Systematic Reviews of Surgical Comprehensive Geriatric Assessment and Assessment of Drivers of Cost in Elderly Emergency Surgery Patients

by

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Abstract

Aging populations are increasing the demand for surgical intervention in those over 65 years of age. Older patients experience higher morbidity and mortality. Comprehensive geriatric assessment (CGA) is a multi-faceted approach to in-patient care that addresses medical, functional and psychosocial factors. It is proposed to decrease cost and adverse outcomes in the elderly. I will investigate the effectiveness of CGA in published studies then examine the costs associated with emergency abdominal surgery in a cohort of elderly surgical patients.

Two systematic reviews of CGA in surgical patients were conducted. Both examined CGA in surgical patients 65 and older. The primary outcomes for the Cochrane review were mortality and return of pre-morbid function. The primary outcome in the economic review was reported economic outcomes. We also retrospectively examined general surgical inpatient costs over two fiscal years at four hospitals within the Edmonton zone. Costs were compared between surgical risk profile, urgency and age.

The Cochrane review found end-of-study mortality trended towards improvement and discharge disposition was significantly improved. Length of stay and readmission were unchanged and complications were decreased. The economic systematic review found lower cost while loss of function, length of stay and mortality were all reduced suggesting CGA may be the economically dominant choice when compared to usual care. All but one study in each review were in orthogeriatric patients; there are insufficient studies to draw conclusions about other surgical populations.

Within the Edmonton zone, unscheduled cases were statistically and clinically significantly costlier for 65-79 and 80+ year-old age groups when compared to those under 65. Scheduled surgeries were not clinically significantly different between age groups.

Economic evaluation of acute abdominal surgical patients aged 65 and older was conducted. Patients were prospectively enrolled in the Elder-friendly Approaches to the Surgical Environment (EASE) study at two Canadian hospitals in a trial of CGA versus usual surgical care. Baseline clinical, social and demographic characteristics were assessed. Follow-up was conducted at 6 weeks and 6 months following discharge. The Alberta Health Services (AHS) microcosting database along with other AHS and Alberta Health costing databases were used to calculate inpatient, readmission and total healthcare costs from enrolment to 6-months following discharge. Patient-reported resource use within 6 months of discharge was measured using a validated Health Resource Utilization Inventory (HRUI). The primary outcome for database costs analysis was total government healthcare costs; which was assessed using multivariate generalized linear regression. HRUI costs were assessed in a separate analysis with regression.

Analysis of the costs accrued by patients enrolled in the EASE study found mean total government costs was $33,752. Multivariate regression found the cost of care increased with higher ASA (Adjusted ratio [AR]=1.24, $p=0.002$), higher frailty (AR=1.27, $p<0.001$) and both minor (AR=1.50, $p<0.001$) and major complications (AR=2.01, $p<0.001$). After controlling for clinical and demographic data, patients who completed the HRUI had frailty predicted increased cost of healthcare services (AR=1.50, $p=0.001$) and medical products (AR=1.62, $p=0.005$) and decreased cost in lost productive hours (AR=0.39, $p=0.002$). Complications did not predict any change in cost in any category.

Overall, CGA is a promising tool to reduce the cost of care while improving outcomes in seniors undergoing unscheduled orthogeriatric procedures. Retrospective analysis identified increased surgical costs with age for unscheduled surgery. Screening elective surgical candidates may decrease admission costs; innovative programs are needed to reduce emergency admission

costs. Frailty was also found to predict increased total government costs over 6-months and predicted increased cost of healthcare services and medical products. The EASE study is currently examining the effectiveness of CGA in an unscheduled general surgical population.

Preface

This thesis is an original work by Gilgamesh Eamer. The research project, of which this thesis is a part, received research ethics approvals from the University of Alberta Research Ethics Board, Project Names: EASE Study (Study ID Pro00047180), EASE-ECON (Study ID Pro00061609) and EASE cost of stay (Pro00068094).

Research conducted for this thesis forms part of a collaboration, led by Dr. Rachel Khadaroo and Dr. Fiona Clement at the University of Alberta and University of Calgary respectively.

Chapter 2 of this thesis has been published in part as: Eamer G, Taheri A, Chen SS, Daviduck Q, Chambers T, Shi X, Khadaroo RG. Comprehensive geriatric assessment for improving outcomes in elderly patients admitted to a surgical service. Cochrane Database of Systematic Reviews. 2017. The publication represents the approved protocol (Background and Methods sections). The full review is currently under review under the same title and with the same authors. QD and GE coordinated the contributions from the coauthors and wrote the final draft of the protocol. QD, SC, TC, and GE worked on the methods sections. QD and GE drafted the clinical sections of the background, and TC was the contract person with the editorial base. QD and GE wrote the protocol with assistance from AT, SC, RK, and TC. TC devised and carried out the search strategy. QD, GE, and SC wrote the statistical analysis and data synthesis sections. RK, SC, QD, GE, and AT contributed significantly to the protocol. RK was the team lead and coordinator and a major contributor to the initial concept of the protocol. XS provided guidance for statistical analysis. Abstracts, results, discussion and conclusions were written by GE. Editing and revision of these sections was performed by the remainder of the team. The work has been presented at Academic Surgical Congress 2017, Feb 7-9, 2017 Las Vegas, USA by myself and at General Surgery Research Day, April 8, 2016, Edmonton, AB by SC.

Chapter 3 is in press as: Eamer G, Saravana-Bawan B, van der Westhuizen B, Chambers T, Ohinmaa A, Khadaroo RG. Economic Evaluations of Comprehensive Geriatric Assessment in Surgical Patients: A Systematic Review. J Surg Res (In Press). GE conceived, designed and executed the study. BS-B and BvdW assisted with article review and data extraction. TC designed the literature search. AO and RK supervised the project and provided insight. All authors approved the final article. The work has been presented at Academic Surgical Congress

2017, Feb 7-9, 2017 Las Vegas, USA by BvdW and Tom Williams Surgical Research Day 2017, May 12, 2017, Edmonton, AB by GE.

Chapter 4 is a collaborative work by myself, Ronald Brisebois, Fiona Clement and Rachel Khadaroo and is under review at the Canadian Journal of Surgery titled Unscheduled general surgery, but not scheduled general surgery, have higher costs in the elderly. I conceived of the study, analyzed the data and drafted the manuscript. RB supervised the project, facilitated access to the data, provided guidance and revised the manuscript. FC provided assistance with statistical and economic analysis. RK supervised the project and assisted with manuscript preparation and revision.

Chapter 5 is a collaborative work by myself, Fiona Clement, Jayna Holroyd-Leduc, Adrian Wagg, Raj Padwal and Rachel Khadaroo. GE performed the data cleaning, analysis and drafted the manuscript. RK conceived of the original overall study, is the research lead for the EASE study, supervised the projects and assisted with manuscript revision. JH-L, AW and RP all assisted with study development and provided editorial support. FC provided guidance on data acquisition, cleaning, analysis, and provided mentoring for all components of the economic analysis.

Chapter 6 is a collaborative work by myself, Fiona Clement, Jenelle Pederson, Tom Churchill, and Rachel Khadaroo; revisions are under review at the Canadian Journal of Surgery as Cost Analysis of Post-Discharge Costs Following Emergent General Surgery in the Elderly. GE performed the data extraction, analysis and authored the manuscript. FC helped develop the initial study design, provided insight into the economic evaluation and helped revise the final manuscript. JP assisted with data cleaning, statistical analysis and manuscript revision. TC assisted with statistical analysis and supervised manuscript development and revision. RK conceived of the original study design, supervised the overall EASE study and assisted with manuscript revision. This work has been presented in parts at the University of Alberta School of Public Health INSIGHTS' 15 conference, the University of Alberta General Surgery Research Day 2016, Academic Surgical Congress, Jacksonville, Florida Feb 2-4, 2016 and Surgical Congress 2016, Oct 16-20 Washington, DC, USA.

Acknowledgements

I would like to acknowledge the experience and support provided by my committee members, Drs. Rachel Khadaroo, Tom Churchill, Arto Ohinmaa and Fiona Clement. They have provided valuable and timely advice and encouragement over the last two years. Dr. Churchill was always available for discuss any challenges I faced and Dr. Khadaroo could not have been more supportive for my career development and for abstract development to allow attendance at national and international conferences.

I would like to acknowledge all the members of the Khadaroo Lab, in particular Jenelle Pedersen, Lindsey Warkentin, Carrie Le and Justin Lowes for their assistance with patient recruitment and data acquisition. Jenelle Pedersen also provided valuable advice about statistical methodology and analysis and Lindsey Warkentin provided valuable assistance with data cleaning and analysis.

I must also thank agencies that have provided financial support of the past two years. The University of Alberta Clinician Investigator Program provided salary support for two years. Without their support, I would not have been able to enrol in my program. Additional support from the Canadian Frailty Network, through their Interdisciplinary Fellowship Program, was also greatly appreciated.

I would like to thank my father, Wally Eamer, for assistance with proof reading. I have also received support from colleagues on many aspects of this thesis including Thane Chambers, Sidian Chen, Quinn Daviduck, Bianka Saravana-Bawan, Xinzhe Shi, Amir Taheri and Brenden van der Westhuizen.

Finally, I would like to thank my family. My wife, Erin Eamer, has been a constant confidant and has supported me during my medical training and research. Without her, I would not have been able to pursue my research interests. My two children, Rory Eamer and Felix Eamer, who are a constant reminder of the wonders the world holds. I would like to thank them for their understanding and patience with my frequent absences for my medical and research training.

Gilgamesh Eamer MD

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Abbreviations

AADL: Alberta Aids to Daily Living
ACS-NSQIP: American College of Surgeons – National Surgical Quality Improvement Program
AHS: Alberta Health Services
ANOVA: Analysis of variance
AR: Adjusted ratio
ASA: American Society of Anesthesiologists
AHS: Alberta Health Services
BIC: Bayesian information criterion
BMI: Body mass index
CAD: Canadian Dollar
CCI: Charlson co-morbidity index
CENTRAL: Cochrane central register of controlled trials
CFS: Clinical Frailty Scale
CGA: Comprehensive geriatric assessment
CI: Confidence interval
CINAHL: cumulative index to Nursing and allied health literature
DAD: Discharge Abstract Database
EASE: Elder-friendly Approach to the Surgical Environment
EPOC: Effective practice and organization of care
GDP: Gross domestic product
GLM: generalized linear model
GNH: Grey Nuns Community Hospital
HRUI: Health resource utilization
ICER: Incremental cost effectiveness ratio
IQR: Interquartile range
LOS: Length of Stay
MCH: Misericordia Community Hospital
MD: Mean difference
mFI: modified Frailty Index
NHS EED: National Health Services Economic Evaluation Database
OECD: Organization for Economic Co-operation and Development
OR: Operating room
PPP: Purchasing power parity
QHES: Quality of health economic surveys
PIN: Pharmaceutical Information Network
RAH: Royal Alexandra Hospital
REB: Research Ethics Board
RIW: Resource Intensity Weight
RR: Risk ratio
SD: Standard deviation
TX: Texas
UAH: University of Alberta Hospital
UK: United Kingdom
USA or US: United States of America
USD: United States Dollars
WHO ICTRP: World Health Organization International Clinical Trials Registry Platform
ZINB: Zero-inflated negative binomial

Chapter 1 – Introduction

Shifting Demographics and Frailty

The developed world, including Canada, Western Europe, Japan and Australia/New Zealand face rapidly aging populations. These aging populations are increasingly in need of surgical interventions. Improved medical technology, support and experience has allowed greater numbers of elderly patients to become surgical candidates[1,2]. Currently, 11.4% of Alberta residents, and 15.7% of Canadians are over the age of 65[3]. This is projected to grow to 24% of Canadians by 2036[4]. Expanding the treatment criteria not only leads to more surgical candidates but increases the marginal cost of delivering care. Those who have become surgical candidates because of improved technique, technology and experience are those at highest risk of post-operative complications, prolonged hospitalization and increased dependency or institutionalization following discharge.

Many elderly people slowly loose strength and become dependent on others for their instrumental activities of daily living and eventually basic activities of daily living. Frequently this is due to increasing frailty, defined as poor physiological reserve limiting response to acute physiologic insult such as surgery. Frailty is predictive of post-operative morbidity and mortality[1,2,5–8]. It continues to be a relative contraindication to surgery in some circumstances, however advances have allowed patients with advanced frailty to become surgical candidates. It is independently associated with increased post-operative complications including readmission[9], 30 day and 1-year mortality[6,10] as well as post-discharge institutionalization[2]. Post-operative complications in the elderly are also associated with longer hospital admissions, increased disability, increased hospitalization cost[11,12], loss of independence, and mortality[6,7]. While continuously increasing the scope of surgical practice allows for definitive treatment of more frail and elderly patients; the increased complications experienced by this cohort must be addressed. The adverse effects of lost productive years, increased dependency on family and government services and the increased mortality are costly to the patient, their family and society in general. Additionally, in a publicly financed health system, careful stewardship of scarce healthcare resources is critical in taming our ever-increasing healthcare budgets.

Healthcare in Canada has been increasing more that the national inflation rate for decades and currently represents 10.9% of Canadian GDP or $219.1 billion in 2015[13]. Our health expenditure is in the top quartile of OECD nations[13] and Alberta, in particular, remains at the top of per capita expenditure among all provinces ($6,966 per person year)[13]. Despite high healthcare spending, outcomes in Alberta are no better than the Canadian average according to the Conference Board of Canada[14]. Physicians represent the most significant cost driver in Canadian healthcare. They prescribe medication, order investigations and determine when and for how long a patient needs admission to hospital. To control Canadian healthcare spending we must target the largest cost drivers.

Significant demographic shifts are occurring as we grapple with increased spending. As the baby-boom generation ages, a large cohort of people will enter the most expensive phase of their medical lives. Per capita spending for patients 75-79 in Alberta in 2012 was over $10,000 (adjusted to 1997 dollars) per year. This represents a three-fold increase above the 60-64 age cohort[15]. It remains unclear how age affects the cost of surgical care. Age has been shown to increase the cost of surgical care[16], however advancing age may be confounding since it is also strongly correlated with frailty and frailty predicts increased cost better than age[17]. Most recent estimates are that age accounts for only 0.4% of the increase[15]. However, this is likely to change as the oldest age categories swell as it is unclear how specifically age and frailty affect the cost of surgical care or if we can improve patient care without increasing the cost of surgical care.

Comprehensive Geriatric Assessment

To control health spending, we need to find innovative ways to improve care while decreasing costs. Seniors represent a major demographic cohort and often present with complex medical needs. They are more prone to medical complications, particularly after undergoing a significant physiologic insult such as surgery. Increased costs associated with complications are well documented in the hospital setting[11,12].

Interventions to improve mobilization, orientation and oral nutrition in frail patients' undergoing elective surgery have been shown to improve elder specific post-operative outcomes[18]. Comprehensive geriatric assessment (CGA) is "an established method for evaluating and optimising physical, psychological, functional and social issues in older patients to improve longer-term outcomes"[19]. It is typically interdisciplinary in nature and involves thorough geriatric history, medication review, rehabilitation planning and long-term follow-up. CGA for geriatric surgical patients is increasingly being investigated as a means to predict and reduce post-operative complications in this vulnerable population. It has been shown to not only be predictive of complications and mortality[19–22] but to be effective at reducing complications, post-discharge institutionalization, prolonged length-of-stay and mortality[23–27].

There have been no systematic reviews examining CGA in high quality studies or of studies which performed economic analysis in geriatric emergency surgery populations. Several small systematic reviews that included lower quality studies have examined patients who receive CGA versus usual surgical care[28–31]; most studies to date have been conducted in hip fracture patients. Overall, the reviews found improved clinical outcomes in the CGA arm, but the findings were contradictory between studies, possibly in part due to the low-quality studies included in each review. A small number of studies have reported the economic effects of CGA in geriatric surgery patients[24,27,32–37]; again, predominantly in hip fracture patients. No systematic review of the economics of CGA versus usual surgical care have been conducted. It is particularly important that we develop tools to improve the outcomes of elderly surgical patients after emergency surgery since it, by definition, is not planned and therefore there is no opportunity to surgically optimize patients beforehand.

The elderly population will be growing in Canada over the course of the next generation. They will require increasing levels of healthcare and will be more prone to complications following surgical interventions. Increasing evidence suggests CGA in the geriatric surgical population leads to decreased healthcare cost while improving outcomes however most evidence to date comes from orthogeriatric studies. CGA may lead to decreased length of stay, reduced readmission and decreased post-discharge institutionalisation. If this holds true, CGA will offer a cost-effective method to reduce health expenditure while improving outcomes. This innovative approach could allow frail elderly surgical patients to continue as productive members of society.

Comprehensive Geriatric Assessment and the Elder-friendly Approaches to the Surgical Environment Study

The Elder-friendly Approaches to the Surgical Environment (EASE) study is a pre-post cohort controlled study examining CGA in elderly emergency general surgery patients. The EASE study focuses on four key pillars of care: a specialized geriatric care environment, patient-centred care, medical review by a geriatrician and interdisciplinary team care plans. It recruited patients in the pre-intervention phase from Spring 2014 until Fall 2015. Patients were enrolled upon admission or shortly after surgical intervention and provided written consent. Demographic, medical and surgical data was collected prospectively and follow-up was conducted at 6 weeks (in person or by phone) and at 6 months (by phone). The study protocol was published[38], registered with clinicaltrials.gov (NCT02233153) and received ethical approval (Pro00047180). Experimental data presented in part of this thesis is drawn from the EASE study pre-intervention cohorts in both Edmonton and Calgary.

Goals

This thesis will focus on two aspects surrounding CGA and surgical care. First, we assessed the literature for current evidence of CGA in surgical patients compared to usual care. There have been several studies of CGA compared to usual surgical care, but no high quality systematic reviews have been conducted to date and no systematic reviews have assessed the economics of CGA versus usual surgical care. We assessed the effect of CGA interventions compared to standard care on the postoperative outcomes of older patients admitted to hospital for care. We performed a second systematic review assessing the economic effects of CGA versus usual surgical care. Three cost analyses were conducted examining the cost of surgical care in general surgery patients. First, a retrospective assessment of the cost of inpatient general surgery within the local health region determined how age affects the cost of care for elective and unscheduled general surgery interventions. The second cost analysis focused on the government cost of care (costs covered by the government insurance program in this jurisdiction) from admission until 6-months following discharge. Finally, a cost analysis developed models to predict the total costs accrued by the patient and public insurance program from discharge until 6-month follow-up. We hypothesize that CGA will improve outcomes in surgical patients and that frailty will play a significant role in predicting increased cost within our models.

Chapter 2 – Meta-analysis of comprehensive geriatric assessment in a post-operative setting: A Cochrane review

Publication citation for Protocol

Eamer G, Taheri A, Chen SS, Daviduck Q, Chambers T, Shi X, Khadaroo RG. Comprehensive geriatric assessment for improving outcomes in elderly patients admitted to a surgical service. Cochrane Database of Systematic Reviews. 2017 DOI: 10.1002/14651858.CD012485

The text of the Background and Method sections have been changed from the published version to change from the future tense to present tense.

Citation for full review

Eamer G, Taheri A, Chen SS, Daviduck Q, Chambers T, Shi X, Khadaroo RG. Comprehensive geriatric assessment for improving outcomes in elderly patients admitted to a surgical service. Submitted to Cochrane Database of Systematic Reviews for peer review.

Author contributions

QD and GE coordinated the contributions from the coauthors and wrote the final draft of the protocol. QD, SC, TC, and GE worked on the methods sections. QD and GE drafted the clinical sections of the background, and TC was the contract person with the editorial base. QD and GE wrote the protocol with assistance from AT, SC, RK, and TC. TC devised and carried out the search strategy. QD, GE, and SC wrote the statistical analysis and data synthesis sections. RK, SC, QD, GE, and AT contributed significantly to the protocol. RK was the team lead and coordinator and a major contributor to the initial concept of the protocol. XS provided guidance for statistical analysis. Abstracts, results, discussion and conclusions were written by GE. Editing and revision of these sections was performed by the remainder of the team. All authors approved the final manuscript.

Conference presentations

The work presented in Chapter 2 has been presented at Academic Surgical Congress 2017, Feb 7-9, 2017 Las Vegas, USA by myself and at General Surgery Research Day, April 8, 2016, Edmonton, AB by SC.

Abstract

Background

Aging populations are at increased risk of post-operative complications. Unless we implement new methods to care for elderly surgical patients, post-operative complication rates will increase. Comprehensive geriatric assessment (CGA) has been shown to improve outcomes in medical patients, and has been proposed to have the same effect in surgical patients.

Objectives

To assess the effect of CGA interventions compared to standard care on the postoperative outcomes of older patients admitted to hospital for care.

Search methods

We used a sensitive search strategy approved by the Cochrane Effective Practice and Organization of Care (EPOC) groups and searched CENTRAL, MEDLINE, Embase, PsycINFO, CINAHL and clinical trials registers on January 13, 2017. We also searched grey literature for additional citations.

Selection criteria

Randomized clinical trials of surgical patients 65 and older comparing CGA with usual surgical care. Studies were excluded if the patients did not receive a complete CGA, did not undergo surgery, included patients under 65 or was not conducted on patients admitted to an acute care hospital.

Data collection and analysis

Two review authors independently screened, assessed bias, extracted data and assessed certainty of evidence from identified articles. Dichotomous treatment effects were expressed as risk ratios (RR) with 95% confidence intervals and continuous outcomes were expressed as mean difference (MD).

Main results

We identified 8 randomised trials, 7 examined hip fracture patients (N=1583) and one examined elective surgical oncology patients (N=260).

CGA results in little or no difference in mortality in patients with hip fracture (RR 0.85, CI 0.68 to 1.05, 5 trials, 1316 participants, I2 = 0%; high certainty evidence). Five hip fracture trials

identified decreased adverse discharge disposition with CGA (RR 0.71, CI 0.55 to 0.92, 941 participants, I^2 = 0%; high certainty evidence). After excluding one trial for incomplete reporting, length of stay is probably slightly decreased with CGA (MD 1.47, CI -2.8 to -0.14, 4 trials, 841 patients, I^2 = 87%; moderate certainty evidence). There is probably no difference in readmission rates (RR 1.00, CI 0.76 to 1.32, 3 studies, 741 participants, I2 = 37%; moderate certainty evidence). One study did not identify a difference in cost (MD 5154 Euros, CI -13,288 to +2980, 397 patients, moderate certainty evidence) but demonstrated that CGA was the economically dominant choice with bootstrap analysis. Two studies may have found decreased major complications with CGA (RR 0.83, CI 0.69 to 1.00, 579 patients, I^2 = 83%, fixed effect; low certainty evidence) however there was no difference when using a random effects model. There may be decreased delirium rates with CGA (RR 0.63, CI 0.43 to 0.91, 2 trials, 386 patients, I^2 = 0%; low certainty evidence).

There are an inadequate number of studies to assess CGA in non-hip fracture populations.

Authors' conclusions

There is evidence that CGA can improve outcomes in hip fracture patients. There are not enough studies to determine when CGA should be delivered in relation to surgical intervention or if CGA is effective in surgical patients presenting with conditions other than hip fracture.

Background

This review assesses the effects of Comprehensive Geriatric Assessment (CGA) on postoperative outcomes of elderly patients admitted to hospital with a surgical problem.

Description of the condition

As the world's population ages, the demand for surgery among the elderly is increasing[39]. It is estimated that over half of all operations are performed on people over the age of 65[40]. Compared to their younger counterparts, older patients experience higher rates of postoperative complications, have a longer length of stay in hospital, and are more likely to require institutionalisation after discharge[41,42]. The increased costs and health resource use associated with older surgical patients will place a tremendous strain on the healthcare system, highlighting the need for evidence-based interventions that can improve the outcomes of this patient population[43].

Description of the intervention

CGA is a "multidisciplinary diagnostic process intended to determine a frail elderly person's medical, psychosocial, and functional capabilities and limitations in order to develop an overall plan for treatment and long-term follow-up"[44]. CGA is not any one intervention in isolation, but rather a coordinated, multidisciplinary collaboration. This has already been successfully demonstrated on medical and orthogeriatric units[23,24,45]. Aspects of CGA are organised into three categories (medical, psychosocial, and functional) and may include a combination of the following factors[46].

Medical

- Primary diagnosis resulting in admission.
- Geriatrician following every eligible patient during their admission.
- Minimising the use of medications prone to causing delirium and adjusting dosing for geriatric syndromes.
- Comprehensive medication review by pharmacist.

Psychosocial

- Environmental cues to orient patient.
- Regular comfort rounds by nursing staff.
- Early discharge planning to anticipate and manage potential challenges.

Functional

- Fall risk assessment and mitigation.
- Physiotherapist intervention to prevent neuromuscular deconditioning.
- Occupational therapist to identify and manage barriers to independence.
- Physical environment modifications to reduce confusion, falls, delirium.

These interventions are conducted within a multidisciplinary collaboration to develop a unified plan of care for the elderly patient and will be compared with usual care in a standard inpatient ward. CGA can be delivered at any point in a patient's care for elective surgical interventions, but can only be delivered postoperatively for emergency procedures. It is unclear if geriatric interventions before and after surgery are equally effective or if the interventions produce different effects in elective versus emergency surgery.

How the intervention might work

Older surgical patients have complex healthcare needs: frailty, multi-morbidity, and polypharmacy are common in this patient population[47]. However, most hospitals are structured to care for patients with a single, acute illness and are often ill-equipped to meet the needs of older patients, leading to poor surgical outcomes. By performing a CGA, healthcare providers can identify and optimise medical and social issues associated with surgical complications before they have a negative impact on the health of the patient, which could improve outcomes.

Why it is important to do this review

Previous studies, notably Ellis and colleagues' 2011 Cochrane review examining the effect of CGA on medical patient outcomes[45], have been promising, showing CGA interventions to be associated with a decrease in death or deterioration, improved cognitive function, and less institutionalisation. However, most studies have focused on patients admitted to hospital with general internal medicine issues, and to date there have not been any systematic reviews of CGA interventions focusing only on surgical patients.

