-morbidities identified include ischaemic heart disease, congestive heart failure, stroke, diabetes mellitus, renal impairment, anaemia, dementia including Alzheimer's disease, asthma or COPD and primary hypertension. This supports the clinical rationale of the clinic in that outcomes will be worse in the subset of patients for whom such co-morbidities are poorly controlled, and that timely intervention to improve control in the period prior to surgery will improve postoperative outcomes.

A review of the literature

A systematic review of the literature found that the effectiveness of preoperative medical consultation is uncertain due to a lack of high-level comparative evidence (Chapter 4). The design and implementation of preoperative assessment applied to date was heterogeneous, with minimal detail from each of the included studies on the actual services provided as part of the intervention. However, the consolidation of existing evidence identified potential elements of preoperative assessment that may contribute to better outcomes, such as the eligibility criteria for referral, and the timing and process of assessment.

The evaluation of the costs and outcomes

An evaluation of the costs and effects of a local outpatient clinic providing physician-led preoperative assessment and management was conducted using a propensity score-based approach with retrospective and prospective data (Chapter 5). The clinic was found to reduce the frequency of unnecessary admissions and cancellations, but significant uncertainty remained around the effect of the clinic on length of hospital stay, postoperative complications, hospital costs and post-discharge mortality. Supplemental data on a prospective cohort of patients identified preoperative health-related quality of life as a potential unmeasured confounder in the evaluation. The lower mean preoperative QoL index score reported in clinic patients suggested that preoperative QoL could improve the characterisation of clinic patients (Chapter 6). This evaluation illustrates the value of mixed retrospective prospective observational study designs but also highlights the need to prospectively plan for the evaluation of costs and effects alongside the implementation of significant service innovations.

Validating the evaluation findings

Semi-structured interviews with surgeons found that the factors influencing their decision to refer a patient to the high-risk clinic appear to be driven by the aim to manage the uncertainty and risk to the patient regarding surgery and it was seen as a strategy for managing difficult and complex cases (Chapter 7). The current ad hoc nature of determining which patient to refer to the clinic may explain the

variations in the clinical outcome measures from the quantitative evaluation, and suggest a high likelihood of unmeasured confounding, with the surgeon's subjective clinical assessment of the patient, frailty and quality of life measures not captured in current routinely collected hospital data. Further, the integration of the services provided by the clinic in this study appear to offer additional value in supporting the surgical decision making process for the surgical team and patient beyond the clinical outcomes, such as managing the patient's expectations regarding care and assistance after discharge from hospital. Additional perspectives from patients, the clinic team and other medical professionals collaborating with the clinic should be explored and would provide further insight into the aspects of care that provide additional value.

8.2 Contributions to public health and medicine

This research represents the first comprehensive evaluation of services for the preoperative assessment and management of high-risk surgical patients. This evaluation suggests that preoperative intervention may be cost-effective in selected patients, and the identification of key preoperative indicators that influence postoperative outcomes may better inform shared decision-making around the risks and benefits of elective surgery. In the quantitative evaluation, propensity-based matching reduced the differences in the postoperative outcomes between clinic and control patients and, in some cases, improved outcomes in favour of the clinic. This suggests that there is a subset of patients who have a greater capacity to benefit from the services provided by the clinic. The inclusion of clinic patients with a lower capacity to benefit, due to the ad hoc nature of referral to the clinic, may have diluted the effectiveness of the clinic. Alternatively, the control patients may have had a lower risk of poor postoperative outcomes due to unmeasured confounding.

The involvement of the clinic in the communication of risks to the patient, particularly in predicting how the patient would cope post-surgery, was valued by the surgeons. This appeared to provide additional support to both the patient and the surgeon and contributed to the decision making process. Moreover, the surgeon and clinic physician relationship and the collaborative care provided has been described in detail, an area not well described previously. Documenting the collaborative

nature of the care provided in this setting enabled the identification of additional elements of value and an understanding of the challenges with managing complex patients. This would also enable future comparisons with similar clinics nationally and internationally.

Methodologically, this research has illustrated the difficulties with retrospective service evaluations involving complex patient populations. It has demonstrated the value of the novel covariate balancing propensity score method to minimise observed confounding, and of the prospective assessment of the likelihood of an unmeasured confounder. As demonstrated in the quantitative evaluation, there are limitations to the use of routinely collected data. Despite the benefits of immediate access to a large, longitudinal dataset, some variables of interest were missing or not collected. The prevalence of co-morbidities in the routinely collected data was underestimated as the coding of data was based on the information in patient casenotes. Through the data collection process in the quantitative evaluation, stroke, anaemia and dementia were under-reported and required additional manual searching of the patient's medical history for previous hospital admissions, pathology results and hospital discharge summaries. The level of severity for each co-morbidity was also difficult to determine, even with supplementary information from pathology results and medications. The routine collection of patient-reported outcomes, such as health-related quality of life, would have improved this evaluation and could inform evaluations of other models of care.