Objectives

To assess the effect of CGA interventions compared to standard care on the postoperative outcomes of older patients admitted to hospital for surgical care.

Methods

Criteria for considering studies for this review

Types of studies

We included only randomised trials of postoperative patients. These could be from any surgical specialty, including emergency and elective surgery. The intervention groups received CGA, with comparison to a control group receiving standard care. To reduce the likelihood of publication bias, we did not limit articles to the English language. We screened studies found in trial databases and the grey literature for eligibility.

Types of participants

The focus of this review is people age 65 years or older in hospital under the care of an inpatient surgical ward. Although there is not a standard numerical criterion to define old age, 65 years old is widely accepted as the chronological age to be considered an older person.

People admitted to hospital for elective or emergency surgery, or for an acute medical condition or injury requiring close observation and expectant management by a surgical team, were eligible for inclusion in the analysis.

Studies containing a subset of surgical patients above the age of 65 were eligible for inclusion; however, only study data pertaining to our population of interest were included in the meta-analysis.

Types of interventions

We included studies in which a geriatrician, internist, hospitalist, or geriatric nurse performed a multi-component geriatric assessment in hospital, and in which patients receiving the intervention were compared with patients receiving standard postoperative care. The CGA intervention could be performed as part of a mobile, multidisciplinary team consulted to provide patient management recommendations, or as part of a specialised ward dedicated to providing multidisciplinary care to geriatric surgical patients. The CGA intervention may be carried out preoperatively, postoperatively, or throughout the patient's stay in hospital.

We excluded studies in which CGA was used only as a tool to predict adverse postoperative events. We also excluded studies examining only one aspect of the CGA instead of employing a multidimensional assessment, and we also excluded cross-over studies. We excluded enhanced recovery after surgery programmes because CGA is not a routine component of these programmes.

Types of outcome measures

Primary outcomes

The primary outcomes that were assessed were mortality and discharge destination.

We measured mortality as a dichotomous outcome to the end of follow-up after treatment. We measured discharge destination as a dichotomous outcome reported as patients returning to their pre-admission place of residence versus being discharged to an increased level of care such as an assisted-living or long-term care facility.

Secondary outcomes

Secondary outcomes included postoperative complication rates, length of stay, readmission rate, and cost.

We measured length of stay as a continuous outcome reported as the number of days spent in hospital after surgery. Readmission was measured as a dichotomous outcome. Cost was recorded in euros (EUR) for 2016 after converting using Purchasing Power Parity (PPP) and the Gross Domestic Product (GDP) inflator as per the Cochrane Handbook for Systematic Reviews of Interventions[48], but was not combined due to cross-jurisdictional differences in cost reporting and variation in data sources.

Postoperative complications included any of the following events in hospital after surgery: intensive care unit admission, vascular complications (e.g. myocardial infarction, stroke, deep venous thrombosis, and pulmonary embolism), serious infection, and delirium. For studies that do not report major complication categories, we recorded complication frequency by organ system (e.g. cardiovascular, respiratory, gastrointestinal, neurologic, etc.). We reported all complications as a dichotomous (yes or no) outcome. Complications that are not prone to detection bias, such as stroke and myocardial infarction, and those detected in studies with appropriate blinding of complication assessment, were more strongly weighted in the discussion. Delirium is particularly prone to detection bias due to the CGA intervention; we assessed how each study controls for this.

Search methods for identification of studies

Electronic searches

We used a sensitive search strategy designed to retrieve studies from electronic databases. We searched the following databases, with publication dates ranging from inception to January 13, 2017.

- Cochrane Central Register of Controlled Trials (CENTRAL), including the Cochrane Effective Practice and Organisation of Care (EPOC) Group Specialised Register, part of the Cochrane Library (www.cochranelibrary.com)
- MEDLINE In-Process & Other Non-Indexed Citations, OvidSP (1946 - January 13, 2017)
- Embase, OvidSP (1974 - January 13, 2017)
- PsycINFO, OvidSP (1987- January 13, 2017)
- CINAHL (Cumulative Index to Nursing and Allied Health Literature), EBSCO (1980 - January 13, 2017)

The search terms combined Medical Subject Headings (MeSH) and free text words as shown in the MEDLINE strategy in the Appendix: Chapter 2. The MEDLINE strategy was translated using appropriate syntax and controlled vocabulary headings for other databases. No restrictions were placed on language, publication type, or publication year.

Searching other resources

We conducted a grey literature search to identify non-indexed studies not appearing in the databases listed above. Sources include:

- World Health Organization International Clinical Trials Registry Platform (WHO ICTRP) (www.who.int/ictrp/en/); and
- US National Institutes of Health Ongoing Trials Register ClinicalTrials.gov (clinicaltrials.gov).

We used Science Citation Index to search the cited and citing articles of included studies.

Data collection and analysis

Selection of studies

Two reviewers screened titles and abstracts to identify potentially eligible articles for full-text review. We assessed potential eligibility based on design, participants, intervention, and outcomes as described, and excluded studies that did not meet the inclusion criteria at this stage. Two review authors independently carried out full-text review. We resolved conflicts between review authors at all stages of article screening and data extraction by discussion and consensus. We reported the number of excluded studies and the reason for exclusion as per Section 7.2.5 of the *Cochrane Handbook*[48].

Data extraction and management

Two review authors independently extracted data onto web-based electronic data collection forms (Covidence.org), resolving disagreements between review authors by discussion and consensus. Data was exported to Review Manager 5[49] for analysis.

During data extraction, review authors took note of the study source, eligibility, methods, participants, interventions, outcomes of interest, results, and other information as defined in Table 7.3.a of the *Cochrane Handbook*[48] and the EPOC good-practice data extraction form[50]. All costs were reported in euros.

Assessment of risk of bias in included studies

Two independent authors used Cochrane's 'Risk of bias' tool[48] modified based on the EPOC guidance for risk of bias criteria[51] to assess each study. Each study was evaluated based on the following criteria as low risk, high risk, or uncertain risk.

1. Random sequence generation - was the allocation sequence adequately generated.
2. Allocation concealment - was allocation concealment adequate.
3. Baseline demographics between groups - were baseline outcomes measured before the intervention and were they similar between groups.
4. Incomplete data - were loss to follow-up or dropouts low enough to limit risk of bias.
5. Blinding of participants and personnel - were participants and personnel blind to the intervention.
6. Blinding of outcome assessment - were outcome assessors blind to the intervention.
7. Protection from cross-contamination - were there safeguards to cross-contamination of the control group.
8. Selective reporting - were all outcomes in the methods reported in the results.
9. Other risks of bias - were any additional risks noted during bias assessment.

Measures of treatment effect

We reported dichotomous outcome data, such as the effect of CGA on patient mortality and discharge destination, as risk ratios with 95% confidence intervals. We reported continuous outcome data such as the effect of CGA on length of stay using the mean difference between the CGA intervention and standard care with a 95% confidence interval. For all continuous-variable outcomes, we reported the mean and standard deviations or standard error of the outcome measurements in each intervention group, as well as the number of participants on which the outcome was measured.

Unit of analysis issues

We performed analyses at the participant level to avoid unit of analysis errors. If we had identified cluster randomised controlled trials, we would have used a ratio estimator approach to reduce the size of each cluster trial to its effective sample size[52], which is its original sample size divided by design effect. The design effect is 1 + (M – 1) ICC, where M is the average cluster size and ICC is the intra-cluster correlation coefficient. For dichotomous data, the number of participants and the number of events would have been divided by the design effect. For continuous data, the sample size would have been divided by the design effect. Missing ICCs would have been selected from other cluster randomised controlled trials included in the review or obtained from similar external studies. We would have conducted sensitivity analyses to investigate whether removing clustered trials affects the conclusions.

If the results of a study could not be adjusted for the unit of analysis error, we would have excluded it from the pooled analysis. We pooled data based on time since admission to discharge and end of follow-up as predefined outcome measurement points.

Dealing with missing data

Where feasible, we obtained missing data from authors. We investigated attrition rates (e.g. dropouts, losses to follow-up, and withdrawals), and critically appraised issues of missing data and imputation methods (e.g. last observation carried forward). Where standard deviations for outcomes were not reported, we imputed these values by assuming the standard deviation of the missing outcome to be the average of the standard deviations from those studies where this information was reported. We investigated the impact of imputation on meta-analyses by means of sensitivity analysis.

Assessment of heterogeneity

Where we considered studies similar enough based on population, study design, and setting to allow pooling of data using meta-analysis, we assessed the degree of heterogeneity by visual inspection of forest plots and by examining the Chi^2 test for heterogeneity. We quantified heterogeneity between studies using the I^2 test. An I^2 of less than 40% was considered unimportant; 40% to 60% may indicate moderate heterogeneity; 60% to 75% may indicate substantial heterogeneity; and 75% to 100% indicates considerable heterogeneity. Where we detected substantial clinical, methodological, or statistical heterogeneity across included studies, we did not retain the pooled results from meta-analysis but instead used a narrative approach to data synthesis.

Assessment of reporting biases

We assessed publication bias by searching trial registries and searching for grey literature through citation chaining. For studies published after 1 July 2005, we noted lack of registration of the trial protocol with the WHO ICTRP in the 'Risk of bias' table. We also noted selective reporting of predefined outcomes.

Data synthesis

We compared random-effects and fixed-effect models to assess if smaller studies affect the results. Given the complex and multidimensional nature of CGA, variation is expected in measured outcomes due to sampling error and differing patterns of implementation of CGA. If there was a difference between fixed-effect and random-effects models, we assessed the impact of small studies on the estimate of effect before deciding which model to use.

Summary of findings

We summarised the findings of the main intervention comparison for the most important outcomes included in the review. We graded our primary outcomes (mortality and discharge destination) and secondary outcomes (postoperative complication rates, length of stay, readmission rate, and cost) as a means to assess the certainty of the evidence. Two review authors independently assessed the certainty of the evidence (high, moderate, low, and very low) using the five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness, and publication bias). We used the methods and recommendations described in Section 8.5 and Chapter 12 of the Cochrane Handbook[48], the EPOC worksheets[50], and the GRADE Working Group guidelines[53], and the GRADEpro software[54] (GRADE Working Group, Hamilton, Canada) was used to grade each outcome. Disagreements on certainty ratings were resolved by discussion. Justification for decisions to either downgrade or upgrade the ratings are available as footnotes in a Summary of findings table (Table 2.1).

Subgroup analysis and investigation of heterogeneity

We conducted subgroup analysis for the a priori defined variables listed below.

1. Orthopaedic versus other surgical specialties.
2. CGA timing - is the CGA conducted preoperatively, postoperatively, or throughout an admission?
3. Emergency versus elective surgery.

We analysed these subgroups at discharge and at end of follow-up. We determined if the subgroups differ significantly by inspecting the overlap of confidence intervals and testing for subgroup differences using Review Manager 5[49].

Timing of the CGA in relation to surgery could affect patient outcomes because the potential benefits of CGA intervention could arise from optimising patient medical and social issues before surgery; by providing a better level of care following surgery; or both pre- and post-operative intervention may be necessary to see benefits. Most studies of CGA in surgical patients have been performed in orthopaedic trauma (hip fracture); the effect of CGA may play an important role in recuperation from hip surgery but not in other surgical interventions or populations. Finally, elective versus emergency surgery can give rise to different risk profiles. Determining if there is a benefit in one population versus another is important.

Sensitivity analysis

We were unable to performed sensitivity analysis to explore changes in effect size, after removing studies with a high risk of bias due to the small number of studies identified. We did, however, compare the use of a fixed-effect and random-effects models.

Results

Description of studies

Results of the search

A literature search identified 14,874 citations for title screening after removing 2953 duplicate citations. The search was conducted by a trained librarian on January 13, 2017 and identified citations from CENTRAL (666 citations), MEDLINE (5663 citations), Embase (7823 citations), PsychINFO (446 citations) and CINAHL (3229 citations). We identified three additional citations through reference screening. During title and abstract screening, we identified 655 additional duplicated citations leaving 14,222 records to screen; 363 citations underwent full text screening (Figure 2.1). We included eight randomised trials[24,55–61]. Three randomised controlled trials reported their results spread over two separate publications. Prestmo *et al*[24] published an abstract with additional information[25]. All relevant results analysed below are drawn from Prestmo *et al*[24]. Hempenius *et al* published two articles from their study of elective surgical oncology patients; the first study[55] focused on delirium during admission and reported in-hospital outcomes, the second study[62] reported outcomes 3-months after discharge. All findings from this study are reported from the first manuscript[55] when the results were reported in both manuscripts. Finally, Stenvall *et al* published two reports of their trial[60,63]. The second study is a subgroup analysis of patients with dementia[63] and is included for those interested in this subgroup; results used in our analysis are exclusively from the first paper[60]. All hip fracture studies excluded pathologic fractures and patients who were entirely dependent on other for care before their fracture.

Included studies

We included eight randomised trials with a total of 1843 patients enrolled. Three studies only enrolled patients 70 years and older[24,59,60] while the remaining five enrolled patients who were 65 and older[55–58,61]. All but one study[55] were conducted at a single site. Seven studies examined hip fracture patients[24,56–61] while the remaining study examined elective surgical oncology patients[55]. Six studies randomised patients to CGA versus standard care pre-operatively[24,55,58–61] and two studies[56,57] randomised post-operatively. CGA and geriatric care were delivered during acute post-operative recovery in six studies[24,58–62] and in a rehabilitation setting in two trials[56,57]. Additionally, two studies included a pre-operative assessment[24,55]. All studies were published in the English language and no studies are awaiting classification.

Three studies[64–66] are ongoing and will likely meet inclusion and exclusion criteria once results are reported.

Intervention

The model for delivery of the geriatric intervention was quite varied; the physician most responsible for care was a surgeon in three studies[55,58,59], a geriatrician in three[24,60,61], a general practitioner in one[57] and was unclear in one study[56]. Trials with a non-orthopedic primary physician all had consultation from the orthopedic surgeon available as needed. The interventions varied among studies, but all included a comprehensive geriatric assessment. One study[55] developed a geriatric treatment plan pre-operatively that was monitored by a geriatric nurse post-operatively; post-operative consultation with a geriatrician was performed as needed. Three studies performed geriatric rounds as a consultation service, two conducted rounds on a daily basis[58,59] and one conducted rounds twice a week[57]. One study[57] only included female participants.

Outcomes

Our primary outcomes were mortality and discharge destination. Six studies reported mortality[24,55,56,59–61] and six studies reported adverse discharge disposition[24,55,57,59–61].

Our secondary outcomes were length of stay, readmission, cost and complications. Five studies reported length of stay[24,56,59–61], three studies reported readmission[24,55,60], one study reported cost[24] and three studies reported complications[55,58,61]. Complications were presented in different manners among studies, limiting the ability to pool results.

Location

The eight trials we identified were from seven countries. All countries are traditionally European in ethic origin. Two studies[58,59] were conducted in North America (USA and Canada) and six studies[24,55–57,60,61] were conducted in Western Europe (Spain, UK, Netherlands, Norway and Sweden). All studies involved patients admitted to a hospital who had undergone or would be undergoing surgical intervention.

Excluded studies

We assessed 329 studies as irrelevant and excluded 23 studies with reasons, most commonly due to having the wrong patient population (Figure 2.1).

Risk of bias in included studies

Allocation (selection bias)

Six studies used adequate methods to generate their random sequence[24,55,57,59,60,67] and five studies appropriately concealed allocation[24,55,59,60,67]. One study was unclear about randomisation technique[61], one did not adequately perform allocation and did not conceal their allocation[56] and one study did adequately describe their allocation concealment methods[57] to permit judgement.

Blinding (performance bias and detection bias)

Blinding of participants was not possible because of the nature of the intervention; however, many of the studies included in our review measured outcomes, such as mortality or length of stay, that are less prone to performance or detection bias. Consequently, where we felt the outcome being assessed was not prone to bias and the study design was adequately described, we assessed the risk of bias for blinding of participants as low. Overall 5 studies were deemed to have a low risk of performance bias[56–60] and 4 studies had a low risk of detection bias[56,58–60]. Two studies did not adequately explain how they blinded participants[24,61] and 4 did not explain the how they blinded their outcome assessors[24,55,57,61]. One study had a high risk of performance bias[55]; the primary outcome was delirium and we cannot be sure that lack of blinding did not influence the results.

Incomplete outcome data (attrition bias)

Seven of eight studies reported low attrition rates[24,55–60] while one study provided insufficient data to assess attrition[61].

Selective reporting (reporting bias)

Seven studies reported all outcomes that were expected and were therefore judged to be a low risk of reporting bias[24,55,57–61]. One study did not report all expected outcomes and consequently was deemed to have a high risk of reporting bias[56]. Two studies were published during or after 2005 and did not register their trial. One trial collected data in 1997[61] and one collected data between 2000 and 2002[60], consequently we did not downgrade the risk of bias assessment for these trials for being unregistered.

Other potential sources of bias

Only one study was assessed to have an increased risk of bias[59]. The population studied seems biased towards healthy patients without dementia. All other studies were deemed to have no other risks of bias[24,55–58,60,61]. For further details see Figure 2.2 and Figure 2.3.

Effects of interventions

See the Summary of findings table (Table 2.1) for summarized results and certainty of evidence.

We identified eight trials, representing 1843 patients. Seven trials, with 1583 patients, were in hip fracture patients while one study[55], with 260 patients, was in elective surgical oncology patients. Pooled analysis conducted both with and without the elective surgical oncology trial are presented below.

Comprehensive geriatric assessment versus usual care for surgical patients

Primary outcomes

Five orthopedic trials with 1316 patients reported mortality outcomes. Using a fixed effect model, CGA makes little or no difference in mortality in patients with hip fracture (Risk ratio (RR) 0.85, 95% confidence interval (CI) 0.68 to 1.05, 5 trials, 1316 participants, Figure 2.4, high certainty). No heterogeneity was identified between the trials reporting mortality (I^2 = 0%). Using a random effects model did not change the outcome of the analysis (RR 0.85, CI 0.68 to 1.05, 5 trials, 1316 participants). The fixed effect model has been chosen to represent the measured risk ratio due to the low heterogeneity. When the elective surgical oncology trial was included in the analysis, heterogeneity increased (I^2 = 26%) and the risk ratio moved closer to 1 (RR 0.90, CI 0.73 to 1.10, 6 trials, 1576 patients).

Five orthopedic trials reported adverse discharge disposition from hospital from 941 patients. Using a fixed effect model, the intervention slightly reduces adverse discharge disposition (RR 0.71, CI 0.55 to 0.92, 5 trials, 941 participants, Figure 2.5, high certainty). There was no heterogeneity between the orthopedic studies (I^2 = 0%). Using a random effects model did not change the risk ratio (RR 0.71, CI 0.55 to 0.92, 5 trials, 941 participants) or the heterogeneity (I^2 = 0%). The fixed effect model has been chosen to represent the measured risk ratio due to the low heterogeneity. One study[58] only reported discharge from hospital to a "nursing home [or] rehab hospital". They did not distinguish between nursing home admission and rehabilitation hospital stay and did not report discharge destination following rehabilitation. Consequently, this study was excluded from the assessment. Inclusion of the elective surgical oncology trial profoundly increased heterogeneity (I^2 = 61%) and resulted in CGA having no effect on discharge disposition (RR 0.86, CI 0.69 to 1.07, 6 trials, 1164 participants).

Secondary outcomes

Five trials reported length of stay. Little or no difference was identified between comprehensive geriatric care and usual care (Mean difference (MD) 0.03, CI -0.93 to 0.98, 5 trials, 1238 patients, Figure 2.6, moderate certainty) and there was considerable heterogeneity among studies (I^2 = 88%). Using a random effects model did not change the heterogeneity (I^2 = 88%); mean difference was profoundly changed but continued to demonstrate no effect (MD -0.61, CI -4.45 to 3.23, 5 trials, 1238 patients). When the study that did not report length of stay including rehabilitation hospital admission[24] was excluded, CGA probably slightly decreases length of stay (MD -1.47, CI -2.80 – -0.14, 4 trials, 841 patients, Figure 2.7), however, heterogeneity remained considerable (I^2 = 87%). We have reported the fixed effect model for length of stay, since the random effects model did not improve heterogeneity (I^2 = 87%). The elective surgical oncology study did not report length of stay.

Readmission was reported by 3 trials, two orthopedic and one surgical oncology. Pooled results are limited by the small numbers of studies reporting readmission, however the intervention probably makes little or no difference in readmission rates (RR 1.00, CI 0.76 to 1.32, 3 studies, 741 participants, Figure 2.8, moderate certainty). The random effects model was chosen due to the broad range of measured means in the studies and the difference in the nature of the interventions measured (orthopedic and elective surgical oncology). There was moderate heterogeneity (I^2 = 37%) among the three studies. Removing the elective surgical oncology study[55] increased heterogeneity (I^2 = 53%) but did not change the pooled results.

Cost was reported by one study[24]. CGA probably makes little or no difference to cost (MD 5154 Euros, CI -13,288 to +2980, 1 trial, 397 patients, moderate certainty). They did not find a significant difference in cost but through bootstrap analysis demonstrated that CGA was the economically dominant choice. This means CGA was assessed to be less costly with better clinical outcomes.

Three studies reported postoperative complications but we were unable to pool these results due to the manner in which they were reported. Two studies[55,61], representing 250 patients, reported major complications. Using a fixed effect model, major complications may be reduced by CGA (RR 0.83, CI 0.69 to 1.00, 2 studies, 579 patients, Fixed effect, Figure 2.9, low certainty) however heterogeneity was considerable (I^2 = 83%) and significance differed based on whether fixed effect or random effect models were used for analysis (RR 0.90, CI 0.58 to 1.39, 2 studies, 579 patients, Random effect). We have reported the random effect model due to differences in patient population in the two studies. Two studies reported delirium[55,58], representing 386 patients. Using a fixed effect model, CGA may slightly decrease delirium (RR 0.63, CI 0.43 to 0.91, 2 trials, 386 patients, Figure 2.10, I^2 = 0%, moderate certainty). The fixed effect model was chosen due to similarities between study design and population along with low heterogeneity. One study reporting cardiovascular complications[55] found no difference between CGA and usual care arms.

Sensitivity analysis by trial quality

There are too few studies in the low risk of bias subgroups to permit sensitivity analysis by trial quality.

Subgroup analysis

Analysis of orthopedic versus non-orthopedic results was conducted by removing the one non-orthopedic trial from pooled analysis. The results are reported above. The only non-orthopedic trial was also the only elective trial identified through our search.

Subgroup analysis of trials where CGA was conducted post-operatively was performed by excluding studies where CGA was conducted before surgery. The primary outcomes were assessed after removing Hempenius *et al*[55] and Prestmo *et al*[24]; CGA continued to have little or no effect on mortality (RR 0.87, CI 0.68 to 1.11, 938 patients, 4 studies, Fixed effect, I^2 = 0%) and discharge disposition remained improved with CGA (RR 0.72, CI 0.53 to 0.99, 612 patients, 4 studies, Fixed effect, I^2 = 25%). We also assessed secondary outcomes. Length of stay probably improves with CGA using a fixed effect model after removing Prestmo *et al*[24] (Mean difference (MD) -1.47, CI -2.80 to -0.14, 4 studies, 841 patients, I^2 = 87%), however it was not improved when analysed with a random effects model (MD -2.82, CI -10.30 to 4.67). Three of the four remaining studies found decreases in length of stay however the largest study[59] found an increase in the length of stay and did not report why this might be. Prestmo *et al*[24], the trial excluded in this sensitivity analysis, reported that their CGA arm had a longer length of stay due to fewer patients being transferred to rehabilitation facilities and only reported length of stay for the acute hospital stay. After removing both studies that performed pre-operative assessment, only one trial reported major complications[61], delirium[58] and readmission[60] and no trials reported cost.

Meta-regression could not be performed due to the small number of studies identified.

Discussion

Summary of main results

We included eight randomised trials (N=1843). Seven were hip fractures trials (N=1583) and one was in elective surgical oncology (N=260). Pooled analysis of five hip fracture studies that reported mortality found CGA had little or no effect on mortality (RR 0.85, CI 0.68-1.05, N = 1316, high certainty evidence). The intervention slightly reduces adverse discharge disposition in five hip fracture trials (RR 0.71, CI 0.55-0.92, N = 941, high certainty evidence).

CGA probably slightly decreases length of stay (MD 1.47 days, CI -2.8 to -0.14, N = 841, moderate certainty evidence) and probably makes little or no difference to readmission (RR1.00, CI 0.76-1.32, N = 741, moderate certainty evidence) or cost. Major complications may have little or no change with CGA (RR 0.90, CI 0.58 to 1.39, 2 studies, 579 patients, Random effect, low certainty), although only two trials reported this outcome. Delirium may be slightly reduced with CGA (RR 0.63, CI 0.43-0.91, N = 386, low certainty evidence), although this outcome was also only reported by two studies and the results changed depending on whether a fixed effect or random effect model was used.

Overall completeness and applicability of evidence

All studies recruited surgical patients who were admitted to an acute care hospital in Western Europe or North America. Our findings are limited to hip fracture patients, as only one high quality trial in non-orthopedic surgical populations was identified. We have, however, identified two ongoing studies from non-orthopedic surgical patients that have not yet reported results[65,66].

All geriatric assessments were supervised by a geriatrician, however the physician responsible for care varied among studies. The most responsible physician was a geriatrician in three studies and the orthopedic surgeon in three. Two studies didn't perform geriatric assessment until the patients were transferred to a rehabilitation hospital[56,57]. The patients in these studies were cared for by an orthopedic surgeon until they were transferred to a rehabilitation facility where they were cared for by a general practitioner or it was unclear who cared for them. This introduces considerable heterogeneity to the study and may limit comparability of the outcomes. The total number of patients identified (N = 1843) is large enough that we feel we can confirm efficacy and safety for outcomes reported by most trials. Outcomes reported by a small number of trials include fewer patients and may not reliably represent the true safety and efficacy. These outcomes include cost (N = 397), complications (N = 579) and readmission (N = 516). The time of follow-up was also quite varied between studies; some patients were followed until discharge while others as long as one year. This may affect our results.

The potential to improve the care of elderly surgical patients is particularly relevant; aging populations are increasingly requiring surgical intervention and are prone to increased post-operative morbidity and mortality. The studies we have identified support the implementation of

CGA to decrease adverse discharge disposition and complications for hip fracture patients, but we cannot extend this recommendation for other surgical populations due to lack of high quality studies.

Certainty of evidence

We assessed certainty of evidence using the GRADE method and classified the certainty of evidence for our primary outcomes as high for orthopedic studies. Individual studies had varied risk of bias, which partially depended on what outcome was being examined. Despite an overall elevated risk of bias in some of the included studies, the nature of our primary outcomes (mortality and adverse discharge disposition) reduces the risk that their outcomes are not representative of the overall population as these outcomes are not prone to detection or performance bias. The included studies had low rates of dropout and most authors responded when contacted. One study did not report mortality and the authors were unable to provide the data due to the age of the study. We noted no heterogeneity for mortality or adverse discharge disposition when orthopedic studies were pooled.

Secondary outcomes had lower certainty of evidence. Length of stay was downgraded due to high variability, readmission and cost were downgraded due to indirectness; all were graded as moderate certainty. Post-operative delirium was downgraded due to high risk of bias and imprecision; however, it was upgraded because of a large effect resulting in a low certainty of evidence. Major complication was graded as a low certainty of evidence due to indirectness and imprecision of the measure.

Potential biases in the review process

We used the standard review methods of the Cochrane EPOC group to conduct this review. The use of an inclusive search strategy will have included all relevant studies.

Agreements and disagreements with other studies or reviews

Several other published reviews have examined the effect on CGA on outcomes. All identified reviews were for orthopedic trauma patients (hip fracture) and included both randomised trials and lower quality studies. Sabharwal *et al*[28] identified 5 articles that found lower mortality in the CGA arm. They identified multiple, predominantly retrospective, studies that identified reduced post-operative complications. They also found that length of stay was lower in 2 of 2 studies identified, and three studies identified improved functional outcomes in the intervention arms. They did not pool their results for meta-analysis. Grigoryan *et al*[29] performed a systematic review of 18 studies. They found geriatric consultation services but not shared care reduced short and long-term mortality and conversely found that shared care but not geriatric consultations services reduced length of stay. Both models showed a significant reduction in complications. Buecking *et al*[30] identified 5 trials, with high inter study heterogeneity, that found little or no effect on length of stay and short or long term mortality. Finally, Deschodt *et al*[31] reported no effect on functional status with CGA in 11 trials, no effect on length of stay in 10 trials and no effect on readmission in 8 trials. They identified discordant results for mortality; it was reduced at 6 and 8 month follow-ups but not at 1, 3 or 12 month follow-ups.

Prestmo *et al*[24] conducted a systematic review as part of their publication searching for orthogeriatric care models. They did not summarize the results. Kammerlander *et al*[68] performed a systematic literature review of enhanced orthopedic care for hip fracture patients and summarized their finding separated by geriatric intervention type. However, they did not pool the data from the studies they identified.

No reviews identified worsened outcomes with the addition of CGA while most reviews identified improvement in at least one outcome. Two studies identified reduced mortality with CGA[28,29], one review did not[30] and one review identified discordant results[31]. Sabharwal *et al* identified decreased adverse discharge disposition[28] while Deschodt *et al* did not identify a difference[31]. One review reported lower cost and improved clinical outcomes with CGA[69], while only one review reported complications[28], which were significantly decreased. All identified reviews included lower-quality study designs, including retrospective chart reviews and historically controlled trials. All reviews concluded that CGA has shown benefit, Deschodt *et al* however were unable to identify a clear added benefit from an integrated geriatric consultation service[31].

Authors' conclusions

Implications for practice

There is evidence that comprehensive geriatric assessment can improve some of the outcomes we assessed in hip fracture patients. The is little or no difference in mortality (high certainty) however adverse discharge disposition is decreased (high certainty) and there is probably a slight decrease in length of stay (moderate certainty). There is probably little or no difference in readmission rates (moderate certainty) and there is probably little or no difference in cost (moderate certainty) although only 1 study reported this outcome and their bootstrap analysis did show an effect favouring CGA. Finally, there may be decreased major complications (low certainty) and decreased delirium rates (low certainty) in hip fracture patients. There are not enough studies to determine if one of many CGA delivery methods are better than other methods. There have also not been enough studies in surgical patients to determine if CGA is effective in improving outcomes in patients presenting with surgical complaints other than hip fracture.

Implications for research

Large high-quality trials in non-hip fracture surgical patients are needed to determine if CGA is effective in these populations. Trials to determine the effect of CGA in elective surgical patients are also needed. Furthermore, trials are needed to determine which CGA delivery method is most effective and if the timing of CGA affects its effectiveness.

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Contributions of authors

QD and GE coordinated the contributions from the coauthors and wrote the final draft of the protocol. QD, SC, TC, and GE worked on the methods sections. QD and GE drafted the clinical sections of the background, and TC was the contract person with the editorial base. QD and GE wrote the protocol with assistance from AT, SC, RK, and TC. TC devised and carried out the search strategy. QD, GE, and SC wrote the statistical analysis and data synthesis sections.

RK, SC, QD, GE, and AT contributed significantly to the protocol. RK was the team lead and coordinator and a major contributor to the initial concept of the protocol. XS provided guidance for statistical analysis.

Abstracts, results, discussion and conclusions were written by GE. Editing and revision of these sections was performed by the remainder of the team.

Declarations of interest

Gilgamesh Eamer: nothing to declare.
Amir Taheri: nothing to declare.
Sidian S Chen: nothing to declare.
Quinn Daviduck: nothing to declare.
Thane Chambers: nothing to declare.
Xinzhe Shi: nothing to declare
Rachel G Khadaroo: nothing to declare.

Differences between protocol and review

We performed minimal subgroup analysis due to the small number of trials identified. We were unable to assess CGA timing and emergency versus elective subgroup analyses, and were only able to perform surgical specialty subgroups by excluding the only non-orthopedic study from analysis. We were unable to perform sensitivity analysis by bias due to the small number of low risk studies (2). We were also unable to assess publication bias with funnel plots due to the small number of trials identified. We did not identify any cluster randomised trials, so did not experience any unit of analysis issues. There were low attrition rates in all our identified studies, so we did not impute any missing data. We attempted to contact authors who we felt may have had more data, but did not receive much due to the age of many of the included studies.

Published notes

This protocol is based on standard text and guidance provided by the Cochrane Effective Practice and Organisation of Care (EPOC) Group.

Table 2.1: Summary of Findings for Geriatric Care compared to Control for improving outcomes in elderly patients admitted to a surgical service

Patient or population: Improving outcomes in elderly patients admitted to a surgical service
Setting: Acute hospital or rehabilitation hospital following acute admission. **Intervention:** Comprehensive Geriatric Care (CGA). **Comparison:** Control

Outcomes	Anticipated absolute effects (95% CI) Risk with Control	Risk with CGA	Relative effect (95% CI)	№ of participants (studies)	Certainty of evidence (GRADE)	Comments
Mortality	Study population 214 per 1,000	182 per 1,000 (145 to 225)	Effect of CGA RR 0.85 (0.68 to 1.05)	1316 (5 RCTs)	⨁⨁⨁⨁ HIGH	Hip-fracture studies only
Adverse DC disposition	Study population 247 per 1,000	176 per 1,000 (136 to 227)	Effect of CGA RR 0.71 (0.55 to 0.92)	941 (5 RCTs)	⨁⨁⨁⨁ HIGH	Hip fracture studies only
Length of stay	Study population Mean 24.1 Days	MD 1.47 Days lower (-2.8 to -0.14)	Effect of CGA -	841 (4 RCTs)	⨁⨁⨁⊖ MODERATE [1 2]	Hip-fracture patients only - length of stay until final discharge from hospital (including rehabilitation hospital). Prestmo 2015 did not report length of stay including rehabilitation hospital admission time.
Readmission	Study population 316 per 1,000	316 per 1,000 (240 to 418)	Effect of CGA RR 1.00 (0.76 to 1.32)	741 (3 RCTs)	⨁⨁⨁⊖ MODERATE [3]	All studies included; removing elective surgical oncology study doesn't change effect
Total cost	Study population Mean 59,486 €	MD 5154 Euros lower (-13288 to +2980)	Effect of CGA -	397 (1 RCT)	⨁⨁⨁⊖ MODERATE [4]	Only 1 study reported cost
Major complication	Study population 465 per 1,000	386 per 1,000 (321 to 465)	Effect of CGA RR 0.83 (0.69 to 1.00)	579 (2 RCTs)	⨁⨁⊖⊖ LOW [3 5]	Hempenius 2013 defined major as 2 or more complications. Vidan 2005 defined major as delirium, congestive heart failure, pneumonia, DVT, PE, pressure ulcer, arrhythmia and myocardial infarction.
Major complication - Delirium	Study population 259 per 1,000	163 per 1,000 (111 to 236)	Effect of CGA RR 0.63 (0.43 to 0.91)	386 (2 RCTs)	⨁⨁⊖⊖ LOW [2 5 6]	Delirium assessed by Delirium Observation Scale (Hempenius 2013) or confusion assessment method (Marcantonio 2001)

***The risk in the intervention group** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: Confidence interval; **RR:** Risk ratio; **OR:** Odds ratio;
GRADE Working Group grades of evidence
High quality: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate quality: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low quality: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low quality: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Footnotes
[1] Wide confidence intervals, [2] High variation between studies, [3] A clear link between outcome and intervention is not clear, [4] Costing was calculated based on length of stay and an estimated per-day cost, [5] Inconsistently measured outcome between studies, [6] Risk of bias in assessment of outcome in one of the two studies

Figure 2.1: flow diagram of study selection

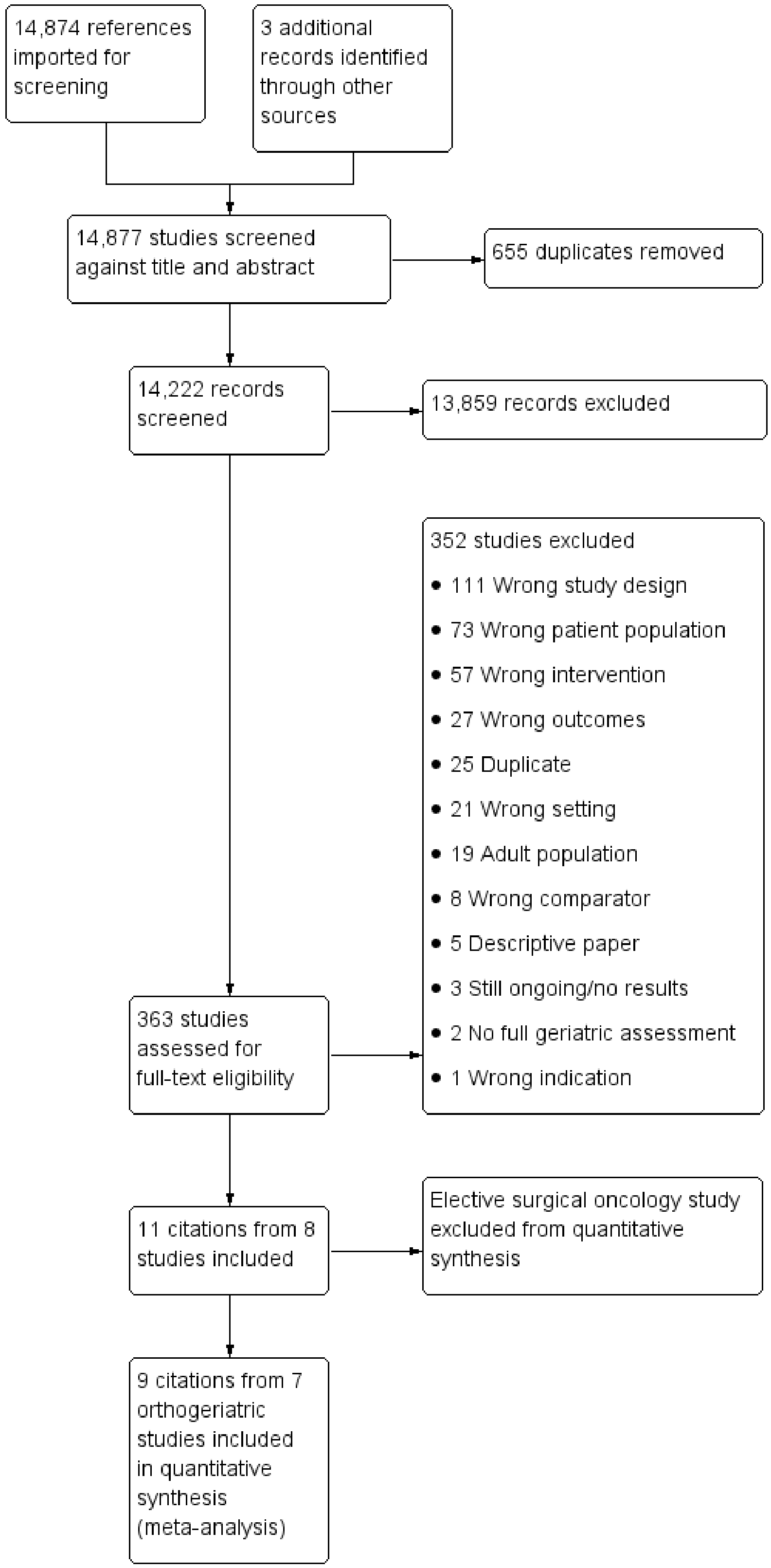


Figure 2.2: Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

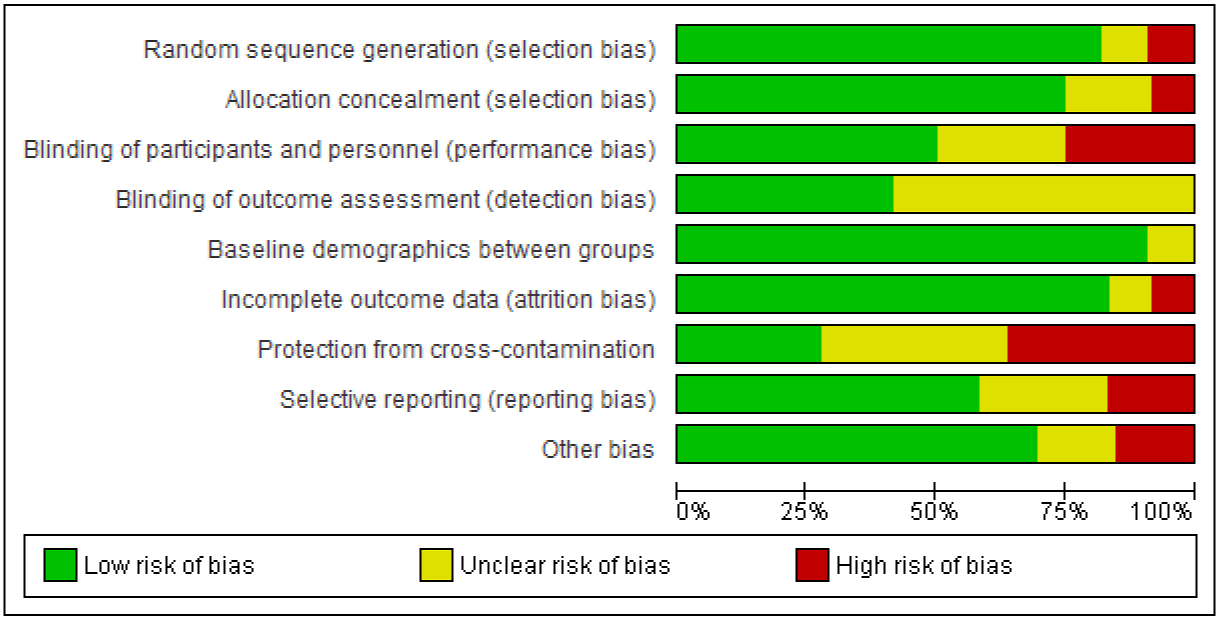


Figure 2.3: Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Baseline demographics between groups	Incomplete outcome data (attrition bias)	Protection from cross-contamination	Selective reporting (reporting bias)	Other bias
Hempenius 2013	+	+	−	?	+	+	−	+	+
Hempenius 2016	+	+	−	?	+	+	−	?	+
Hempsall 1990	−	−	+	+	+	+	?	−	+
Kennie 1988	+	?	+	?	?	+	+	+	?
Marcantonio 2001	+	+	+	+	+	+	−	?	?
Naglie 2002	+	+	+	+	+	+	+	+	−
Prestmo 2015	+	+	?	?	+	+	+	+	+
Stenvall 2007	+	+	+	+	+	+	?	+	+
Stenvall 2012	+	+	+	+	+	+	?	−	−
Taraldsen 2015	+	+	?	?	+	−	?	?	+
Vidan 2005	?	?	?	?	+	?	−	+	+

Figure 2.4: Forest plot of pooled mortality comparing CGA with usual surgical care

Study or Subgroup	Geriatric Care Events	Geriatric Care Total	Control Events	Control Total	Weight	Risk Ratio IV, Fixed, 95% CI
1.1.3 4-6 months						
Hempsall 1990	28	82	22	73		Not estimable
Naglie 2002	17	141	21	138	12.8%	0.79 [0.44, 1.44]
Prestmo 2015	19	193	21	191		Not estimable
Stenvall 2007	9	101	13	96	7.0%	0.66 [0.29, 1.47]
Stenvall 2012	4	28	6	36		Not estimable
Subtotal (95% CI)		**242**		**234**	**19.9%**	**0.74 [0.46, 1.20]**
Total events	26		34			
Heterogeneity: Chi² = 0.13, df = 1 (P = 0.72); I² = 0%						
Test for overall effect: Z = 1.22 (P = 0.22)						
1.1.4 1 year						
Hempsall 1990	34	77	27	66	30.9%	1.08 [0.74, 1.58]
Prestmo 2015	30	192	37	186	23.7%	0.79 [0.51, 1.22]
Stenvall 2012	9	28	8	36		Not estimable
Vidan 2005	29	155	41	164	25.5%	0.75 [0.49, 1.14]
Subtotal (95% CI)		**424**		**416**	**80.1%**	**0.87 [0.69, 1.11]**
Total events	93		105			
Heterogeneity: Chi² = 1.91, df = 2 (P = 0.38); I² = 0%						
Test for overall effect: Z = 1.11 (P = 0.27)						
Total (95% CI)		**666**		**650**	**100.0%**	**0.85 [0.68, 1.05]**
Total events	119		139			
Heterogeneity: Chi² = 2.41, df = 4 (P = 0.66); I² = 0%						
Test for overall effect: Z = 1.54 (P = 0.12)						
Test for subgroup differences: Chi² = 0.36, df = 1 (P = 0.55), I² = 0%						

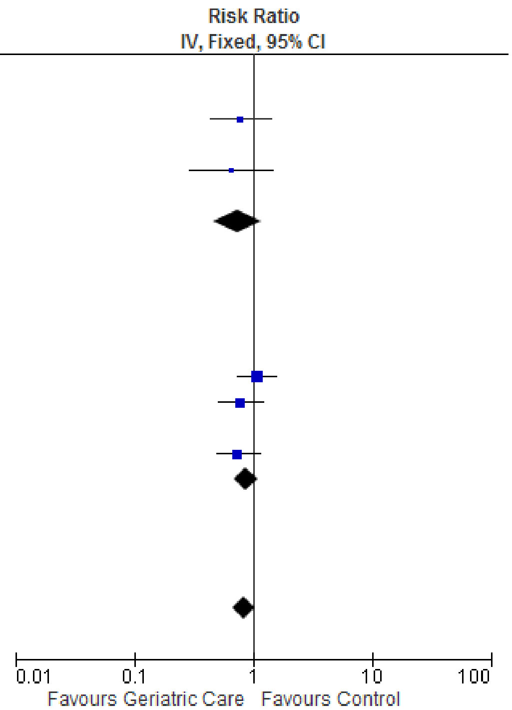


Figure 2.5: Forest plot of pooled discharge disposition comparing CGA with usual surgical care

Study or Subgroup	Geriatric Care Events	Geriatric Care Total	Control Events	Control Total	Weight	Risk Ratio IV, Fixed, 95% CI
1.2.2 discharge						
Hempenius 2013	37	113	23	110		Not estimable
Hempsall 1990	18	62	19	58		Not estimable
Kennie 1988	5	54	16	54	7.5%	0.31 [0.12, 0.79]
Stenvall 2007	15	96	22	90		Not estimable
Stenvall 2012	22	26	27	32		Not estimable
Subtotal (95% CI)		**54**		**54**	**7.5%**	**0.31 [0.12, 0.79]**
Total events	5		16			
Heterogeneity: Not applicable						
Test for overall effect: Z = 2.45 (P = 0.01)						
1.2.4 4-6 months						
Hempsall 1990	12	54	16	49	15.7%	0.68 [0.36, 1.29]
Naglie 2002	22	124	23	117	23.2%	0.90 [0.53, 1.53]
Prestmo 2015	25	179	36	177		Not estimable
Stenvall 2007	19	92	18	83		Not estimable
Stenvall 2012	20	24	24	30		Not estimable
Subtotal (95% CI)		**178**		**166**	**38.9%**	**0.81 [0.54, 1.21]**
Total events	34		39			
Heterogeneity: Chi² = 0.44, df = 1 (P = 0.50); I² = 0%						
Test for overall effect: Z = 1.04 (P = 0.30)						
1.2.5 1 year						
Prestmo 2015	28	168	39	161	34.2%	0.69 [0.45, 1.06]
Stenvall 2007	17	84	19	76	19.4%	0.81 [0.46, 1.44]
Stenvall 2012	16	19	26	28		Not estimable
Subtotal (95% CI)		**252**		**237**	**53.6%**	**0.73 [0.52, 1.03]**
Total events	45		58			
Heterogeneity: Chi² = 0.20, df = 1 (P = 0.66); I² = 0%						
Test for overall effect: Z = 1.78 (P = 0.08)						
Total (95% CI)		**484**		**457**	**100.0%**	**0.71 [0.55, 0.92]**
Total events	84		113			
Heterogeneity: Chi² = 4.02, df = 4 (P = 0.40); I² = 0%						
Test for overall effect: Z = 2.62 (P = 0.009)						
Test for subgroup differences: Chi² = 3.38, df = 2 (P = 0.18), I² = 40.8%						

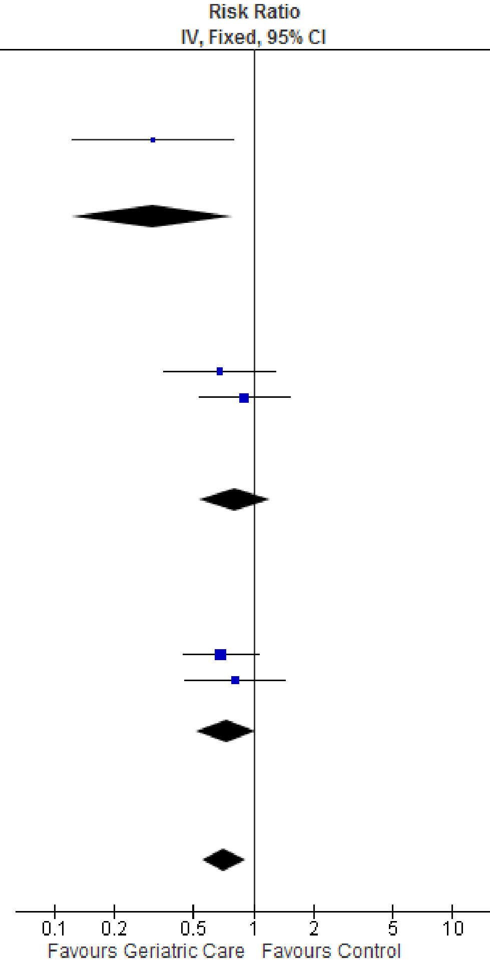


Figure 2.6: Forest plot of pooled length of stay comparing CGA with usual surgical care (Prestmo *et al* included)

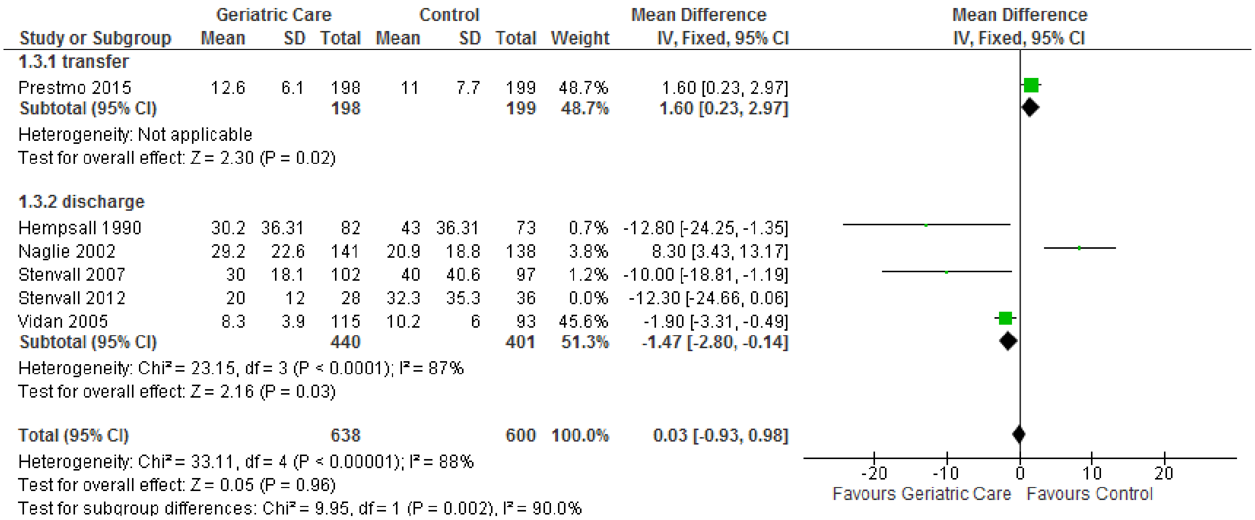


Figure 2.7: Forest plot of pooled length of stay comparing CGA with usual surgical care (Prestmo *et al* excluded)