As a result of the reported findings, changes in clinical practice have already been implemented with primary hypertension now targeted for medical optimisation and a frailty assessment (checking for five key criteria: unintentional weight loss, self-reported exhaustion, grip strength, walking speed and physical activity) has been included in the standard assessments conducted by the high-risk clinic.

8.3 Recommendations for future research

Further research is required to inform the value, and the optimal design and implementation of coordinated involvement of physicians and surgeons in the provision of care for high-risk surgical patients. A standardised approach to perioperative decision-making processes should be developed and evaluated with a clear protocol

or guideline for the assessment and management of surgical patients.

Clearly, some form of randomised controlled trial is the preferred study design for the evaluation of such interventions, but in the absence of resources and buy-in to undertake an experimental study, sufficiently robust data will need to be collected and analysed to overcome the limitations observed in this study. Further evaluation could be expanded to include hospitals in which the preoperative clinic has not been implemented in order to provide greater covariate balance between the intervention and control groups. The need to collect prospective data precludes the use of a conventional pretest/posttest study with a contemporaneous control study design for this intervention, as the clinic is currently operational and only retrospective data would be available for the pretest period. Focusing on the differences in outcomes for the same surgical procedure and matching clinic and control patients at the study hospital to a control hospital could inform an adapted pretest/posttest approach, though the issue of small sample sizes remains a key challenge.

Findings from the quantitative evaluation of the clinic highlighted an area of further interest regarding mortality. There was a high proportion of deaths at 12 months in patients undergoing a TURP procedure compared with the other more invasive procedures included in the analysis. This was an unexpected finding for a procedure that is meant to improve quality of life, not life expectancy. Further investigation ruled out prostate cancer as the cause of death, and suggests that this could potentially be due to a higher proportion of unwell patients undergoing the procedure. In contrast, the low proportion of deaths in patients undergoing a TKR may be due to the procedure only being offered as an option if the patient is considered fit for surgery. Identifying the preoperative patient and clinical factors associated with an increased risk of death within 12 months as well as other patient-reported outcomes (e.g. functional decline and discharge institutionalisation after surgery) could be advantageous. This has the potential to enhance the shared decision-making process and improve informed patient consent for surgery or alternative treatment options in patients where risks outweigh benefits. This is particularly relevant for cancer patients who may have to choose between surgery (with a chance of prolonged survival but increased risks of adverse postoperative outcomes and poor quality of life) and palliative care (certain death but quality of life is maintained).

The perceived benefits to both the patient and the surgeon through the assessment and management of risk and uncertainty regarding surgery should be explored through further qualitative interviews or validated shared decision making questionnaires. Additional perspectives from the patients, the clinic team and other medical professionals collaborating with the clinic would also provide further insight into the aspects of care that provide additional value.

8.4 Concluding remarks

An increasing ageing population will affect the demand and provision of hospital services and the presence of co-morbidities adds to the complexity of patient care. High-risk clinics were established in two large metropolitan public hospitals in South Australia to optimise medical co-morbidities in patients in preparation for elective surgery and coordinate postoperative care. Currently, there are no clear recommendations regarding the selection of surgical patients for medical consultation. Substantial practice variation exists with the decision to refer a patient at the discretion of the treating surgeon and influenced by the surgeon's individual preference for the intervention and subjective assessment of the patient's need for medical assessment.

However, in a resource constrained health care system, it is necessary to provide evidence on costs and benefits to support funding decisions for new services. Moreover, the decision to fund preoperative optimization is not a single, binary decision to fund or not to fund. There are also decisions around the capacity and scope of the service. Given that the capacity is likely to be insufficient to cover all surgical patients with potentially modifiable co-morbidities, there is a need to determine the prioritisation of patients and to develop a systematic and evidence-based process to guide referral of elective surgical patients for preoperative physician-led medical optimisation. The development, validation and evaluation of a checklist, based on the key factors identified through qualitative and quantitative evaluations in this thesis and future research, could guide in the assessment and selection of patients who would benefit most from such services. Ensuring the optimal use of such services, as opposed to the ad hoc nature of the current referral process, would improve the effectiveness of existing clinics and inform the implementation of clinics at other

hospitals.

This evaluation provides a guide to the identification of elective surgical patients who are likely to benefit most from preoperative physician-led medical optimisation. It also provides clarity on the collaborative care provided by the high-risk clinic and surgical teams in managing complex patients to inform the assessment of such clinics in Australia. This research has demonstrated the need to plan for the robust evaluation of new health service initiatives, which may be facilitated through better co-ordinated planning and evaluation across Australian hospitals.

“Medicine is a science of uncertainty and an art of probability.”

– William Osler, 1965