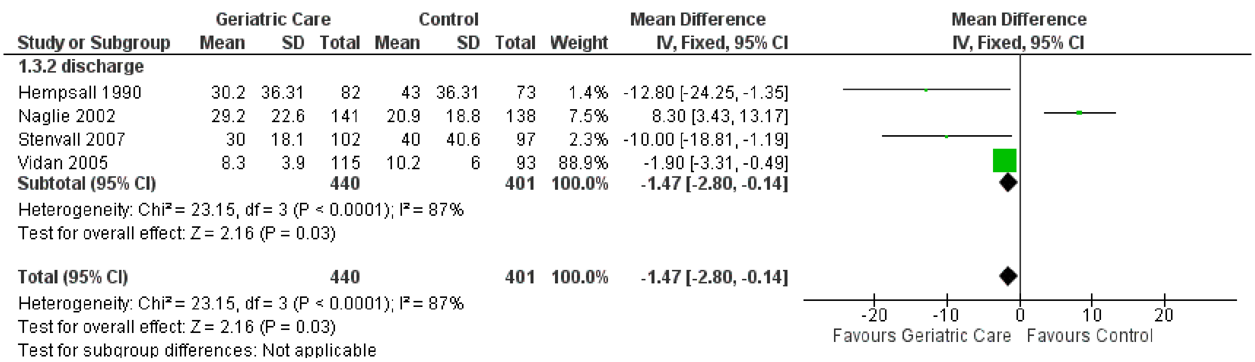


Figure 2.8: Forest plot of pooled readmission rate comparing CGA with usual surgical care

Study or Subgroup	Geriatric Care Events	Geriatric Care Total	Control Events	Control Total	Weight	Risk Ratio IV, Random, 95% CI
1.4.1 1-3 months						
Hempenius 2016	24	105	22	120	21.4%	1.25 [0.74, 2.09]
Subtotal (95% CI)		**105**		**120**	**21.4%**	**1.25 [0.74, 2.09]**
Total events	24		22			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.84 (P = 0.40)						
1.4.4 1 year						
Prestmo 2015	54	179	66	177	44.0%	0.81 [0.60, 1.09]
Stenvall 2007	38	84	30	76	34.6%	1.15 [0.80, 1.65]
Subtotal (95% CI)		**263**		**253**	**78.6%**	**0.95 [0.67, 1.33]**
Total events	92		96			
Heterogeneity: Tau² = 0.03; Chi² = 2.13, df = 1 (P = 0.14); I² = 53%						
Test for overall effect: Z = 0.32 (P = 0.75)						
Total (95% CI)		**368**		**373**	**100.0%**	**1.00 [0.76, 1.32]**
Total events	116		118			
Heterogeneity: Tau² = 0.02; Chi² = 3.18, df = 2 (P = 0.20); I² = 37%						
Test for overall effect: Z = 0.01 (P = 0.99)						
Test for subgroup differences: Chi² = 0.77, df = 1 (P = 0.38), I² = 0%						

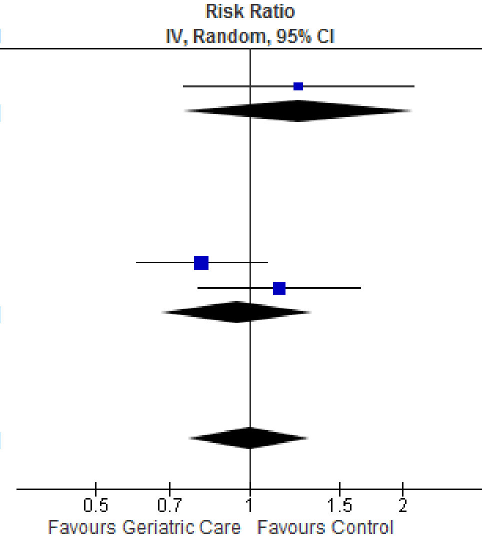


Figure 2.9: Forest plot of pooled major complications comparing CGA with usual surgical care

Study or Subgroup	Geriatric Care Events	Geriatric Care Total	Control Events	Control Total	Weight	Risk Ratio IV, Random, 95% CI
1.5.1 discharge						
Hempenius 2013	42	127	38	133	44.2%	1.16 [0.80, 1.67]
Vidan 2005	70	155	100	164	55.8%	0.74 [0.60, 0.92]
Subtotal (95% CI)		**282**		**297**	**100.0%**	**0.90 [0.58, 1.39]**
Total events	112		138			
Heterogeneity: Tau² = 0.08; Chi² = 4.29, df = 1 (P = 0.04); I² = 77%						
Test for overall effect: Z = 0.46 (P = 0.64)						

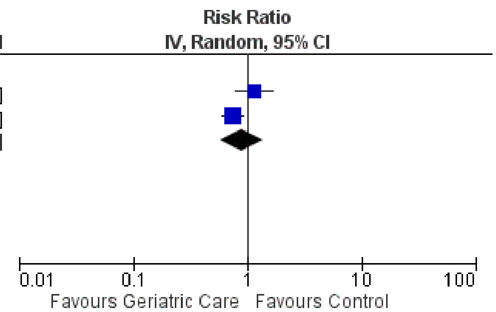
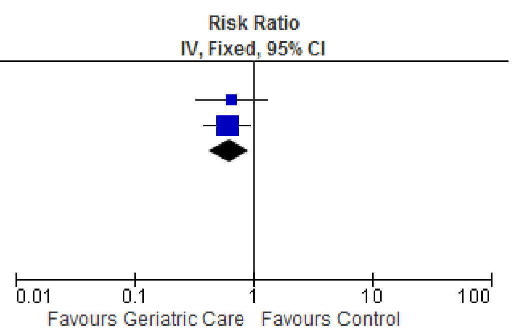


Figure 2.10: Forest plot of pooled delirium rate comparing CGA with usual surgical care

Study or Subgroup	Geriatric Care Events	Geriatric Care Total	Control Events	Control Total	Weight	Risk Ratio IV, Fixed, 95% CI
1.7.1 discharge						
Hempenius 2013	12	127	19	133	30.2%	0.66 [0.33, 1.31]
Marcantonio 2001	19	62	32	64	69.8%	0.61 [0.39, 0.96]
Subtotal (95% CI)		**189**		**197**	**100.0%**	**0.63 [0.43, 0.91]**
Total events	31		51			
Heterogeneity: Chi² = 0.03, df = 1 (P = 0.85); I² = 0%						
Test for overall effect: Z = 2.45 (P = 0.01)						



Chapter 3 – Economic Evaluations of Comprehensive Geriatric Assessment in Surgical Patients: A Systematic Review

Publication citation

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Author contributions

GE conceived, designed and executed the study. BS-B and BvdW assisted with article review and data extraction. TC designed the literature search. AO and RK supervised the project and provided insight. All authors approved the final article.

Academic presentations

The work has been presented at Academic Surgical Congress 2017, Feb 7-9, 2017 Las Vegas, USA by BvdW and Tom Williams Surgical Research Day 2017, May 12, 2017, Edmonton, AB by GE.

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The paragraph at the end of this chapter, in square parentheses, has been added to the thesis after publication

Abstract

Background

Seniors presenting with surgical disease face increased risk of post-operative morbidity and mortality, and have increased treatment costs. Comprehensive Geriatric Assessment (CGA) is proposed to reduce morbidity, mortality and cost following surgery.

Methods

A systematic review of CGA in emergency surgical patients was conducted. The primary outcome was cost-effectiveness; secondary outcomes were length-of-stay, return-of-function and mortality. Inclusion and exclusion criteria were pre-defined. Systematic searches of MEDLINE, EMBASE, Cochrane and NHS-EED were performed. Text screening, bias assessment and data extraction were performed by two authors.

Results

There were 560 articles identified; abstract review excluded 499 articles and full-text review excluded 53 articles. Eight studies were included; 1 non-orthopedic trauma and 7 orthopedic trauma studies. Bias assessment revealed moderate to high risk of bias for all studies. Economic evaluation assessment identified 2 high-quality studies and 6 moderate or low-quality studies. Pooled analysis from four studies assessed loss of function; loss of function decreased in the experimental arm (OR 0.92, 95% CI 0.88-0.97). Pooled results for length of stay from 5 studies found a significant decrease (Mean difference -1.17, 95% CI -1.63 – -0.71) after excluding the non-orthopedic trauma study. Pooled mortality was significantly decreased in seven studies (RR 0.78, 95% CI 0.67 – 0.90). All studies decreased cost and improved health outcomes in a cost-effective manner.

Conclusion

CGA improved return of function and mortality with reduced cost or improved utility. Our review suggests CGA is economically dominant and the most cost-effective care model for orthogeriatric patients. Further research should examine other surgical fields.

Introduction

In the developed world, improved medical technology, support and experience has allowed greater numbers of elderly patients to become surgical candidates[1,2]. Elderly patients are commonly defined as those who are aged 65 and older[70,71] although some western countries define it as age 60 and older[72]. Currently, 15.7% of Canadians are over the age of 65[3] and by 2050, 22% of all North Americans will be over 65[73].

Indications for surgery in those over 65 have been expanding as surgical technique and technology have improved; however, seniors presenting with surgical disease continue to face increased risk of post-operative morbidity and mortality. They are at higher risk of post-operative complications, prolonged hospitalization, increased dependency and institutionalization[74–76]. This population also experiences higher healthcare costs[16], particularly following post-operative complications[11,12], and are more prone to complications following emergency surgery[77]. Spending on healthcare represents 17.1% of United States gross domestic product (GDP) in 2015 and 10.4% of Canadian GDP[13,78] in 2016; costs are expected to increase as our population ages.

Comprehensive Geriatric Assessment (CGA) is a multidimensional assessment designed to define an elderly individual's medical, psychosocial and functional capabilities and allow for restoration of their premorbid function [46]. CGA is typically performed by a multidisciplinary team and, for non-elective surgical patients, is performed during the post-operative inpatient period. Assessment can include physical assessment, medication review, sensory assessment (vision, hearing evaluation etc.), neuropsychiatric assessment and evaluation of a patient's social supports and environment. CGA has been proposed to reduce morbidity, mortality and costs following surgery in geriatric surgical populations. Randomized controlled studies have demonstrated improved clinical outcomes predominantly in hip fracture patients[24,55,59] however most of these studies did not assess the cost-effectiveness of the intervention. CGA models include (1) having a standard geriatric consultation, (2) comanaged care, or (3) geriatricians as the primary physician. Traditional models of care, or 'usual care', can include: (1) a traditional single-discipline surgical team without automatic geriatric consultation, (2) the surgeon as the primary caregiver and an automatic internal medicine consultation or (3) the surgeon as the independent primary physician without any team-based care. This systematic review aims to synthesize the available evidence from economic evaluations of comprehensive geriatric assessment (CGA) of elderly patients undergoing surgery.

Methods

A systematic search of MEDLINE, EMBASE, Cochrane and NHS-EED was designed and conducted by a trained research librarian on March 11, 2016 asking: do surgical patients over 65 receiving CGA, compared to usual care, receive more cost-effective care. The search strategy was divided into three key concepts: geriatric assessment, economic analysis and surgery while limiting results to patients 65 and older (Appendix: Chapter 3).

Systematic abstract and full-text screening, bias assessment and data extraction was performed by two authors. Inclusion and exclusion criteria were defined a priori. Articles were included if an economic evaluation of CGA versus usual care was conducted on emergency surgery patients aged 65 and older. Studies were excluded if they included non-surgical patients, included patients under 65, did not report economic outcomes, only performed a cost analysis or did not perform a full comprehensive geriatric assessment. We did not exclude studies solely based on their study design. The pre-defined primary outcome was cost effectiveness and secondary outcomes were length-of-stay, return of function and end-of-study mortality (as determined using vital statistics). Conflict between reviewers was resolved through consensus. Cost-effectiveness was examined by assessing the Incremental Cost Effectiveness Ratio (ICER) when available or comparing outcomes and change in cost when the ICER was not reported. When outcomes were improved and costs decreased, the intervention was deemed to be cost-effective without further calculation.

Each included article was assessed for bias according to the Cochrane collaboration guidelines[48] using Covidence software[79]. Studies were assessed as low risk of bias if at least 5 of the 7 categories were graded as having a low risk of bias. Moderate risk of bias studies had 3 or 4 low risk assessments and high risk studies had fewer than 3 low risk assessment categories[48]. The quality of the economic evaluation was assessed according to the validated Quality of Health Economic Surveys (QHES) instrument[80]. Studies were defined as low quality if their QHES score was less than 50, moderate if they scored 50-74 and high if they scored 75 or higher on a 0-100 scale.

Data extraction was conducted with Covidence software[79] and meta-analysis was performed using the fixed effects model with RevMan5 software[49]. Dichotomous outcomes will be reported with odds ratios and continuous outcomes will be reported with mean difference along with their 95% confidence intervals (CI). When appropriate, comparable groups will be pooled separately (e.g. Orthopedic patients). Economic evaluations and reported costs will be converted to constant 2016 United States Dollars (USD) using purchasing power parity (PPP) and the USD Gross Domestic Product (GDP) inflator. Meta analysis of healthcare cost is not recommended due to the significant variation in costing technique[48] and will consequently not be performed. Cost differences of each study will be reported along with the conclusion of each economic evaluation performed. Heterogeneity between studies will be assessed using the chi-square test reported in RevMan (Cochran's Q test) and I^2 tests. The quality of evidence from our systematic review will be assessed using GradePro software[54].

Results

There were 557 articles identified from database searches and three from reference searching. There were 499 articles, including 3 duplicate articles, excluded based on abstract and 53 after full-text review (Figure 3.1). Eight different studies were identified[24,27,32–37]; 1 non-orthopedic trauma and 7 orthopedic trauma studies (Table 3.1). Bias assessment revealed moderate to high risk of bias for all studies (Table 3.2) however all studies identified improved overall cost effectiveness (Table 3.3).

All included studies reported acute hospital stay cost from both control and experimental arms with two studies also reporting rehab hospital costs (Table 3.4). One measured one year cost[24] and one reported combined acute and rehabilitation hospital costs[36]. Only Prestmo *et. al.*[24] found increased cost associated with CGA at discharge. However, the increased cost was more than offset at one year follow-up due to much lower costs following discharge from the acute care hospital. Overall, after converting costs to 2016 USD, weighted mean cost savings for the acute hospital admissions was $3,465 USD per primary patient admission. Costs were calculated based on length of stay in 6 studies[32–36], one of which also included patient-specific OR costs[24], one used insurance reimbursement rates[37] and one did not report how costs were calculated[27].

Two studies were of high quality, four were moderate quality and two were low quality with the QHES ratings ranging from 42 to 93 (Mean: 64.5 ±20.6) (Table 3.4). Bias assessment found significant risks posed by the design of the majority of the studies and, given the nature of the intervention, blinding of the assessors and the participants was not possible in any of the studies. All but one study used retrospective controls and four analyzed a retrospective experimental cohort as well. The methods used to ensure the accuracy of the data being used for analysis were not described. The grade of evidence from this review is presented in Table 3.5. All outcomes were downgraded due to the inclusion of non-randomized studies. Most outcomes were also downgraded due to the risk of bias due to patients not being blinded to the intervention. Mortality was not downgraded due to the nature of the outcome.

Four studies assessed loss of function[24,27,33,35]. Two studies reported assessment at discharge from any hospital, including rehabilitation, and two reported at discharge from the acute hospital. Pooled risk ratio demonstrates decreased loss of function (RR 0.92, 95% CI 0.88 to 0.97, I^2=63%, p<0.001) at discharge with CGA (Figure 3.2) although with moderate to substantial heterogeneity.

Seven studies assessed length of stay, including six orthopedic studies [24,27,33,35–37]. Five out of six orthopedic studies identified a decreased length of stay; the remaining study[24] identified longer length of stay in the CGA arm but also reported higher rates of discharge directly home in the CGA arm. Shanahan *et. al.*[36] also identified a reduced length of stay in the CGA arm but did not report their data in a manner that allows for pooled analysis. Five orthopedic studies were pooled for analysis using a fixed effect model (Figure 3.3) which demonstrates a significant reduction (mean difference -1.17, 95% CI -1.63 to -0.71, I^2=82%, p<0.001) in length of stay in the acute hospital. Acute hospital stay was used in the pooled analysis, however using total length of stay reported in two studies[33,35] did not affect the outcome of the analysis.

Seven studies[24,27,33–37] assessed all-cause one year mortality. At discharge, pooled analysis of five studies found no difference in in-hospital mortality between CGA and standard care. However, pooled analysis of mortality at one year from index admission for four studies found a significant decrease in mortality for those in the CGA arm (RR 0.76, 95% CI 0.65-0.88, I^2=54%, p<0.001). When the final follow-up point for all seven studies are pooled (Figure 3.4) the CGA arm remains significantly reduced (RR 0.78, 95% CI 0.67-0.90, I^2=32%, p=0.0009) and had low heterogeneity between studies.

Although not a pre-defined outcome, we captured time to OR from four studies. One study reported no difference between CGA and usual care but did not provide the corresponding data[24]. The remaining three studies[27,35,37] reported time to OR using a dichotomous outcome or days to OR. All these studies found decreased time to OR in the CGA arm. Pooled analysis (Figure 3.5) found a significant decrease in time to OR (RR 0.60, 95% CI 0.52 to 0.69, I^2=46%, p<0.001). The highest quality study[24] did not report the time to OR data but stated they did not see a statistical difference. This reduces the reliability of the pooled assessment of time to OR.

Discussion

We have identified 8 studies, predominantly in orthopedics, that have all found that CGA improves outcomes at lower cost when compared to usual care. This suggests that, in orthogeriatric care, CGA is economically dominant versus usual care.

Similar findings between studies suggests the findings are valid. However, despite similarities between study populations, assessment of validity is dependent on what data was collected and recorded in their respective medical databases during admission. None of the studies described any attempt to blind the outcome assessors. Additionally, due to the nature of the intervention, there was no way to blind the participant or those delivering care. Since most studies did not have any blinding there is a significant risk of bias. Overall, only Prestmo *et. al.*[24] had acceptable levels of bias. Evaluation of the quality of each economic assessment revealed that the overall quality of their economic assessments was moderate. Considering that 7 of the 8 studies were in the same surgical population and that all studies found CGA improved outcomes at lower cost compared to usual care, we feel there is a low likelihood the results are influenced by bias.

In all but one study assessment of clinical effectiveness demonstrated that CGA improved at least two of the reported patients' outcomes. Prestmo *et. al.*[24] did find that length of stay was longer in the experimental arm; however, more people in this arm were discharged directly home. This may explain the increased length of stay in the CGA arm. However, overall the CGA arm improved the assessed quality of life (utility), and the incremental cost effectiveness ratio (ICER) was €-71,751 per quality adjusted life year gained. Negative ICERs suggest the CGA model of care, when compared to usual orthopedic care, is the dominating economic choice of care. Additionally, Prestmo *et. al.* also did not show any long-term effect on mortality or return to function at one year. This is contrary to all other studies conducted but should not be ignored as the Trondheim hip fracture trial is the only prospective randomized trial identified. A Cochrane review of CGA versus usual care is currently underway to assess such outcomes in high quality studies[81]. Overall, all 8 studies demonstrated improved outcomes at a lower cost

(Table 3.3) making CGA in the perioperative period the economically dominant choice when compared to usual care.

The quality of the economic evaluations found all studies posed a well-defined question with a comprehensive description of the study arms. Two of the eight studies were of high quality, according to the QHES tool. The majority of studies adjusted for the time-value of money when necessary and all studies established the cost-effectiveness of their CGA intervention and reported the cost savings per hospital stay ($3,465 in 2016 USD). However, most studies used length of stay to calculate cost and did not include the added cost of conducting a CGA. Additionally, most studies did not include the cost of rehabilitation in their analysis but were able to show reduced rehabilitation requirements and reduced admission to long term care facilities following discharge. It is likely that if the costs generated after discharge from the acute hospital were included that overall total cost reduction would have been even greater. Shanahan *et. al.* included these costs in their estimate of annual program costs versus savings and were able to show €1.2 million reduction in costs with an investment of only €171,000 per year. Overall, the quality of the economic analysis was moderate, however, all eight studies found the same result; CGA reduces costs while improving outcomes.

The pooled analysis of the secondary outcomes identified a significant overall reduction in length of stay, end-of-study mortality and increased return to pre-hospitalization functional ability. We also identified a reduction in time to OR resulting in patients more frequently meeting current clinical guideline recommendations for time to OR for hip fracture. However, we recognize that drawing clinical conclusions from our secondary data is not possible, since our search was limited to studies that reported economic outcomes only.

This review is limited by several factors. First, all but one identified study was conducted in an orthogeriatric population. This review cannot draw conclusion about the effectiveness of CGA outside of the orthogeriatric setting. Further investigations of the cost-effectiveness of CGA in other surgical fields outside of orthopedics needs to be conducted. Second, most studies included in this review included a retrospective patient population in either their control group or both their control and experimental arms. Third, comparison of health care costs between differing medical systems and across decades is challenging and cannot be easily pooled in a traditional meta-analysis. However, given the agreement on cost reduction across all eight studies, we feel this limitation is less significant.

The following paragraph has been added following publication

[An additional limitation of this review includes the nature of the systematic search. Drawing clinical conclusions from our secondary outcomes is not possible, since our search was limited to studies that reported economic outcomes only. They were included, mostly, to allow a systematic and pre-defined clinical outcome to assess in conjunction with our primary economic outcome. Our finding that length of stay, mortality and return of function are all improved in studies that report economic outcomes does not represent all clinical research examining these outcomes and therefore our secondary outcomes are incomplete and at risk of detection bias. For a complete analysis of these outcomes, please refer to the protocol for a systematic review for the Cochrane collaboration by Eamer *et al*[81]; once the full review is published it should serve as a guide for clinical decision making.]

Conclusions

This systematic review found CGA provides better orthogeriatric care for hip fracture than the usual models of care at a lower cost. This review suggests incorporation of CGA may be beneficial in this population. We cannot determine if CGA is the best care model overall as we have not compared it to alternative orthopedic care models. All but one study identified examined hip fracture patients. Drawing conclusions about CGA in other surgical populations cannot be done with the current data; further research should be conducted.

Table 3.1: Study characteristics, design and field for the included studies

	Title	Surgical Field	Year	Study design	Number enrolled	Number enrolled in CGA arm
DeLa'O et. al.	The Geriatric Trauma Institute: reducing the increasing burden of senior trauma care.	Trauma	2014	Retrospective pre-post cohort	740	355
Elliot et. al.	The added effectiveness of early geriatrician involvement on acute orthopaedic wards to orthogeriatric rehabilitation.	Orthopedic	1996	Retrospective concurrently controlled cohort	118	61
Ginsberg et. al.	A cost-utility analysis of a comprehensive orthogeriatric care for hip fracture patients, compared with standard of care treatment.	Orthopedic	2013	Retrospective pre-post cohort	3114	847
Ho et. al.	To investigate the effect and cost-effectiveness of implementing an orthogeriatric intervention for elderly patients with acute hip fracture: the experience in Hong Kong.	Orthopedic	2009	Prospective cohort with retrospective control	554	281
Ling et. al.	Can geriatric hip fractures be managed effectively within a level 1 trauma center?	Orthopedic	2015	Prospective cohort with retrospective control	390	199
Prestmo et. al.	Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial.	Orthopedic	2015	Randomized controlled trial	397	198
Shanahan et. al.	Implementation of a dedicated orthogeriatric service saves the HSE a million euro	Orthopedic	2014	Retrospective pre-post cohort	412	206
Miura et. al.	Effects of a geriatrician-led hip fracture program: improvements in clinical and economic outcomes.	Orthopedic	2009	Prospective cohort with retrospective control	163	91

Table 3.2: Risk of bias assessment for each included article according to the Cochrane collaboration bias assessment guidelines

	Prestmo et. al.	Elliot et. al.	Ginsberg et. al.	Ho et. al.	Ling et. al.	Miura et. al.	Shanahan et. al.	DeLa'O et. al.
Sequence generation	Low	High	High	High	High	High	High	High
Allocation concealment	High	High	High	High	High	High	High	High
Blinding of participants and personnel	High	High	High	High	High	High	High	High
Blinding of outcome assessors	Unclear	High	Unclear	High	High	High	High	Unclear
Incomplete outcome data	Low	High	Unclear	Unclear	Low	Low	Unclear	Low
Selective outcome reporting	Low	High	Low	Low	Low	Low	Low	Low
Other sources of bias	Low	Unclear	Low	Low	High	Low	Unclear	Unclear

Table 3.3: Clinical outcomes of CGA when compared to usual care and assessment of cost of CGA compared to usual care for each study (outcomes not studied in each trial are blank)

	Prestmo et. al.	Elliot et. al.	Ginsberg et. al.	Ho et. al.	Ling et. al.	Miura et. al.	Shanahan et. al.	DeLa'O et. al.
Length of stay	Worsened	Improved		Improved	Improved	Improved	Improved	Improved
Mobility	Improved							
Return of function	No change	Improved			Improved		Improved	
Utility	Improved		Improved					
Time to OR	No change			Improved	Improved	Improved		
1-year mortality	No change		Improved	Improved			Improved	
Inpatient mortality		No change		Improved	No change	No change	No change	
Cost effectiveness of geriatric care	Cost effective	Cost effective	Cost effective	Cost effective	Cost effective	Cost effective	Cost effective	Cost effective

Table 3.4: QHES quality assessment, location, sample size and adjusted cost outcomes at study defined endpoints

	QHES score	Country	Year	Currency	Sample size	Cost for control group - 2016 USD	Cost for CGA-group - 2016 USD	Cost savings from CGA (Pre-Post)	End-point for cost calculation
DeLa'O et. al.	42	USA	2013	USD	664	$9,796.54	$7,694.80	$2,101.74	Acute admission
Elliot et. al.	70	New Zealand	1993	NZD	118	$12,805.41	$10,467.03	$2,338.38	Acute admission
Ginsberg et. al.	92	Israel	2011	USD	3114	$17,019.19	$12,093.78	$4,925.41	Acute admission
Ho et. al.	53	Hong Kong	2006	USD	554	$10,411.70	$9,384.23	$1,027.47	Acute and rehab admission
Ling et. al.	50	Australia	2011	AUD	390	$9,573.08	$5,743.85	$3,829.23	Acute admission
Prestmo et. al.	93	Norway	2010	EUR	344	$18,606.36	$19,385.75	-$779.39	Acute admission
						$57,736.98	$52,734.52	$5,002.46	1-year follow-up
Shanahan et. al.	43	Ireland	2011	EUR	412	$6,063.09	$4,409.52	$1,653.57	Acute admission
						$14,868.74	$10,553.00	$4,315.74	Acute and rehab admission
Miura et. al.	73	USA	2002	USD	163	$14,959.88	$12,060.32	$2,899.56	Acute admission

USD: United States dollars
CGA: Comprehensive geriatric assessment
QHES: Quality of Health Economic Studies

Table 3.5: Assessment of quality of evidence for selected pooled outcomes when comparing comprehensive geriatric care with usual care

Quality assessment						№ of patients		Effect		Quality
№ of studies (Clinical Relevance)	Risk of bias	Inconsistency	Indirectness	Imprecision	Other	CGA	Usual care	Relative (95% CI)	Absolute (95% CI)	
Length of Stay										
5 (Important)	serious [a]	not serious	not serious	not serious	strong association	830	792	-	MD **1.17 lower** (-1.63 to -0.71)	⊕⊕ LOW
Loss of Function										
4 (Critical)	serious [a]	not serious	not serious	serious [b]	none	524/714 (73.4%)	553/679 (81.4%)	**RR 0.92** (0.88 to 0.97)	**65 fewer per 1,000** (from 24 fewer to 98 fewer)	⊕ VERY LOW
Mortality										
7 (Critical)	not serious	not serious	not serious	not serious	strong association	228/1877 (12.1%)	540/3252 (16.6%)	**RR 0.78** (0.67 to 0.90)	**37 fewer per 1,000** (from 17 fewer to 55 fewer)	⊕⊕⊕ MODERATE
Mortality - 1 year										
4 (Critical)	not serious	not serious	not serious	not serious	strong association	206/1526 (13.5%)	523/2932 (17.8%)	**RR 0.76** (0.65 to 0.88)	**43 fewer per 1,000** (from 21 fewer to 62 fewer)	⊕⊕⊕ MODERATE
Time to OR										
3 (Important)	serious [a,c]	not serious	not serious	not serious	strong association	390/571 (68.3%)	252/536 (47.0%)	**RR 0.60** (0.52 to 0.69)	**188 fewer per 1,000** (from 146 fewer to 226 fewer)	⊕⊕ LOW

CI: Confidence interval; **MD:** Mean difference; **RR:** Risk ratio, **CGA**: Comprehensive Geriatric Assessment

a. Participants could not be blinded

b. Discharge to rehab may have been recorded as loss of function

c. Study personnel were not blinded

Figure 3.1: Flow diagram of study selection

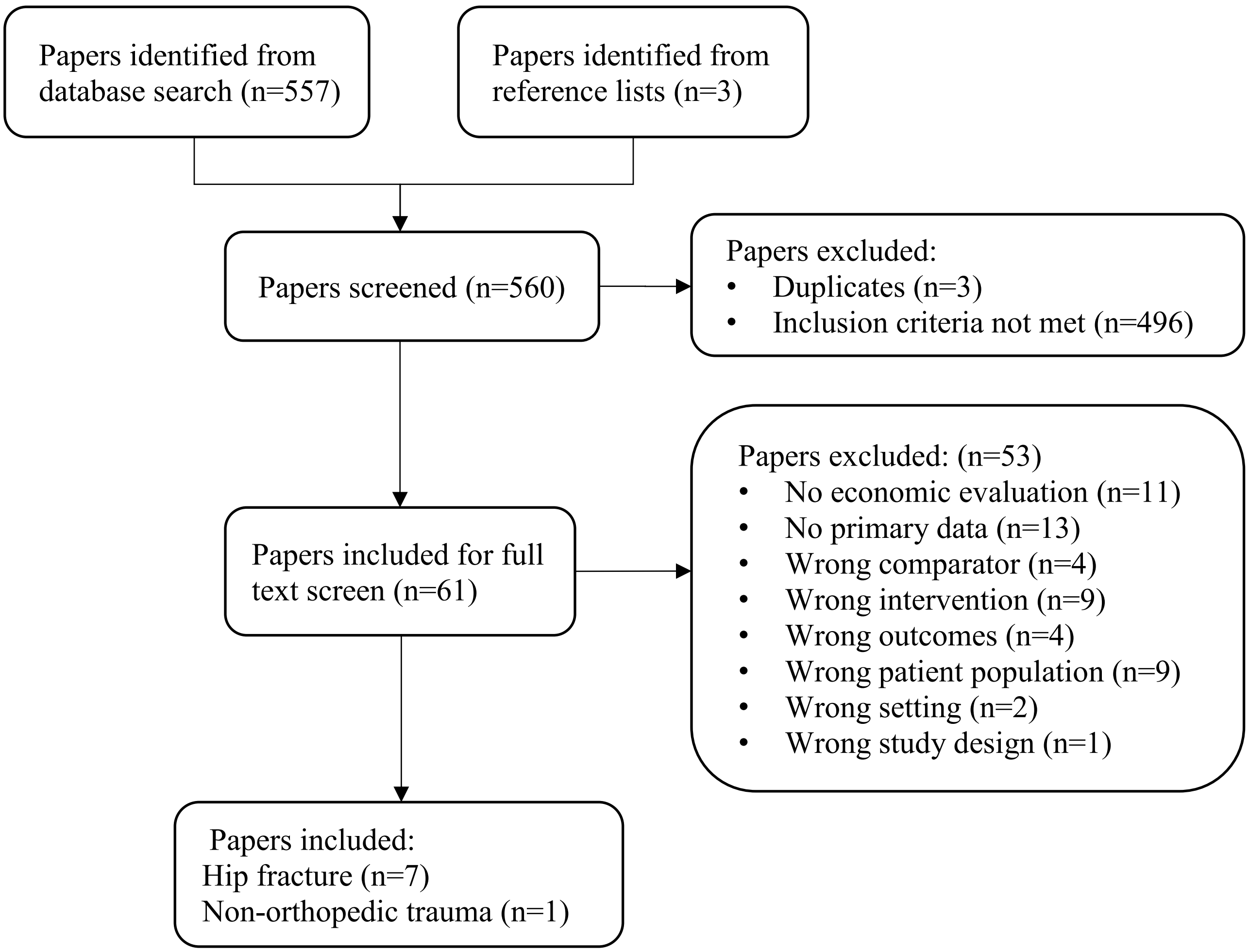


Figure 3.2: Forest plot of the pooled 'loss of function' for four studies comparing comprehensive geriatric care with usual care

Study or Subgroup	Comprehensive geriatric care Events	Comprehensive geriatric care Total	Usual care Events	Usual care Total	Weight	Risk Ratio IV, Fixed, 95% CI
1.6.1 Acute hospital discharge						
Ho 2009	242	278	240	262	64.2%	0.95 [0.90, 1.01]
Ling 2015	121	184	160	173		Not estimable
Prestmo 2015	144	191	167	187	24.2%	0.84 [0.77, 0.93]
Subtotal (95% CI)		**469**		**449**	**88.3%**	**0.92 [0.88, 0.97]**
Total events	386		407			
Heterogeneity: Chi² = 4.33, df = 1 (P = 0.04); I² = 77%						
Test for overall effect: Z = 3.29 (P = 0.001)						
1.6.2 Discharge						
Elliot 1996	49	61	43	57	5.8%	1.06 [0.88, 1.29]
Ling 2015	89	184	103	173	5.8%	0.81 [0.67, 0.99]
Subtotal (95% CI)		**245**		**230**	**11.7%**	**0.93 [0.81, 1.07]**
Total events	138		146			
Heterogeneity: Chi² = 3.76, df = 1 (P = 0.05); I² = 73%						
Test for overall effect: Z = 1.04 (P = 0.30)						
Total (95% CI)		**714**		**679**	**100.0%**	**0.92 [0.88, 0.97]**
Total events	524		553			
Heterogeneity: Chi² = 8.12, df = 3 (P = 0.04); I² = 63%						
Test for overall effect: Z = 3.45 (P = 0.0006)						
Test for subgroup differences: Chi² = 0.02, df = 1 (P = 0.88), I² = 0%						

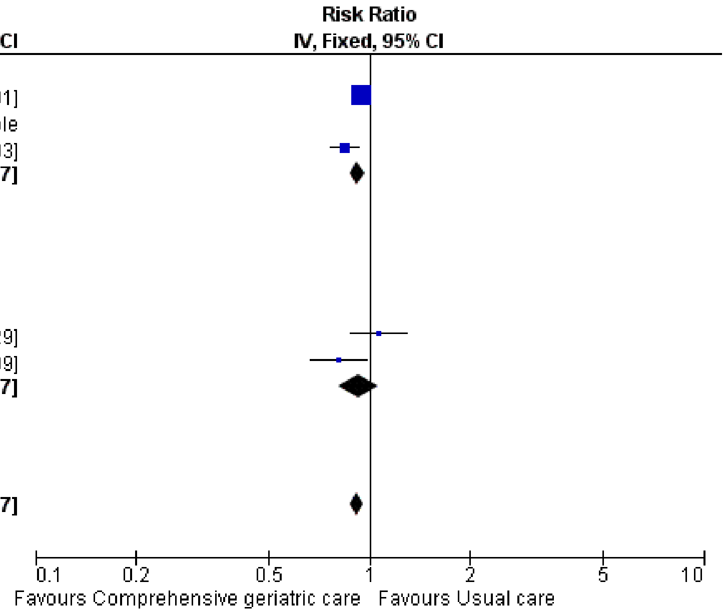


Figure 3.3: Forest plot of the pooled 'length of stay' for five studies comparing comprehensive geriatric care with usual care

Study or Subgroup	Comprehensive geriatric care Mean	SD	Total	Usual care Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
1.1.1 Discharge								
DeLa'O 2014	4.43	37.68288736	355	5.64	51.01568386	385		Not estimable
Elliot 1996	20.7	12.95066911	61	26.3	19.64497736	57	0.6%	-5.60 [-11.65, 0.45]
Ho 2009	8.3	4.4	281	9.7	5.7	273	29.1%	-1.40 [-2.25, -0.55]
Ling 2015	6	38.97550084	199	14	38.14395889	191	0.4%	-8.00 [-15.65, -0.35]
Miura 2009	4.6	1.1	91	6.1	2.4	72	58.7%	-1.50 [-2.10, -0.90]
Prestmo 2015	12.6	6.1	198	11	7.7	199	11.3%	1.60 [0.23, 2.97]
Subtotal (95% CI)			**830**			**792**	**100.0%**	**-1.17 [-1.63, -0.71]**
Heterogeneity: Chi² = 22.36, df = 4 (P = 0.0002); I² = 82%								
Test for overall effect: Z = 4.99 (P < 0.00001)								
Total (95% CI)			**830**			**792**	**100.0%**	**-1.17 [-1.63, -0.71]**
Heterogeneity: Chi² = 22.36, df = 4 (P = 0.0002); I² = 82%								
Test for overall effect: Z = 4.99 (P < 0.00001)								
Test for subgroup differences: Not applicable								

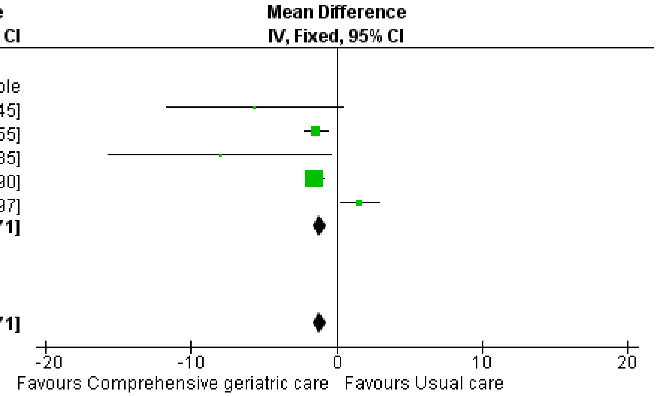


Figure 3.4: Forest plot of the pooled mortality in seven studies comparing comprehensive geriatric care with usual care

Study or Subgroup	Comprehensive geriatric care Events	Comprehensive geriatric care Total	Usual care Events	Usual care Total	Weight	Risk Ratio IV, Fixed, 95% CI
1.7.1 Discharge						
Elliot 1996	5	61	3	57	1.1%	1.56 [0.39, 6.22]
Ho 2009	3	281	11	273	0.0%	0.26 [0.07, 0.94]
Ling 2015	15	199	13	191	4.2%	1.11 [0.54, 2.27]
Miura 2009	2	91	1	72	0.4%	1.58 [0.15, 17.11]
Shanahan 2014	3	206	9	206	0.0%	0.33 [0.09, 1.21]
Subtotal (95% CI)		**351**		**320**	**5.6%**	**1.21 [0.66, 2.24]**
Total events	22		17			
Heterogeneity: Chi² = 0.24, df = 2 (P = 0.89); I² = 0%						
Test for overall effect: Z = 0.62 (P = 0.54)						
1.7.4 1 year						
Ginsberg 2013	125	847	392	2267	62.0%	0.85 [0.71, 1.03]
Ho 2009	32	281	55	273	13.1%	0.57 [0.38, 0.85]
Prestmo 2015	30	192	37	186	11.1%	0.79 [0.51, 1.22]
Shanahan 2014	19	206	39	206	8.1%	0.49 [0.29, 0.81]
Subtotal (95% CI)		**1526**		**2932**	**94.4%**	**0.76 [0.65, 0.88]**
Total events	206		523			
Heterogeneity: Chi² = 6.49, df = 3 (P = 0.09); I² = 54%						
Test for overall effect: Z = 3.57 (P = 0.0004)						
Total (95% CI)		**1877**		**3252**	**100.0%**	**0.78 [0.67, 0.90]**
Total events	228		540			
Heterogeneity: Chi² = 8.81, df = 6 (P = 0.18); I² = 32%						
Test for overall effect: Z = 3.32 (P = 0.0009)						
Test for subgroup differences: Chi² = 2.09, df = 1 (P = 0.15), I² = 52.2%						

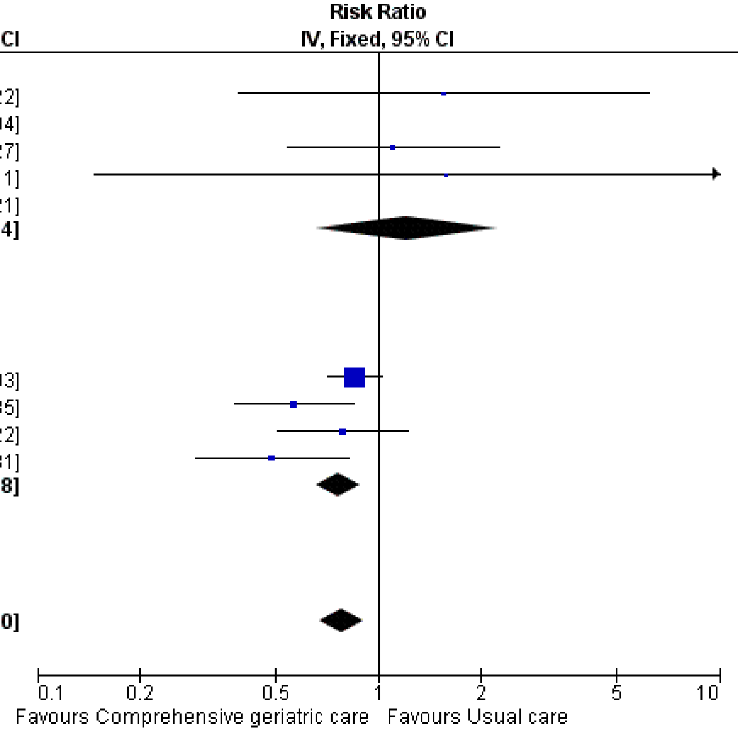
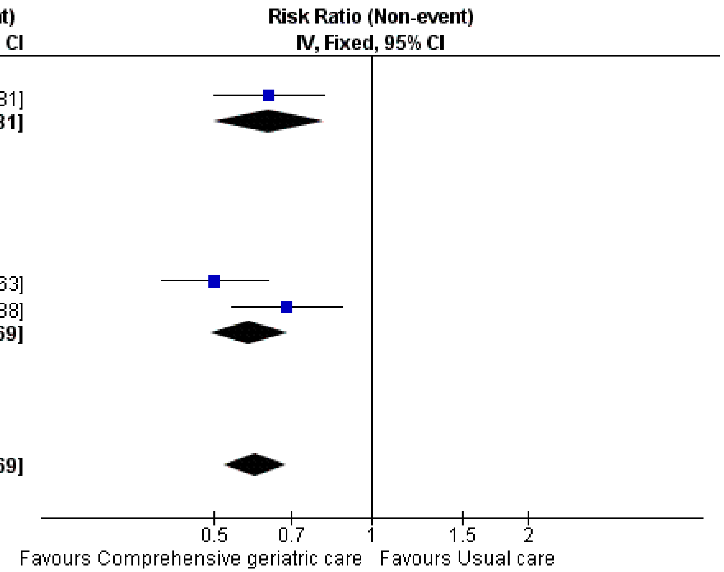


Figure 3.5: Forest plot of the pooled 'time to operating theatre' in three studies comparing comprehensive geriatric care with usual care

Study or Subgroup	Comprehensive geriatric care Events	Total	Usual care Events	Total	Weight	Risk Ratio (Non-event) IV, Fixed, 95% CI
1.8.1 OR under 24h						
Miura 2009	46	91	16	72	33.1%	0.64 [0.50, 0.81]
Subtotal (95% CI)		**91**		**72**	**33.1%**	**0.64 [0.50, 0.81]**
Total events	46		16			
Heterogeneity: Not applicable						
Test for overall effect: Z = 3.67 (P = 0.0002)						
1.8.2 Within 48 hours						
Ho 2009	211	281	137	273	34.9%	0.50 [0.40, 0.63]
Ling 2015	133	199	99	191	31.9%	0.69 [0.54, 0.88]
Subtotal (95% CI)		**480**		**464**	**66.9%**	**0.58 [0.49, 0.69]**
Total events	344		236			
Heterogeneity: Chi² = 3.39, df = 1 (P = 0.07); I² = 71%						
Test for overall effect: Z = 6.23 (P < 0.00001)						
Total (95% CI)		**571**		**536**	**100.0%**	**0.60 [0.52, 0.69]**
Total events	390		252			
Heterogeneity: Chi² = 3.73, df = 2 (P = 0.16); I² = 46%						
Test for overall effect: Z = 7.21 (P < 0.00001)						
Test for subgroup differences: Chi² = 0.34, df = 1 (P = 0.56), I² = 0%						



Chapter 4 - Unscheduled general surgery, but not scheduled general surgery, have higher costs in the elderly

Publication

Eamer G, Brisebois R, Clement F, Khadaroo RG. Unscheduled general surgery, but not scheduled general surgery, have higher costs in the elderly. Under review by the Canadian Journal of Surgery.

Author contributions

I conceived of the study, analyzed the data and drafted the manuscript. R Brisebois facilitated access to the data and provided guidance and revised the manuscript. F Clement provided assistance with statistical and economic analysis. R Khadaroo supervised the project and assisted with manuscript preparation and revision. All authors approved the final manuscript.

Academic presentations

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Abstract

Background

Healthcare costs are increasing. Aging is associated with increased postoperative complications resulting in increased disability, cost and mortality. Elderly populations are growing as baby-boomers age; the cost of caring for them is rising. It is unclear how surgery contributes to costs. Understanding the costs of surgical care for the elderly is crucial for healthcare services planning. We hypothesize that increasing age predicts increasing surgical inpatient costs.

Methods

Retrospective analysis of general surgical inpatient costs over two fiscal years of four hospitals was performed. Cost and number of procedures were reported by age, procedure, hospital, cost category, and urgency. Costs were compared between surgical risk profile, urgency and age. Cost differences of 10% or greater were considered clinically significant.

Results

Surgical inpatient costs for 12,070 procedures, representing 84% of all admissions in the region, were examined. The average cost was $4,351 for scheduled admissions and $4,054 for unscheduled admissions. Only unscheduled admissions were significantly costlier in older age groups; cost increase is attributed to post-operative care. Costs more than doubled for the unscheduled surgery over 80-year-old in both low and moderate risk groups.

Discussion

Costs increased with age in emergency but not elective surgery. Low, moderate and high risk unscheduled surgery all result in higher cost in the elderly suggesting screening elective surgical candidates is effective and medical optimization preoperatively may decrease admission costs.

Conclusion

Elderly surgical patients only incur increased costs if admitted for emergency surgery. Innovative programs to reduce complications in the elderly for emergency surgery should be developed.

Introduction

The common perception of surgical care is that as patients age the cost of care increases. In fact, most reports examining the cost of healthcare will cite increasing cost of care and increased disease burden with age as factors in rising healthcare costs[82,83]. Additionally, studies examining cost of surgical intervention frequently report increasing cost being associated with increasing age[16]. Currently, 11.4% of Alberta residents, and 15.7% of Canadians are over the age of 65[3]. This is projected to grow to 24% of Canadians by 2036[4]. The cost of healthcare in Canada has been increasing faster than the national inflation rate for decades. It represented 10.9% of Canadian GDP, or $219.1 billion, in 2015[13]. Although increasing health care cost has been associated with age, little research has examined the cost of surgical admission in the elderly.

Post-operative complications in the elderly are associated with longer hospital admissions, increased disability, increased hospitalization cost[11,12,75], loss of independence, and mortality[6,7]. The adverse effects of lost productive years, increased dependency on family and government services and the increased mortality result in a high cost for the patient, their family and society in general. Additionally, in a publicly financed health system, careful stewardship of scarce healthcare resources is critical in taming our ever-increasing healthcare budgets.

Expanding surgical treatment criteria has led to more surgical candidates resulting in a higher marginal cost of delivering care. Those who have become surgical candidates because of improved technique, technology and experience are those at highest risk of post-operative complications, prolonged hospitalization and increased dependency or institutionalization following discharge. As the baby-boom generation ages, a large cohort of people will enter the most expensive phase of their medical lives. However, it is unclear how much surgical intervention contributes to increased costs experienced by elderly patients. Understanding the costs associated with surgical care for our growing population of seniors will be crucial for healthcare services planning. To our knowledge, no studies have examined the relationship between cost of in-hospital care, age and emergency status (planned vs. unplanned) in a general surgery population. We hypothesize that costs will increase with age for all surgical risk and for elective and unscheduled surgical procedures.

Methods

Mean inpatient surgical costs and number of cases were gathered from Lighthouse analytics software (AnalysisWorks Inc, Vancouver, Canada) for patients who were admitted from April 1, 2014 to March 30, 2016 and discharged between April 1, 2014 and September 30, 2016. Ethical approval was obtained from the University of Alberta Research Ethics Office (Pro00068273). Lighthouse is a business decision tool that uses surgeon level costing to highlight areas where costs can be reduced without affecting patient care. Operating room (OR) costing for OR supplies and OR salaries are performed using microcosting, the gold-standard in health economics. Pre- and post-operative costing is done using cost-per-day for patient admissions with a higher daily rate assigned to the immediate post-operative period to adjust for increased nursing and diagnostic services required immediately post-operatively. Patients who are deemed to be cost outliers are excluded from the data.

Patients were excluded if they underwent a day-surgery procedure. Costs and number of procedures were reported by age (17-64, 65-79 and 80+), planned surgical procedure, hospital (University of Alberta Hospital [UAH], Royal Alexandra Hospital [RAH], Grey Nuns Community Hospital [GNH] and Misericordia Community Hospital[MCH]), cost category (OR supplies, OR salaries, preoperative inpatient and postoperative inpatient costs), and scheduled versus unscheduled procedure. Length of stay was reported for inpatient, observation and intensive care beds for each surgical procedure. Our length of stay data did not differentiate between scheduled and unscheduled surgical procedures.

All inpatient general surgery procedures at the four hospitals for which data is available were included representing 84% of all general surgical procedures in the region. RAH and UAH have 231 and 181 surgical beds respectively, and are accredited trauma centres with tertiary and quaternary referral services. MCH and GNH are community hospitals with 92 and 60 surgical beds respectively. Together, the hospitals represent four of the five primary hospitals for a catchment population of 1.3 million and are the tertiary referral centre for a population of 2.1 million. Only one other hospital performs a significant volume of inpatient general surgical procedures within the Edmonton region; they do not input data into the Lighthouse database.

Standard deviation and variance were not available from our dataset. Variance between the mean cost for each procedure at each hospital and the pooled mean for each subgroup analyzed was calculated. Two-tailed students' t-test was used to compare the pooled means using the measured variance between means. Degrees of freedom was the number of means used to calculate the pooled mean. Costs were compared between community and trauma hospitals, surgical risk profile, surgical urgency and age category. Low risk surgical procedures included head and neck, breast and superficial procedures such as open inguinal hernia repair, moderate risk procedures entered the peritoneum but did not enter the bowel (cholecystectomy, appendectomy, ventral hernia or laparoscopic inguinal hernia) and included ileostomy reversal, and high-risk procedures involved bowel resection of any kind and 'laparotomy' procedures. Cost differences were statistically significant when $p<0.05$ and clinically significant when overall cost differences were 10% or greater or cost subgroups were over 25% different. The 10% cut-off was chosen to reflect a financially significant change that would be of interest to health administrators. Sensitivity analysis with 5% and 15% cut-offs for overall cost was conducted.

Results

Overall there were over 14,300 inpatient general surgery procedures performed in the region over the two years studied. There were 12,070 general surgical procedures performed at the 4 hospitals included in this study; 42.8% of the cases studied were unscheduled. One third of procedures were performed on patients 65 years and older (Table 4.1).

The average case cost was $4,351 for scheduled cases and $4,054 for unscheduled cases. Length of stay increased with age, averaged 4.4 days per case and was 1.5 days longer at trauma hospitals compared to community hospitals (Table 4.2).

There was less than a 10% difference in cost between those under 65 and both 65-79 and 80+ age groups for scheduled cases for all three surgical risk categories. Overall costs were statistically, but not clinically, significantly lower for scheduled low risk procedures for both 65-79 (-8.8%, $p<.001$) and 80+ (-8.8%, $p<.001$) age groups. Overall costs were not statistically or clinically different for moderate or high-risk procedures. However, for unscheduled cases there was a significant increase for both 65-79 (Low risk [48.1%, $p<.001$], moderate risk [36.8%. $p=.045$] and high risk [22.6%. $p=.04$]) and 80+ (Low risk [115.3%, $p<.001$], moderate risk [103.3%. $p<.001$] and high risk [46.0%. $p<.001$]) age groups when compared to those under 65.

The total admission cost more than doubled for the 80+ age group undergoing unscheduled low and moderate risk surgical procedures (Table 4.3, Figure 4.1).

It was important to determine what phase of surgical admission resulted in the increased costs. When the total admission costs were examined by cost category stratified by age and urgency there was no clinically significant change in overall cost for elective procedures between age groups (Under 65 $3,494, 65-79 $3,768 [8% increase, p=.001], 80+ $3,422 [2% decrease, p=.64]) however overall cost increased with age for unscheduled procedures (Under 65 $3,306, 65-79 $5,473 [66% increase, p<.001], 80+ $7,091 [114% increase, p<.001]). The pre-operative, operative and post-operative costs were examined to determine where the increased costs were accrued. The cost increase in unscheduled admission were due to increased post-operative costs in all age groups. This is predominantly due to increasing post-operative care costs in the older cohorts. Unscheduled admissions post-operative care cost was no different than scheduled admission post-operative care costs in the under 65 age group. The difference increased to $1,480 higher in the 65-79 age group and $3,143 higher in the 80+ age group. Case costs were lower for unscheduled cases in the under 65 age group (Table 4.4). The difference between scheduled and unscheduled OR supplies became smaller in older age groups which contributed to increased overall cost in unscheduled compared to scheduled admissions in the older cohort. When procedures were divided by surgical risk, this trend persisted for all three risk categories (Table 4.5). Post-operative admission costs were the most significant source of increased cost of unscheduled surgical admission in older age groups. Sensitivity analysis assessed the effect of a 5% and 15% cut-off for clinically significant changes in overall cost. Using a 15% cut-off, no costs groups for any age or surgical risk group became clinically insignificant (Table 4.3). Using a 5% cut-off, scheduled low risk surgery was significantly less costly in both the 65-79 (-8.8%) and 80+ (-8.8%) age groups and high-risk surgery was significantly more costly in the 80+ (+5.1%) age group (Table 4.3).

Discussion

We hypothesised that increasing age would predict increasing operative case costs, mostly due to prolonged length of stay. Interestingly, admission costs were only statistically and clinically significantly increased for unscheduled procedures and not increased for scheduled procedures. This finding persisted when surgical interventions were divided into surgical risk groups. The increased admission cost was predominantly due to higher post-operative care costs in the 65-79 and 80+ age groups. Surgical expertise may be being used to select who would be a good candidate for surgical intervention in scheduled surgical cases. Another possible explanation could be that elderly patients who would not tolerate surgery and being steered towards medical management of their presenting complaints or are being optimized for surgery before intervention. Patients presenting with surgical disease through the emergency department, however, are not able to undergo medical optimization or the presenting condition necessitates surgical management despite the increased risk of morbidity and mortality. This leads to increased complications, length of stay and consequently, increased cost.

Improving the post-operative care of our elderly to allow reduced morbidity and mortality is the critical to improving outcomes. Fortunately, multiple studies in hip fracture patients have found that comprehensive geriatric assessment (CGA) can decrease length of stay, improve functional status at discharge while decrease overall cost. Risk assessment tools have used age as a surrogate for risk prediction, however frailty has been shown to be more predictive of post-operative morbidity and mortality[1,2,6–8]. It is independently associated with increased post-operative complications including readmission[9], 30 day and 1-year mortality[6,10] as well as post-discharge institutionalization[2]. A systematic review of the economics of CGA by Eamer *et al*[69] suggested CGA reduced cost and improved clinical outcomes. Additional savings from decreased requirements for higher levels of care following discharge including long-term care homes and transitional housing would be in addition to these savings. The additional cost of CGA by geriatricians or trained nursing staff have not been calculated. However, all studies examined by Eamer *et al* found a net cost savings. There have not been any quality controlled studies of CGA in the emergency general surgery patient population to date. However, the Elder-friendly Approach to the Surgical Environment (EASE) Study[38], examining novel approaches to post-operative surgical care in the elderly, hopes to answer that very question.

Patient selection is likely influencing our comparison of scheduled and unscheduled cases. This is not a limitation, because our data most-likely better represents the reality of modern surgical practice. Patient selection, through pre-operative assessment and advising high risk patients of possible adverse outcomes is standard practice and leads to some patients choosing to forgo surgical intervention. Unscheduled surgical procedures do not allow for patient selection in the manner scheduled cases permit.

This study is limited by several factors. First, the data is retrospective and only available as aggregate population level data. Controlling for patient specific factors was not possible. Second, variance was calculated as the variance of means instead of the variance of the population since we did not have access to this data. This likely results in our calculated variance being less than the population variance. However, given the large sample size – we have captured a significant portion of the population (84% of all procedures performed in the region) – our measured means should be close to the population mean, reducing the error that this method of analysis could introduce. Finally, excluding cost outliers from the data will likely bias out results towards the null hypothesis since the elderly (or more specifically those with higher frailty), have been shown to be at increased risk of complications and increased cost.

Conclusion

Surgical intervention in the elderly results in higher costs of care for only unscheduled cases. This is likely due to surgeons screening patients at risk of adverse outcomes due to medical comorbidities which results in pre-operative medical optimization or medical management of non-emergent surgical conditions for high risk patients. Programs that offer comprehensive geriatric assessment for elderly emergency surgical patients, such as those shown to be cost effective in hip fracture patients, must be examined in other surgical settings. These programs are innovative approaches to patient care that result in cost savings with improved patient outcomes and should undergo further study to assist in preventing the rising cost of care for older adults in our health system.

Acknowledgements

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Table 4.1: Total, scheduled and unscheduled cases with average case cost by age

Age Category	Total Cases	Inpatient cost	Total Scheduled Cases	Inpatient Cost Scheduled Cases	Total Unscheduled Cases	Inpatient Cost Unscheduled Cases
64 and Under	8451	$ 3,951	4373	$ 4,422	4078	$ 3,447
65 to 79	2863	$ 4,794	2021	$ 4,333	842	$ 5,902
80+	756	$ 5,105	500	$ 3,815	256	$ 7,622
Average	12070	$ 4,224	6894	$ 4,351	5176	$ 4,054

Table 4.2. Length of stay by acuity of care, hospital type and age for general surgical inpatients

Age Category	Total Cases	Acute Days	Observation Days	ICU Days	Total Days	Average LOS - community hospital (n)	Average LOS - trauma hospital (n)
64 and Under	8451	3.7	0.1	0.0	3.8	3.0 (3515)	4.4 (4936)
65 to 79	2863	5.4	0.1	0.1	5.5	4.4 (1355)	6.5 (1508)
80+	756	6.7	0.1	0.1	6.8	6.3 (367)	7.4 (389)
Overall	12070	4.3	0.1	0.0	4.4	3.5 (5237)	5.0 (6833)

Table 4.3. Percent difference between age groups for total inpatient cost by risk category, urgency and age compared to under 65 (Clinically significant differences highlighted in bold)

Risk category	Age group	Overall			Scheduled			Unscheduled		
		% change	n	p	% change	n	p	% change	n	p
Low risk	Under 65		1574			1258			316	
	65 to 79	-2.90%	678	0.06	-8.80%	621	<.001	**48.10%**	57	<.001
	80+	8.60%	244	<.001	-8.80%	206	<.001	**115.30%**	38	<.001
Moderate risk	Under 65		3,497			760			2737	
	65 to 79	**29.70%**	757	<.001	2.50%	414	0.052	**36.80%**	343	0.045
	80+	**63.00%**	132	<.001	1.50%	56	0.94	**103.30%**	76	<.001
High risk	Under 65		1,096			600			496	
	65 to 79	9.70%	679	0.019	2.60%	424	0.6	**22.60%**	255	0.04
	80+	**25.80%**	186	0.002	5.10%	98	0.6	**46.00%**	88	<.001

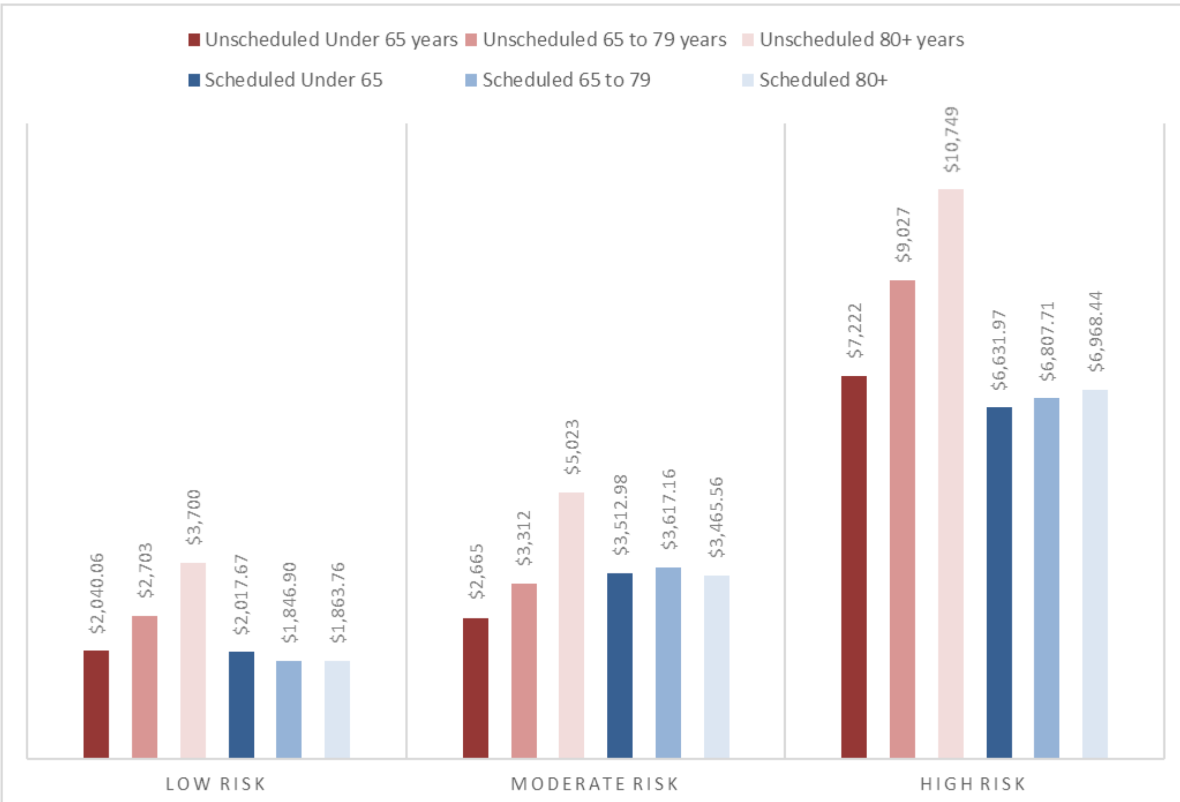
Table 4.4: Cost of surgical admission by age group, urgency and cost category compared to under 65 age group

		n	Cost OR supplies	% change from under 65 (p)	Cost OR salaries	% change from under 65 (p)	Cost pre-op inpatient	% change from under 65 (p)	Cost post-op inpatient	% change from under 65 (p)	Total cost	% change from under 65 (p)
Under 65 years	Scheduled	2618	$ 873		$ 963		$ 38		$ 1,620		$ 3,494	
	Unscheduled	3549	$ 585		$ 719		$ 381		$ 1,621		$ 3,306	
	Increased cost of unscheduled		-$ 288		-$ 244		$ 343		$ 2		-$ 187	
65-79 years	Scheduled	1459	$ 904	4% (.15)	$ 918	-5% (<.001)	$ 36	-7% (.62)	$ 1,911	18% (<.001)	$ 3,768	8% (.001)
	Unscheduled	655	$ 599	2% (.62)	$ 813	13% (<.001)	$ 672	76% (<.001)	$ 3,390	109% (<.001)	$ 5,473	66% (<.001)
	Increased cost of unscheduled		-$ 305		-$ 105		$ 636		$ 1,480		$ 1,705	
80 years and over	Scheduled	381	$ 687	-21% (<.001)	$ 796	-17% (<.001)	$ 52	36% (.69)	$ 1,886	16% (0.03)	$ 3,422	-2% (.64)
	Unscheduled	208	$ 576	-2% (.80)	$ 835	16% (<.001)	$ 651	71% (<.001)	$ 5,029	210% (<.001)	$ 7,091	114% (<.001)
	Increased cost of unscheduled		-$ 112		$ 39		$ 599		$ 3,143		$ 3,669	

Table 4.5: Subcategories of surgical admission cost by age group and urgency compared to under 65 age group divided by surgical risk

Risk	Age group	Urgency	n	Cost OR supplies	% change from under 65 (p)	Cost OR salaries	% change from under 65 (p)	Cost pre-op inpatient	% change from under 65 (p)	Cost post-op inpatient	% change from under 65 (p)
Low risk	Under 65 years	Scheduled	1258	$ 524		$ 864		$ 24		$ 609	
		Unscheduled	316	$ 368		$ 607		$ 270		$ 764	
		Increased cost of unscheduled		-$ 156		-$ 257		$ 246		$ 154	
	65-79 years	Scheduled	621	$ 463	-12% (<.001)	$ 747	-13% (<.001)	$ 23	-2% (0.85)	$ 610	0% (0.965)
		Unscheduled	57	$ 274	-26% (0.002)	$ 579	-5% (0.218)	$ 261	-3% (0.736)	$ 1,398	**83% (<.001)**
		Increased cost of unscheduled		-$ 189		-$ 168		$ 238		$ 788	
	80 years and over	Scheduled	206	$ 345	**-34% (<.001)**	$ 650	-25% (<.001)	$ 17	**-26% (0.033)**	$ 830	**36% (<.001)**
		Unscheduled	38	$ 274	**-26% (0.008)**	$ 684	13% (0.015)	$ 318	18% (0.478)	$ 2,375	**211% (<.001)**
		Increased cost of unscheduled		-$ 70		$ 33		$ 301		$ 1,545	
Moderate risk	Under 65 years	Scheduled	760	$ 927		$ 786		$ 29		$ 1,714	
		Unscheduled	2737	$ 565		$ 650		$ 341		$ 1,108	
		Increased cost of unscheduled		-$ 362		-$ 135		$ 312		-$ 606	
	65-79 years	Scheduled	414	$ 955	3% (0.465)	$ 733	-7% (<.001)	$ 42	**48% (0.002)**	$ 1,811	6% (0.254)
		Unscheduled	343	$ 503	-11% (0.08)	$ 726	12% (<.001)	$ 572	68% (0.098)	$ 1,524	**38% (<.001)**
		Increased cost of unscheduled		-$ 453		-$ 7		$ 529		-$ 287	
	80 years and over	Scheduled	56	$ 713	**-23% (0.002)**	$ 747	-5% (0.483)	$ 186	552% (0.254)	$ 1,840	7% (0.612)
		Unscheduled	76	$ 531	-6% (0.515)	$ 827	**27% (<.001)**	$ 531	**56% (0.002)**	$ 3,053	**175% (<.001)**
		Increased cost of unscheduled		-$ 181		$ 80		$ 345		$ 1,213	
High risk	Under 65 years	Scheduled	600	$ 1,534		$1,397		$ 82		$ 3,619	
		Unscheduled	496	$ 960		$1,099		$ 672		$ 4,491	
		Increased cost of unscheduled		-$ 574		-$ 298		$ 589		$ 872	
	65-79 years	Scheduled	424	$ 1,499	-2% (0.339)	$1,348	-4% (0.02)	$ 48	-41% (0.051)	$ 3,913	8% (<.001)
		Unscheduled	255	$ 800	-17% (0.004)	$ 981	-11% (<.001)	$ 899	**34% (<.001)**	$ 6,346	**41% (<.001)**
		Increased cost of unscheduled		-$ 699		-$ 366		$ 851		$ 2,433	
	80 years and over	Scheduled	98	$ 1,325	-14% (0.002)	$1,174	-16% (<.001)	$ 60	-27% (0.278)	$ 4,409	22% (<.001)
		Unscheduled	88	$ 713	**-26% (<.001)**	$ 921	-16% (<.001)	$ 955	**42% (<.001)**	$ 8,160	**82% (<.001)**
		Increased cost of unscheduled		-$ 612		-$ 253		$ 895		$ 3,751	

Figure 4.1: Admission cost (CAD) by age and surgical risk profile for planned and unplanned general surgical patients



Chapter 5: Frailty Predicts Increased Costs in Emergent General Surgery Patients: A Prospective Cohort Cost Analysis

Publication

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Author contributions

GE performed the data extraction, analysis and authored the manuscript. RK conceived of the original study design, supervised the overall EASE study and assisted with manuscript revision. JH-L, AW and RP all assisted with study development and provided editorial support. FC helped develop the initial study design, provided insight into the data analysis and cost analysis and helped revise the final manuscript. All authors approved the final manuscript.

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Abstract

Background

Aging populations have led to increasing numbers of seniors presenting for emergency surgery. Older patients are at higher risk of post-operative complications, prolonged hospitalization and increased institutionalization. We hypothesized that increased frailty would be a risk factor for increased healthcare costs in elderly surgical patients who have undergone emergency abdominal surgery.

Methods

A prospective cost analysis of emergency general surgery patients 65 and older was conducted. Demographic and clinical characteristics were obtained. Pre-admission Clinical Frailty Scale (CFS) score and Clavien-Dindo post-operative complications were collected. Patients were followed for 6 months following discharge. Hospitalization costs were calculated using the Alberta Health Services (AHS) microcosting database, other costs were obtained from AHS and Alberta Health databases. The primary outcome was total insured cost (2016 Canadian Dollars). Multivariate generalized linear regression of log-transformed costs was conducted.

Results

Overall, 321 patients were enrolled. Mean age was 76.1 years (Standard deviation [SD] 7.8), median CFS was 3, mean length-of-stay was 15.9 days (SD 23.4), 48% suffered a complication. Mean total insured cost was $33,752 and mean total cost was $40,638. Multivariate analysis found American Society of Anesthesiologists (ASA) score (Adjusted ratio [AR]=1.24, p=0.002), CFS (AR=1.27, p<.001), major (AR=2.01, p<0.001) and minor complications (AR=1.50, p<0001) lead to increased total insured costs.

Conclusion

Costs increased after adjusting for age, comorbidities and pre-admission function as frailty and ASA score increased and if minor or major complications occurred. The detection of frailty represents an opportunity to target risk reduction strategies and interventions to improve outcomes and decrease cost.

Introduction

A higher proportion of people in our population are surviving into very late life, resulting in a profound increase in the number of people presenting for surgery who are 65 years of age and older. Over the past 5 years (2011-2016) the number of Canadians over 65 has increased by 20%, four times the overall population growth rate and the largest increase in 70 years[84]. For the first time in Canadian history there are more people 65 years and older than under 15 years[84]. The cohort of Canadians over 65 is projected to grow to 24% of the populations by 2036[4] and by 2050, 22% of all North Americans are projected be over 65[73].

Healthcare spending represented 17% of the United States (US) gross domestic product (GDP) and 10% of Canadian GDP in 2014[13,78], these costs are expected to increase. Surgery is most commonly performed on people over the age of 65 – over half of all surgeries in the United States[40] – and represents a significant portion of healthcare spending[17]. Older patients are at higher risk of post-operative complications, prolonged hospitalization and increased dependency or institutionalization[74,75]. Surgical complications have been shown to increase both hospital and third-party payer costs per admission[11,85].

Reducing healthcare costs requires identification of patient characteristics that increase the risk for adverse outcomes and the associated increased health care costs, as well as identification of modifiable risk factors that might allow targeted interventions. Most cost prediction models do not sufficiently predict cost after surgery. Of six preoperative risk stratification tools used in cardiac patients, none reliably predicted costs after surgery[86]. All models relied on age and none incorporated frailty, which is defined as a poor physiological reserve limiting response to acute physiological insult. The presence of frailty has been shown, in a recent systematic review, to predict post-operative complications[87]. Post-operative complications also predict increased post-operative morbidity and mortality[1,2,5–8,88], in-hospital cost and costs following discharge[11,12,88].

We aim to identify risk factors for increased healthcare costs in elderly surgical patients who have undergone emergency abdominal surgery at one of two tertiary referral hospitals in Western Canada. Our study sites have enrolled patients into the Elder-friendly Approaches to the Surgical Environment (EASE) study[38] and have collected demographic, medical, and outcome data prospectively. We also have access to patient level inpatient microcosting data, along with ambulatory care, physician billing and patient expenses, that allows us to better develop risk assessment models to predict increased healthcare cost and to identify patient specific interventions that should be explored to improve outcomes.

Methods

Overview

Patients were prospectively enrolled in the EASE study (Pre-registered with clinicaltrials.gov: NCT02233153). The EASE study received approval from the University of Alberta Research Ethics Board (Pro00047180) and the University of Calgary Conjoint Research Ethics Board (REB140729). Briefly, patients 65 years and older undergoing emergency general surgery at one of two tertiary referral hospitals in Alberta, Canada were prospectively enrolled. Combined, the two centres have over 1,450 patient beds and over 1 million unique patient visits per year. Patients were enrolled between January 2014 and September 2015. Patients were excluded if they were transferred from another medical service, underwent elective or trauma surgery, had a Clinical Frailty Scale (CFS)[89] score greater than 6 or resided outside of Alberta.

Demographic and clinical characteristics were obtained through follow-up interviews and detailed chart reviews. Variables collected included demographic data, pre-admission living situation, Charlson comorbidity index, and discharge destination. Pre-operative frailty was assessed using the CFS based on their pre-admission functional status. Surgical intervention, length of stay (LOS), post-operative complications, and clinical outcomes were recorded in the EASE database. Complications were assessed by two independent clinicians and defined as minor (Clavien-Dindo 1-2) and Major (Clavien-Dindo 3-5). Patients were followed for 6 months following discharge from their index admission or until death.

Healthcare resource costing

Costs were obtained retrospectively with ethical approval (Pro00061609). Hospitalization costs were calculated using Alberta Health Services (AHS) microcosting database; a patient level costing database that provides total direct cost (nurses, doctors, drugs, etc.), indirect cost (overhead, transportation, electrical, etc.) and total cost per patient. The microcosting database records all hospital resource utilization including operating time and disposable medical products used by each patient. Microcosting is the gold standard for economic evaluations and is the most accurate method to measure healthcare cost[90]. When microcosting data were not available, admission costs were calculated using AHS Discharge Abstract Database (DAD) Resource Intensity Weighted (RIW) costing data multiplied by the Cost of a Standard Hospital Stay from the Canadian Institute of Health Information. Patients that were transferred to a sub-acute, rehabilitation or community hospital were noted in our EASE database. The cost of these admissions was included in the total cost of the index admission. If data were not available to calculate a cost category they were excluded from analysis of the sub-cost.

The cost of readmission was calculated using microcosting when it was available and RIW data when it was not. Patients missing from both the microcosting and DAD databases were assumed to be lost to follow-up and were excluded from the analysis. The EASE database readmission data were compared to our microcosting and DAD databases to find the number of readmissions that were unable to be costed. Average length of stay (LOS), average cost per admission and number of readmissions was also noted.

Drug costs were estimated based on the provincial Pharmaceutical Information Network (PIN). Prescriptions dispensed to each enrolled patient were recorded and costed. It was assumed that all patients were covered by the Alberta Blue Cross Coverage for Seniors Program. Medications covered by the Blue Cross Seniors Program were recorded as a government expense, less the required 30% co-payment to a maximum of $25 Canadian Dollar (CAD) per dispensed item. It was assumed that the plan only covered the least costly alternative. Chemotherapeutic drugs are fully covered within our jurisdiction; their cost was considered a government expense. Drugs that aren't covered were recorded as being paid by the patient. Drugs that are covered by the government were costed based on published provincial reimbursement rates[91], while uncovered drugs were assigned a price based on market rates. Linkage was performed by matching Drug Identification Numbers.

The cost of ambulatory care encounters, including emergency room visits, was calculated using RIW. All visits that occurred up to 6 months from index discharge were recorded. Physician claims was assessed using Alberta Health physician billing data. All physician visits from the index admission date to the end of the 6-month follow-up period were noted. Salaried physicians who were paid $0 were assigned the reimbursement rate published by the Alberta Health Care Insurance Plan[92,93] for the 2015/16 fiscal year. Physician costs were divided into index admission, readmission and outpatient billing categories and by billing service (surgical, medical, primary care).

The economic costs of lost employment or volunteer hours, care provided following discharge by family and friends, private nursing care, allied health and alternative care costs and medical products purchased by the patient were recorded using the validate Health Resource Utilization Inventory (HRUI)[94].

Statistical analysis and modeling

The primary outcome was total insured cost (costs covered by the single payer health insurance program) during the entire enrollment period. Costs were adjusted for inflation to 2016 CAD, which was valued at 1.34 CAD to 1 US Dollar on December 31, 2016. The distribution of demographic, clinical and cost data was assessed using means and standard deviation (SD) for continuous variables and count data for categorical variables. Data from both research sites were compared then pooled for analysis. Cost of index admission, readmission, physician billing, ambulatory care, prescription medical and costs identified with our HRUI along with total insured and total patient covered cost are presented as mean and SD despite non-normal distribution; this is the typical presentation of costs in economic analyses. Clinical and demographic characteristics were assessed in univariate analysis (Fisher's exact or Chi square tests for categorical variables and t-tests for continuous variables). Cost data were assessed for normality using skewness and kurtosis testing. When the cost distribution was non-normal, it was log transformed and reassessed.

Univariate generalized linear regression was used to assess the association of individual demographic and clinical variables with cost. Multivariate generalized linear regression was then used to model the effect on cost by the variables identified in univariate analysis. Regression outputs were back-transformed from logarithmic results into adjusted ratios (AR). Analyses were done in STATA 14 (StataCorp LP, College Station, TX, USA, 2016).

Results

Overall, 3 506 patients were screened. After assessing patients for exclusion and inclusion criteria 321 patients were enrolled. Mean age was 76.1 (Standard deviation [SD] 7.8), 55% were male, 26% were visible minorities and 72% were living independently before admission. Cohort demographic and clinical results are presented in Table 5.1. The median CFS was 3, mean Charlson Comorbidity Index (CCI) was 1.6, and ASA score was 3 or higher in 60% of patients. The most common surgical intervention site was intestinal (43%), mean length of stay was 15.9

days (SD 23.4), 45% suffered a minor complication, 15% suffered a major complication, 5% died during their index admission, and 34% were readmitted at least once during the 6-month follow-up.

Mean total insured cost was $33 752 CAD (Table 5.2); there was no significant difference in cost between sites (p=0.31). There were few differences between the two sites; Calgary had more visible minorities (p<0.001), more gallbladder procedures (p=0.03), fewer patients living independently before admission (p<0.001), lower ASA scores (p<0.001) and fewer ostomies were created (p=0.006). Overall, 106 patients were readmitted; mean cost for patients with all costs reported was $32 818 CAD per patient for inpatient care during readmissions. The public single payer insurance program covered 83% of the total costs that were measured.

Based on univariate modeling, CFS, age, CCI[95], ASA score[96], major complications, minor complications and the type of facility lived in before admission were included in the multivariate model. Body mass index, sex, marital status, visible minority, smoking status, study site and indwelling urinary catheter use following surgery were excluded based on univariate modelling. Multivariate analysis of log-transformed cost categories identified several significant drivers of cost (Table 5.3). The only significant driver of total prescription cost was CCI, which resulted in a 29% increased cost for each single unit increase in the CCI score (AR 1.29, p<0.001). ASA, CFS and both major and minor complications lead to increased costs in physician billing, index admission costs, total inpatient costs (including readmission) and total insured costs (Table 5.3). Major complications led to the largest single increase for physician billing (AR 1.49, p=0.003), index inpatient cost (AR 2.10, p<0.001), total inpatient cost (AR 2.12, p<0.001) and total insured cost (AR 2.01, p<0.001). However, for each increase in CFS score costs increased by an AR of 1.24 to 1.32 for physician billing, index and total inpatient costs, and total insured costs resulting to a larger total increase. The GLM model was unable to fit our measured ambulatory care cost. In the model of ambulatory care costs CCI was significant (AR 1.19, p=0.03), however the BIC was very high (-68) suggesting it did not fit well. Age and the patients' preadmission living circumstances (living independently, assisted living, or long-term care) did not significantly increase costs in any of the multivariate models; however, including them in the model did improve the fit and both were significant in univariate generalized linear regression models.

Mean total insured costs increased with frailty (Figure 5.1) along with physician billing, total index admission cost, total inpatient cost and total insured cost. Costs increased with frailty whether or not patients experienced minor or major complications. However, when a complication did occur, the resulting increase in costs was higher in patients with greater frailty (Table 5.4).

Discussion

We have conducted a cost analysis using the gold standard for costing healthcare expenditures and found that frailty, major and minor complications, and ASA score predict increased cost of care for elderly patients undergoing emergency general surgery. Development of a major complication led to the single largest increase in cost for patients, but the cumulative effect of increasing frailty led to a larger overall effect. In contrast, after controlling for complications, frailty, pre-operative living situation, ASA score and comorbidities, age itself did not significantly affect any of our cost models.

Frailty has been increasingly recognized as a significant source of morbidity and mortality in both medical and surgical patients. The use of the Clinical Frailty Scale (CFS) allowed rapid assessment, no additional training or equipment and correlates well with the much more labour intensive Frailty Index[89]. This study has examined the effect of frailty, using the CFS, on health care costs using a prospective cohort of emergency general surgical patients.

Previously, Bailey *et al* examined the relationship between inpatient cost with frailty, complications, and loss of independence in a similar population[97]. They identified a significant increase in cost with increasing Frailty Index, but only extensively explored the relationship between increased costs and complications and had a smaller sample size. Frailty appears to be the most significant driver of increased cost. In our study, total cost of inpatient care increased roughly 31% for each increase in frailty level after controlling for age, ASA score, complications, independent living and comorbidities. In fact, frailty predicted increased cost in all but two categories examined, prescription costs and ambulatory care visit costs. However, it may be that these outpatient costs are not well captured among the frailest patients given the fact that many reside and receive care in assisted living facilities.

The finding that costs increase with both frailty and complications is not surprising. However, this study is a unique analysis of prospectively collected gold standard patient costing data in a population at high probability for both inpatient and out-patient health care utilization. Like Bailey *et al*, this study found that age did not affect cost once adjusted for frailty, complications, comorbidities and pre-operative independence in any of our cost models. This suggests that age is less important than a patient's frailty status and medical condition before admission.

Robinson *et al* have examined frailty and cost following elective colorectal surgery[17]. Their costing technique was not as robust as that employed here and their sample size was much smaller, however they also identified the increased costs associated with increasing frailty. They also found that frailty in older people predicts increased complications[98] and increased post-operative institutionalization following surgery requiring post-operative intensive care admission[88].

Many studies have reported that increasing frailty predicted increasing complications [88,97,99]. Interestingly, this study found that costs increased with the degree of frailty regardless of whether or not the patient experienced a complication. Costs increases were larger when a complication occurred, but, even in the absence of any complication, this relationship held (Table 5.4). Targeted interventions focused on frail patients may help reduce the incidence of frailty-related health care complications and costs. Comprehensive Geriatric Assessment (CGA) has been used to assess and manage geriatric patients admitted with acute illnesses. A Cochrane review of acute medical admissions found that outcomes were improved with CGA[45]. Additionally, a systematic review by Eamer *et al* found that CGA improved outcomes and lowered costs in geriatric hip fracture patients[69].

Programs like the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) aim to improve outcomes through the reporting of performance results. ACS-NSQIP can also be used to calculate a modified Frailty Index (mFI), which is commonly used for research. However, not all fields required for calculating the mFI are currently mandatory data collection elements within ACS-NSQIP; in fact 5 of the 11 variables originally used to generate the mFI have been missing since 2012[100] limiting its usefulness. An updated mFI is under development, but it has not been validated in most surgical populations[101]. Reporting on quality identifies areas where modifying care may improve outcomes, but without implementing targeted interventions that actually result in improved care for those at highest risk, programs like ACS-NSQIP will not be optimally effective.

Finally, it is important to note that even though frailty increases with advancing age, when age and frailty were included in models, only frailty remained statistically significant. Most research examining elderly surgical patients, including large retrospective database studies, use age as a proxy for increasing frailty. This may not be an appropriate assumption. We have shown that frailty predicts increasing costs better than age and results in age not having a significant impact on our primary outcome. Tools should be developed to estimate frailty within large patient databases to allow better characterization of patient risk for research and risk prediction modeling.

Limitations

Our study is limited by several factors. First, preoperative assessment of frailty was only performed with one tool, the CFS. Therefore, the discriminatory strength of other commonly used assessment tools cannot be commented on. Second, the population studied is predominantly Caucasian in an urban setting. Applying our findings to more diverse populations may not be appropriate. Finally, not all our enrolled patients had microcosted index admissions. Some patients (n=61 of 318) were costed using a well described but less accurate technique based on RIW data. Most readmissions occurred at hospitals that required RIW costing, since only select hospitals in our jurisdiction have microcosting capabilities.

Conclusion

Frailty, post-operative complications and ASA score are important predictors of increasing cost of surgical care in the elderly. Total insured cost increases 27% for each increase on the CFS scale, additionally, a major complication led to a doubling of costs over 6 months of care. Identifying frailty and developing interventions specifically to address frailty status are critical to improving the care of our aging population and to contain our growing healthcare costs. Targeting frailty may also help reduce frailty-related post-operative complications, further reducing the cost of post-operative care.

Table 5.1: Demographic and clinical characteristics of enrolled patients

	All enrolled patients	
Patient demographics		
Total patients	321	
Age in years, mean (SD)	76.1	7.7
Sex, male	176	55%
Minority race	84	26%
Married	215	67%
Living independently prior to admission	231	72%
Clinical characteristics		
BMI, mean (SD)	27.1	6.1
CCI, mean (SD)	1.6	1.8
To regular ward post-op	274	85%
ASA 3 or higher	194	60%
Surgical site		
Appendix	35	11%
Pancreatobilliary	77	24%
Hernia	51	16%
Intestinal	138	43%
Stomach or rectum	8	2%
Other	3	1%
Ostomy created or revised	31	10%
Cancer/tumour	15	5%
Post-operative data		
Length of stay, mean (SD)	15.9	23.4
Major complication (Clavien 3-5)	48	15%
Minor complication (Clavien 1-2)	144	45%
Inpatient mortality	14	5%
6-month mortality	31	11%
Readmission within 6-months	100	34%

SD: Standard deviation, BMI: Body mass index, CCI: Charlson comorbidity index, ASA: American society of anesthesiologists
All data presented as n (%) unless otherwise stated

Table 5.2: Mean cost (Canadian dollars – 2016) for index admission, readmission, ambulatory care, physician billing, prescription, and total patient costs

	n	Mean	SD	IQR	
Index hospital cost	316	$ 31,143	$ 49,794	$ 10,641	$ 30,619
Index physician billing	306	$ 3,882	$ 5,441	$ 1,732	$ 4,068
Total index cost	306	$ 35,706	$ 55,415	$ 12,773	$ 35,070
Readmission hospital cost	106	$ 28,349	$ 27,680	$ 6,233	$ 29,402
Readmission physician billing	94	$ 3,301	$ 5,378	$ 755	$ 3,719
Total readmission cost	94	$ 32,818	$ 46,031	$ 7,726	$ 33,722
Total ambulatory care cost	287	$ 2,814	$ 5,288	$ 317	$ 2,857
Total physician billing	318	$ 5,563	$ 6,311	$ 2,358	$ 6,702
Total prescription cost	293	$ 2,186	$ 10,975	$ 186	$ 1,384
Total patient costs	297	$ 3,060	$ 8,090	$ 99	$ 1,866
Total insured cost	291	$ 33,752	$ 44,781	$ 11,407	$ 36,701
Total cost - all costs reported	98	$ 40,638	$ 46,795	$ 15,755	$ 50,456

SD: Standard deviation, IQR: Interquartile range
All costs in 2016 Canadian Dollars

Table 5.3: Generalized linear regression models for log-transformed sub-costs and total insured cost with adjusted ratios for log-transformed costs in Canadian dollars

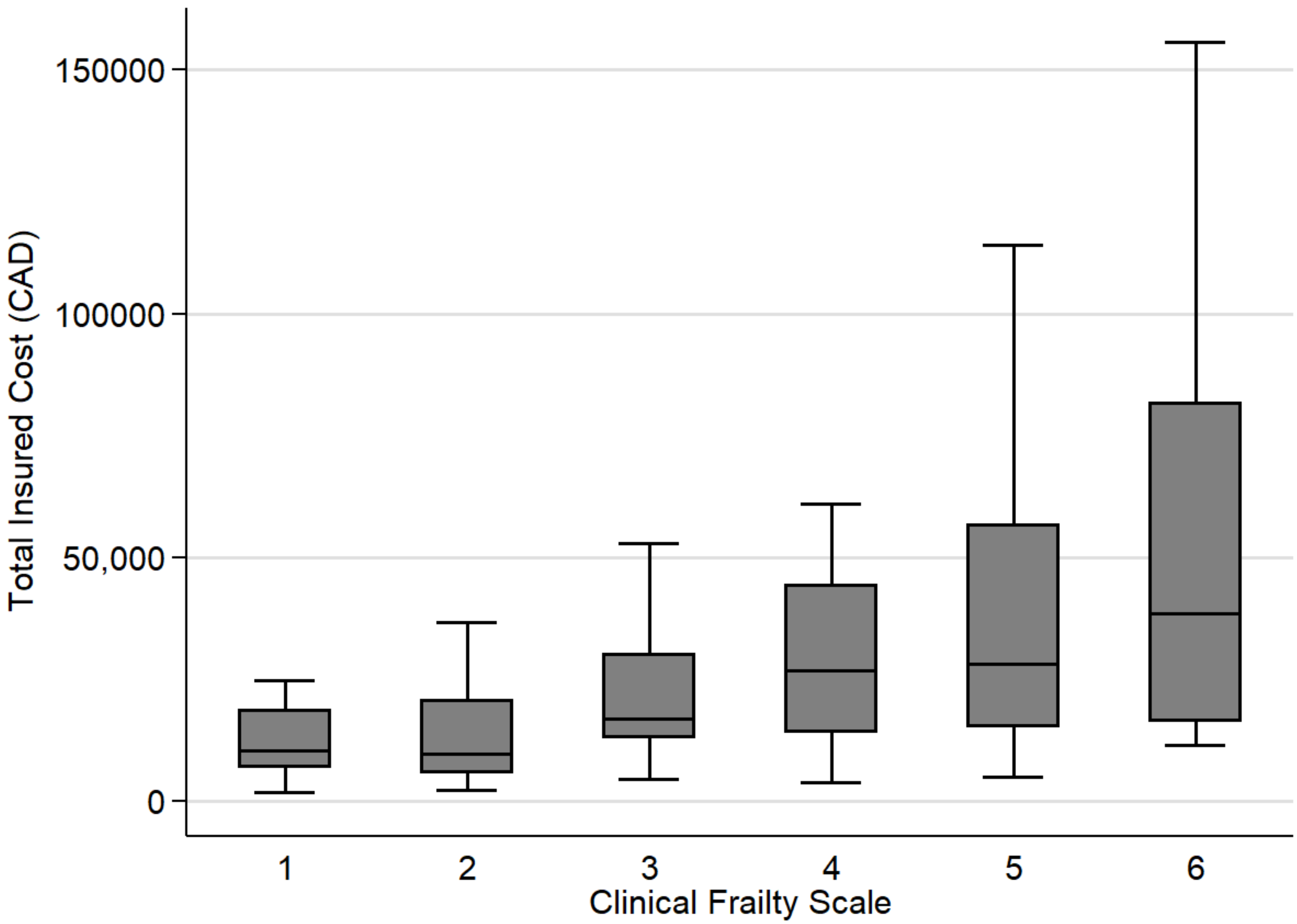
	Rx cost			Physician billing cost			Index inpatient cost			Total inpatient cost			Total government cost		
BIC	-837			-1575			-1665			-1524			-1445		
	AR	CI	p	AR	CI	p	AR	CI	p	AR	CI	p	AR	CI	p
Age	1.00	0.97 - 1.02	0.72	1.00	0.98 - 1.01	0.60	1.00	0.99 - 1.01	0.58	0.99	0.98 - 1.01	0.27	1.00	0.98 - 1.01	0.44
ASA	1.41	1.05 - 1.90	0.02	1.32	1.15 - 1.52	**<0.001**	1.30	1.18 - 1.44	**<0.001**	1.21	1.04 - 1.41	**0.01**	1.24	1.08 - 1.42	**0.002**
CCI	1.29	1.15 - 1.45	**<0.001**	1.05	0.99 - 1.11	0.08	0.99	0.95 - 1.03	0.64	0.97	0.91 - 1.03	0.32	1.03	0.97 - 1.08	0.32
CFS	1.00	0.83 - 1.20	0.98	1.13	1.04 - 1.24	**0.004**	1.16	1.09 - 1.24	**<0.001**	1.31	1.20 - 1.45	**<0.001**	1.27	1.17 - 1.38	**<0.001**
Major complication	0.62	0.33 - 1.17	0.14	1.49	1.14 - 1.95	**0.003**	2.10	1.72 - 2.55	**<0.001**	2.12	1.58 - 2.84	**<0.001**	2.01	1.51 - 2.68	**<0.001**
Minor complication	1.23	0.82 - 1.84	0.309	1.40	1.15 - 1.70	**0.001**	1.74	1.51 - 2.00	**<0.001**	1.62	1.31 - 2.00	**<0.001**	1.50	1.25 - 1.81	**<0.001**
pre-admission living	1.15	0.78 - 1.70	0.49	0.91	0.75 - 1.10	0.31	0.95	0.83 - 1.10	0.52	0.85	0.69 - 1.05	0.14	0.85	0.71 - 1.02	0.08

ASA: American Society of Anesthesiologists score, CCI: Charlson comorbidity index, CFS: Clinical frailty scale, Complications defined as minor (Clavien 1-2) and major (Clavien 3-5), BIC: Bayseian information criterion, AR: Adjusted ratio

Table 5.4: Total insured cost (Canadian dollars – 2016) by Clinical Frailty Scale score and complications

	No complication		Minor complication		Major complication	
Frailty	n	Insured cost	n	Insured cost	n	Insured cost
1	8	$ 9,441.70	7	$ 24,308.81	0	NA
2	36	$ 9,914.12	19	$ 22,839.03	7	$ 32,824.27
3	64	$21,048.82	42	$ 41,517.36	13	$ 72,371.28
4	26	$38,137.24	34	$ 41,860.36	9	$ 70,381.84
5	21	$27,394.05	20	$ 74,679.98	6	$ 168,679.00
6	12	$33,509.66	22	$ 73,171.88	13	$ 115,578.36

Figure 5.1: Total insured cost (Canadian Dollars – 2016) over 6-months by Clinical Frailty Scale score



Chapter 6 – Cost Analysis of Post-Discharge Costs Following Emergent General Surgery in the Elderly

Publication

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Author contributions

GE performed the data extraction, analysis and authored the manuscript. FC helped develop the initial study design, provided insight into the economic evaluation and helped revise the final manuscript. JP assisted with data cleaning, statistical analysis and manuscript revision. TC assisted with statistical analysis and supervised manuscript development and revision. RK conceived of the original study design, supervised the overall EASE study and assisted with manuscript revision. All authors approved the final manuscript.

Conference presentations

The work presented in Chapter 6 has been presented at Surgical congress 2016, Oct 16-20, 2016, Washington DC, USA by myself, at Academic Surgical Congress 2016, Feb 2-4, 2016, Jacksonville, FL, USA by RG Khadaroo and at General Surgery Research Day 2016, April 8, 2016 presented by myself.

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Abstract

Background

As populations age, more elderly patients will undergo surgery. Frailty and complications are considered to increase in-hospital cost in elders, but little is known on costs following discharge, particularly patient-borne cost. We examined risk factors for increased cost and the type of costs accrued following discharge in elderly surgical patients.

Methods

Acute abdominal surgery patients aged ≥65 years were prospectively enrolled at two Canadian hospitals. Baseline clinical characteristics were assessed, including the Clinical Frailty Scale (CFS). We calculated 6-month cost (CAD) from patient-reported use following discharge according to the validated Health Resource Utilization Inventory. Primary outcomes were 6-month overall cost and cost for healthcare services, medical products, and lost productive hours. Outcomes were log-transformed and assessed in multivariable generalized linear and zero-inflated negative binomial regressions and can be interpreted as adjusted ratios (AR).

Results

Patients (n=150) were of mean age 75.5±7.6 years; 54.1% were male and 10.8% had major and 43.2% had minor complications post-operatively. The median 6-month overall cost was $496 (IQR 140-1,948). Disaggregated by cost-type, frailty independently predicted increasing cost of healthcare services (AR: 1.50, 95% confidence interval [CI] 1.19-1.90, p=0.001) and medical products (AR: 1.61, CI 1.15-2.25, p=0.005), but decreasing cost in lost productive hours (AR: 0.39, p=0.002). Complications did not independently predict any cost category.

Conclusion

Frail patients accrued higher healthcare services and product cost, but lower cost from lost productive hours. Interventions in elderly surgical patients should consider patient-borne cost in the elderly and lost productivity in less frail patients. Trial registration: NCT02233153 (clinicaltrials.gov).

Introduction

In the developed world, the aging populations are increasingly in need of surgical interventions. Currently, 16% of Canadians are over the age of 65[3]. This is projected to grow to 24% by 2036[4]. By 2050, 22% of all North Americans will be over 65[73]. Healthcare spending represented 17% of the American gross domestic product (GDP) and 10% of Canadian GDP in 2014 [13,78]; not unexpectedly, costs are expected to increase as populations age. Improved medical technology, support and experience, and more aggressive surgical treatment criteria have allowed a greater number of elderly patients to become surgical candidates[1,2], with more frequent surgery on frail patients.

Older patients are at highest risk of post-operative complications, prolonged hospitalization and increased dependency or institutionalization[74,75]. Alongside increased system cost, patients may also require support in the home, home modifications, outpatient medications and caregiver support. These services may represent a significant burden for patients and their families.

Reducing both inpatient and post-discharge costs requires identification of high-cost patients and potentially modifiable risk factors. However, most cost prediction models do not sufficiently identify cost after surgery. Of 6 preoperative risk stratification tools used in cardiac patients, none reliably predicted costs after surgery[86]; all models relied on age and none incorporated frailty. None of the 6 tools assessed for differences in type of cost following discharge either.

Frailty, defined as a poor physiological reserve limiting response to acute physiologic insult, and post-operative complications have predicted increased post-operative morbidity and mortality[1,2,5–8,88], in-hospital cost and costs following discharge [11,12,88] and outpatient medical costs over 6-months[17]. However, incorporating the full economic impact following surgery may have better predictive strength. There has been only one examination of cost after surgical discharge that incorporated frailty in elderly patients[88] and none for older emergent surgery patients. To our knowledge, no such studies have assessed type of cost, including patient-borne cost following discharge.

Therefore, this study aimed to identify independent predictors of overall cost and types of costs accrued by older patients within 6 months following discharge after acute abdominal surgery. Overall costs included costs for healthcare services utilization, medical products, and productive hours lost. This information will be useful to physicians as they consider the financial burden experienced by their patients and attributes that may be associated with higher cost.

Materials and Methods

Population and Baseline Data Collection

This cohort includes patients enrolled before implementation of the Elder-Friendly Approaches to the Surgical Environment (EASE) study[38] (clinicaltrials.gov identifier: NCT02233153). In short, patients were prospectively recruited at two tertiary referral teaching hospitals in Alberta, Canada, with 1,450 inpatient beds combined and over 1-million unique patient visits per year (University of Alberta Hospital and Foothills Medical Centre). Patients were enrolled during index admissions between January 2014 to September 2015 if they required emergency abdominal surgery and were ≥65 years of age. Exclusion criteria were elective, trauma or palliative surgery, transfers from out-of-jurisdiction or other hospital services, and pre-operative dependence in ≥3 activities of daily living. Heath Research Ethics Boards at each site approved study procedures (Pro00047180). All study participants provided informed consent.

Demographics and clinical characteristics were collected by detailed chart review or during follow-up interviews. Variables includes the Charlson Comorbidity Index[95] and frailty before admission. Frailty was defined by the Canadian Study of Health and Aging Clinical Frailty Scale (CFS)[89] and in this cohort ranged from very-fit to moderately frail on the CFS. Major (Clavien 3-5) and minor (Clavien 1-2) post-operative complications, according to the Clavien-Dindo classification[102], were independently and blindly graded by two clinicians, with disagreement resolved by consensus. All-cause readmissions within 6-month of discharge were also sought and collected from provincial electronic medical database.

Outcomes

The primary outcome was 6-month overall cost including patient born cost, third-party insured costs and lost wages, in the 6-months following discharge after acute abdominal surgery. Costs were calculated based on a modified Health Resource Utilization Inventory (HRUI), previously validated elsewhere [94]. The HRUI includes patient-reported utilization of healthcare services (readmission, emergency room visits, and any allied health care provider interactions e.g., physician, nurses, physical therapists, acupuncturists), medical products used or purchased (e.g., walkers, ostomy supplies, diapers, wheelchairs), and productive hours (i.e., lost wages in paid employment or volunteering) within 6 months after discharge. Eye-glasses, dentures and hearing aids were considered unrelated to surgery and cost of these was excluded. Prescription medications for pain or sedation were additionally sought, as these are commonly prescribed upon surgical discharge, and were considered healthcare services. The HRUI was administered at the 6-month follow-up. Overnight care in rehabilitation programs or outpatient laboratory tests was not assessed. The study is conducted in a single-payer public health-care jurisdiction where inpatient rehabilitation programs and outpatient laboratory investigations costs are covered.

Cost of healthcare services, including medication, were calculated from reimbursement schemes by the Alberta Aids to Daily Living (AADL) program[103] or using market rates when required. Cost of physician or dental visits were based on published fee schedules[93,104,105] and allied health costs were based on local market rates. Costs for medical products were found from government[103] and commercial sources. Total productive hours lost in paid employment or volunteer were multiplied by the mean hourly wage ($29.27 CAD[106]) in Alberta[107]. Costs are reported in Canadian dollars (1 USD = 1.32 CAD) and are based on January 2016 reimbursement or market rates.

Statistical Analysis

Descriptive statistics was conducted. Study sites were compared and pooled for analyses. Clinical characteristics and cost categories were assessed in univariate analyses (Kruskal-Wallis tests for ordinal, Fisher's exact or X^2 tests for categorical, and t-tests for continuous variables). As cost data was skewed according to the Kolmogorov-Smirnov test, outcomes were log-transformed and on reassessment with the Kolmogorov-Smirnov test, log-transformation resulted in normal distribution for all 4 cost categories analyzed. Overall cost and healthcare services cost were analyzed using generalized linear regression (GLM)[108]. Cost for lost productive hours and medical product cost were analyzed using zero-inflated negative binomial (ZINB) regression, which accounts for excess zeros using a zero-inflated model followed by a nested negative binomial model[109,110]. The ZINB model was compared to a traditional negative binomial model using the Vuong test. GLM and ZINB models report beta-coefficients for log count of cost. Variables were sequentially added to models and kept if the p-value<0.20. Age and site was forced into each model.

To ease interpretation, beta-coefficients were inversely transformed and can be interpreted as adjusted ratios (AR). In sensitivity analyses, 6-month readmission was considered in models for medical products and productivity costs but not included elsewhere as readmission is part and parcel of the patient-reported healthcare services utilization. Model fit was assessed by the Bayesian information criterion (BIC), which penalizes for additional variables. Lower BIC indicates a more plausible model given the data. Outliers were retained within the models. Healthcare costs are driven by outliers which represent a disproportionate percent of overall expenditure. Removing outliers would results in excluding patients that use a sizable portion of the healthcare budget. Statistical significance was considered using a two-tailed p-value<0.05. Analyses were done in STATA 14 (StataCorp LP, College Station, TX, USA, 2016).

Results

Of eligible participants (n=308), 66 were unable or unwilling to participate; 242 enrolled. Thirteen patients died within 6-months of being enrolled, and 79 were lost to follow-up (Figure 6.1). Overall, 65.5% of enrolled participants who were alive at 6 months (n=150) completed 6-month assessments (Figure 6.1). The median age for patients was of 73.7 (range 65-96.5) years; 54.1% were male. Nearly all (93.9%) were living independently prior to admission and had a median CFS score of 3 (CFS range 1-6); 10.8% had major and 48% had minor complications post-operatively (Table 6.1). When comparing those who completed the survey and who were lost to follow-up, there was no difference in age, BMI, gender, marital status, ostomy creation, Charlson comorbidity index, ASA classification, pre-admission dementia diagnosis, post-operative complications or number of readmissions. Among those who were lost to follow-up, frailty was higher (p<0.001), length of stay was longer (p=0.01), and there were more visible minorities (p<0.001).

The mean 6-month overall cost was $3,921 (SD: $8,582, max: $48,893) and the median was $496 (interquartile range [IQR] $140-1948; Table 6.2). Stratified by frailty, patients deemed well (CFS=2), managing well (CFS=3) or mildly frail (CFS=5) had the lowest 6-month overall cost (Table 6.2). In multivariable analysis, increasing age predicted slightly decreasing overall cost (AR=0.95, p=0.04) while being admitted to the University of Alberta Hospital predicted a two-fold increase in overall costs (AR 2.14, p=0.02) within 6 months following discharge, after controlling for post-operative level of care, frailty, ASA Class, comorbidities and low BMI (Table 6.3).

In general, healthcare services accounted for the bulk of post-discharge costs ($138, IQR 65-332). Stratified by frailty, costs for healthcare services were greatest among the moderately frail group (CFS=6; Table 6.2). In multivariable analysis, one category increases in frailty independently predicted a 50% increase in healthcare services costs (AR 1.50, 1.19-1.90, p=0.001) within 6 months following discharge (Table 6.3).

Most patients did not accrue costs for medical products within 6 months (Table 6.2). Stratified by frailty, the cost of medical products was highest in moderately frail patients (CFS=6; Table 6.2). In multivariable analysis, increases in frailty independently predicted a 61% increase in cost for medical products (AR 1.61, 1.15-2.25, p=0.006); marital status, age, ostomy creation or modification, length of stay and site also predicted increased cost (Table 6.3).

Lost productive hours were analyzed using a ZINB model. The ZINB model fit our data significantly better than a negative binomial model (p=0.002 by Vuong test) and the log-transformed data was normally distributed by the Kolmogorov-Smirnov test after removing zeros. Most patients also did not accrue costs for lost productive (n=115 of 150) hours within 6 months (Table 6.2). Stratified by frailty, lost productivity was predominantly observed in very-fit (CFS=1) or well (CFS=2) patients but was seen in managing well (CFS=3) and vulnerable (CFS=4) patients as well (Table 6.2, Figure 6.2). In ZINB analysis, one category increases in frailty independently predicted a two-fold increase in probability that the patient was not working or volunteering before admission (AR 2.13, 1.38-3.30, p=.001, Table 6.3) and predicted decreased cost for lost productive hours for those who were working or volunteering before admission (AR 0.39, 0.21-0.71, p=0.002, Table 6.3). Male sex also independently predicted a more than two-fold increase in lost productive hours (2.28, 1.05-4.99, p=0.04, Table 6.3) within 6 months following discharge. Age also was associated with more often reporting no lost productive hours (1.11, 1.03-1.19, p=0.004, Table 6.3).

Sensitivity analyses

On additional assessment, all-cause 6-month readmission independently predicted increased cost for medical products but not cost for lost productive hours. Inclusion in the model improved fit (Table 6.4). Of note, univariate logistic regression of major complications did not identify significant interactions with overall cost, lost productive hours cost or healthcare services cost; only a 9% increase in medical product cost (p=0.002) was identified. Minor complications did not predict a change in any category.

Due to the high number of patients with no cost in the medical product cost category, we also performed a ZINB analysis. GLM regression is more appropriate analysis of this sort of cost data – all patients could experience this cost – but wanted to test the robustness of our findings. Increasing frailty remained a significant predictor of cost in those who experienced cost (AR 1.48, 1.24-1.77, p<0.001). Ostomy creation also predicted higher cost (AR 1.95, 1.05-3.63, p=0.03); increasing age and male gender () predicted lower cost. Increasing frailty (AR 0.60, 0.43-0.84, p=0.003) and age (AR 0.92, 0.87-0.97, p=0.002) also predicted a decreasing probability of experiencing no cost. Overall, the ZINB model fit much worse than the GLM model (ZINB BIC = 1268 vs. GLM BIC 110). Length of stay and marital status were not robust but the effect of frailty and ostomy creation remained large and statistically significant.

When minor or major complications were included in multivariate regression and ZINB models there was no significant interaction and the fit of each model was worsened when compared to our final models.

Discussion

Overview

Elderly surgical patients incur both system and patient-borne costs after discharge. Healthcare services cost account for the majority of post-discharge costs experienced by patients in our study since most patients did not experience costs for medical products or lost productivity within 6 months of discharge. The costs experienced by patients following discharge is dependent on their premorbid health state prior to surgery and clinical course. Frailty was associated with higher healthcare services utilization and higher medical product use. Increasing frailty predicted that patients were less likely to be working or volunteering before admission, however, increasing frailty in patients who had been working or volunteering before admission predicted lower cost of lost productive hours. Additionally, in those who were working or volunteering before admission, increasing age was associated with decreased cost from lost productivity. This is likely due to those who were older or more frail working fewer hours per week before admission which decreases the maximum economic loss they could experience if they were no longer able to work following discharge. This resulted in a non-linear distribution of cost. Patients with frailty scores of 1 and 6 experienced the highest mean costs.

Cost analysis of post-discharge costs typically account for direct medical costs while ignoring the wider economic impact of recuperation. The only other study to examine post-discharge costs in general surgery patients was in older elective colorectal surgery patients. It demonstrated that increased costs following discharge is associated with increasing frailty, as measured by an un-validated assessment of frailty domains[17]. Their study did not incorporate lost wages, use of complementary healthcare providers (massage, chiropractors etc.) or other disposable healthcare products used.

Overall cost was only significantly influenced by age. A 4% decrease in cost was associated with each year increase in age. This is likely a statistical error as there is a significant increase in medical product cost (9%) with age and a significant decrease in lost productive hours cost (5%). We have measured multiple different sources of cost which respond to our measured variables in different manners. Some of our measured cost categories increased with increasing frailty (medical products and healthcare services cost) and other measured variables while others decreased (lost productivity). This results in a non-linear relationship between frailty and total cost. Patients who are well (CFS 1) and those who are frail (CFS 6) experience higher cost than those who were in between. This results in frailty having no statistically significant influence on overall cost in our linear model and most predictors having no significant effect on overall cost.

Frail patients are more likely to be readmitted to hospital, resulting in increased emergency room utilization which is included in our healthcare services cost category. Overall, only frailty predicted increased cost after controlling for age, length of stay and other clinical factors. It predicted a significant increase in the cost of healthcare services. This is consistent with previous findings. Addressing frailty with targeted interventions may help reduce these costs.

Medical product cost was influenced by several factors. Ostomy creation resulted in a 5-fold increase in patients' medical product costs. After controlling for frailty, each additional day of admission and each year of life also resulted in a significant cost increase for patients. Moreover, in addition to being costly in its own right, hospital readmission may also be clinically important drivers of patient-borne costs, as readmitted patients may require additional medical products or require additional medical services.

Paid work and volunteering are treated as economically equivalent in economic analysis. As people age they become less likely to work, however volunteerism among the elderly remains quite common. Our analysis found that increasing age and frailty predicted decreased employment or volunteerism before the index admission. Conversely, younger and less frail patients experienced higher costs (up to $37,000) over 6-months. This is because those that worked or volunteered more hours before admission experienced a higher economic loss if they are unable to return to their work or volunteer activities following surgery.

Previous studies have demonstrated significant costs associated with inpatient care following post-operative complications[11,12]. However, we did not find a statistically significant relationship between major or minor complications in any cost category after controlling for age, frailty and other clinically relevant factors. This may be due to the increased risk of complications associated with increased age and frailty. Adding complications to the model may not add any explanatory power to the model beyond the variables already in the model.

Many of the factors we have identified that influence cost are not modifiable. However, identifying frailty allows for improved assessment and implementation of frailty specific care plans. The use of Comprehensive Geriatric Assessment (CGA) to evaluate seniors has been shown to improve outcomes in a Cochrane review of acute medical admissions[45]. A systematic review of economic evaluations of CGA in a surgical setting suggested CGA improved outcomes while reducing cost in hip fracture patients[69] and a Cochrane review of CGA in surgical patients is currently underway[81]. We are currently investigating the effect of CGA and an elder-friendly care program in an acute general surgery patient population[38] to see if we can improve outcomes is seniors with frailty.

Limitations

To our knowledge, this study is first to examine a range of costs, including lost wages, in elderly patients following discharge after emergent surgery. However, though we conducted in-depth assessment of patient-reported sources of cost after discharge using a validated questionnaire, data collection did not include overnight care in rehabilitation programs or outpatient laboratory tests. Moreover, despite lengthy enrolment, subgroup analyses are limited due to small sample size, as many patients declined questionnaires or were unavailable. It is possible that those with increased frailty and length of stay, as our non-responders did, were more likely to be transferred to higher-levels of care when costs would have been much higher and would result in making follow-up more difficult. This would result in our cost analysis generating conservative estimates for costs. We were also unable to assess cost associated with post-discharge mortality since our survey was conducted at the final follow-up for the survey or in patients who were conservatively managed by a surgical team since they did not meet our inclusion criteria. Further micro-costed analysis of all enrolled patients is planned when the EASE study is published. Despite collecting and assessing a comprehensive list of clinical and operative variables in-hospital, lower R^2 and BIC values suggest that much of the variation between costs results from factors not controlled for in our models. Finally, some of our cost subgroups have a small number of respondents who experienced a cost. This is commonly seen in cost analysis and has been controlled for within our analysis but does limit our results interpretability and may be a source of low R^2 in our models.

Conclusion

Understanding predictors and types of cost accrued following surgical discharge in older patients is important to sufficiently address rising healthcare expenditure and understand the economic impact of surgery in elderly patients. Previously, economic models to predict post-operative costs have mostly been unsuccessful[86]. Our findings will be useful to physicians and policy-makers as they consider the financial burden experienced by patients and attributes associated with higher cost. First, frailty should be considered in prediction models of post-discharge costs. Second, interventions designed to reduce perioperative morbidity, and consequently length-of-stay and readmission, should consider varying degrees of frailty and consider system costs as well as patient-borne costs in the elderly, including lost productivity. Last, this study highlights a need for further investigation on whether targeted interventions can reduce inpatient and post-discharge costs.

Figure 6.1: Flow diagram of study cohort

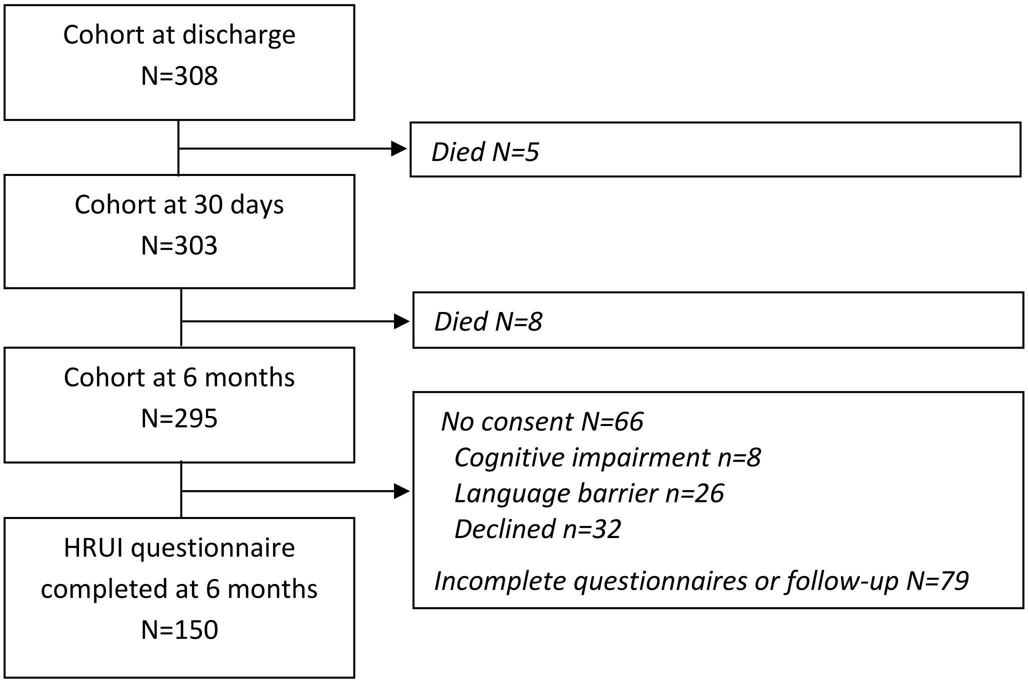

Figure 6.2: Overall and sub-category costs, according to frailty. Boxes represent the interquartile range while whiskers define 1.5 times the interquartile range. Outliers are indicated by symbols.

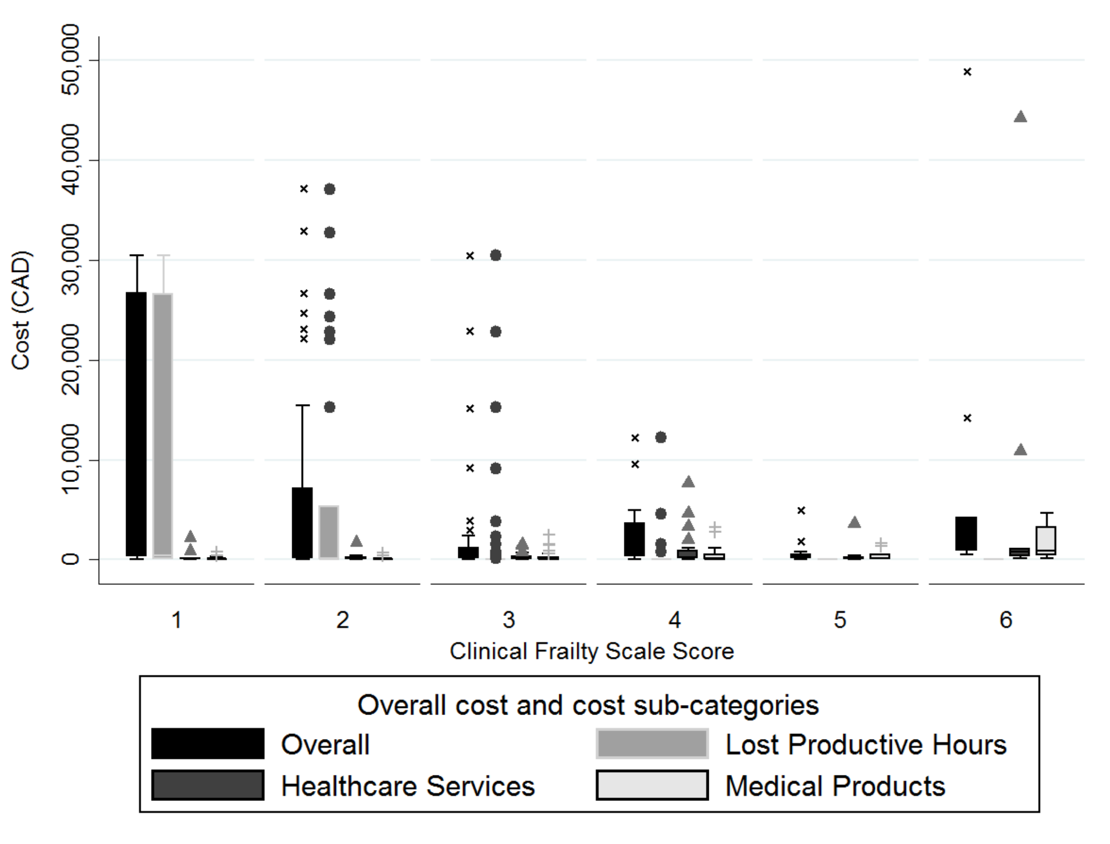

Table 6.1: Baseline characteristics

Table I: Baseline characteristics

Demographics	N=150 (%)
Age in years, mean ± SD	75.5 ± 7.6
Sex, male	81 (54.1%)
Minority race	18 (12.1%)
Married	113 (75%)
Living independently prior to admission	141 (93.9%)
Peri-operative characteristics	
Clinical Frailty Score, median (range)	3 (1-6)
Body Mass Index, mean ± SD	27.6 ± 5.9
Charlson Comorbidity Index, mean ± SD	1.0 ± 1.0
Post-operative recovery on regular ward	134 (89.2%)
ASA ≥3	87 (58.1%)
Type of Surgery	
Appendix	21 (14.2%)
Gallbladder/biliary tree	39 (25.7%)
Hernia	33 (22.3%)
Intestinal	63 (41.9%)
Stomach or Rectum	7 (4.7%)
Other	23 (15.5%)
Ostomy created or revised	16 (10.8%)
Post-operative characteristic	
Length of stay until ready for discharge, mean ± SD	10.3 ± 9.1
Mean Length of stay, mean ± SD	11.0 ± 10.4
Clavien-Dindo 1-2	64 (43.2%)
Clavien-Dindo 3-5	16 (10.8%)
Number of readmissions within 6 months	41 (27.3%)

Footnotes:
[a]ASA: American Society of Anesthesiologists Physical Status Classification; SD: standard deviation.
*Values indicate n (%) unless otherwise specified.

Table 6.2: System and patient borne costs (CAD, 2016) within 6 months of discharge, according to frailty

Table II: System and patient borne costs within 6 months of discharge, according to frailty

Outcomes	Cost for cohort; median (IQR) N=150	Range	Cost for patients in each Clinical Frailty Score category; median (IQR, max) 1 n=12	2 n=34	3 n=55	4 n=26	5 n=14	6 n=9	*p*
Overall Cost	496 (140-1948)	40-48893	1094 (301-26656, 30441)	300 (96-7084, 37231)	358 (115-1124, 30441)	878 (308-3632, 12267)	196 (96-541, 4990)	1343 (913-4189, 48893)	0.01
Healthcare services	138 (65-332)	0-44232	90 (40-2144, 2144)	93 (40-196, 1712)	115 (65-329, 1532)	266 (129-859, 7639)	90 (40-212, 3627)	828 (331-1063, 44232)	<0.001
Medical products	0 (0-371)	0-4661	0 (0-150, 746)	0 (0-85, 679)	0 (0-230, 2489)	0 (0-484, 3267)	85 (0-457, 1630)	885 (417-3279, 4661)	<0.001
Lost productivity	0 (0-0)	0-37100	0 (0-26636, 30441)	0 (0-5327, 37100)	0 (0-0, 30441)	0 (0-0, 12176)	0 (0-0, 0)	0 (0-0, 0)	0.002

Footnotes:
*Results are reported as median (interquartile range, max) unless otherwise specified.
⊥All costs are reported in Canadian dollars (2016).

Table 6.3: Total and subgroup cost 6 months following discharge

Table III: Total and subgroup cost 6 months following discharge				
Covariate	**Adjusted Ratio**	**95% CI**	***p***	**Measure of Fit**
Healthcare services, N=150	**Generalized linear model**			
Age (per 1 year increase)	0.98	0.95-1.02	0.39	BIC[a] = -326
Clinical Frailty Scale (per 1-pt increase)	1.50	1.19-1.90	0.001*	
Length of stay (per 1 day increase)	1.03	0.99-1.06	0.10	
Ostomy creation or modification	2.17	0.88-5.33	0.09	
High acuity bed post-operatively	0.69	0.42-1.14	0.15	
Medical Products, N=150	**Generalized linear model**			
Age (per 1 year increase)	1.09	1.04-1.15	0.001*	BIC = 110
Clinical Frailty Score (per 1-pt increase)	1.61	1.15-2.25	0.006*	
Length of stay (per 1 day increase)	1.06	1.02-1.11	0.003*	
Married	0.35	0.15-0.83	0.02*	
Ostomy	5.36	1.47-19.44	0.002*	
Lost productive hours, N=150	**Zero-inflated Model (chance patient is certain zero?)**			
Age (per 1 year increase)	1.11	1.03-1.19	0.004*	BIC = 1
Charlson Comorbidity Index (per 1-pt increase)	0.79	0.50-1.23	0.30	
Clinical Frailty Score (per 1-pt increase)	2.13	1.38-3.30	0.001*	
Nested negative binomial regression (cost if working before admission)				
Age (per 1 year increase)	0.95	0.88-1.02	0.12	
Clinical Frailty Score (per 1-pt increase)	0.39	0.21-0.71	0.002*	
High acuity bed post-operatively	2.13	0.996-4.54	0.05	
Sex, male	2.28	1.05-4.99	0.04*	
Overall cost, N=150	**Generalized linear model**			
Age (per 1 year increase)	0.96	0.92-0.999	0.04*	BIC = -198
ASA[b] Classification (per 1-pt increase)	0.59	0.34-1.03	0.06	
Charlson comorbidity index (per 1-pt increase)	1.29	0.93-1.79	0.12	
Clinical Frailty Score (per 1-pt increase)	1.06	0.80-1.40	0.69	
High acuity bed post-operatively	1.71	0.97-4.08	0.06	

Footnotes:

[a]ASA: American Society of Anesthesiologists; BIC: Bayesian information criterion; CI: confidence interval.

[b] Lower BIC values indicate better model fit.

*indicates statistical significance with a p-value<0.05.

⊥Age and location were forced into each model.

Table 6.4: Estimated total and subgroup cost 6 months following discharge with readmission

Table IV: Estimated total and subgroup cost 6 months following discharge with readmission				
Covariate	**Adjusted Ratio**	**95% CI**	***p***	**Measure of Fit**
Medical Products, N=150	**Generalized linear model**			
Age (per 1 year increase)	1.09	1.03-1.15	0.003*	BIC = 72
Clinical Frailty Score (per 1-pt increase)	1.45	1.03-2.06	0.04*	
Length of stay (per 1 day increase)	1.07	1.03-1.12	0.001*	
Married	0.35	0.15-0.84	0.02*	
Ostomy creation or modification	3.59	0.97-13.26	0.055	
Readmitted at least once in 6 mo. of discharge	3.34	1.36-8.22	0.009*	
Lost productive hours, N=150	**Zero-inflated Model (chance patient is certain zero?)**			
Age (per 1 year increase)	1.11	1.03-1.19	0.004*	BIC = 5
Charlson Comorbidity Index (per 1-pt increase)	0.79	0.50-1.23	0.3	
Clinical Frailty Score (per 1-pt increase)	2.13	1.38-3.30	0.001*	
Nested negative binomial model (cost if working before admission)				
Age (per 1 year increase)	0.94	0.88-1.01	0.11	
Clinical Frailty Score (per 1-pt increase)	0.42	0.22-0.79	0.007*	
High acuity bed post-operatively	2.25	0.99-5.11	0.05	
Readmitted at least once in 6 mo. of discharge	0.75	0.32-1.76	0.51	
Sex, male	2.29	1.06-4.98	0.04*	

Footnotes:

[a]BIC: Bayesian information criterion; CI: confidence interval.

[b]Lower BIC values indicate better model fit.

*indicates statistical significance with a p-value<0.05.

⊥Age and location were forced into each model.

Chapter 7: Conclusion

Overview of findings

The overall purpose of this thesis has been to examine the relationship between surgical interventions and economic outcomes in senior citizens undergoing surgical interventions. The secondary objective was to try to identify modifiable factors that could be targeted to reduce the cost of care or improve outcomes for this vulnerable population. To that end, I have undertaken several different studies to evaluate the effects of frailty, aging, and other clinical variables on outcomes and cost in elderly surgical populations.

Two systematic reviews were undertaken. The first assessed Comprehensive Geriatric Assessment (CGA) in surgical populations who were 65 and older. The primary outcomes were mortality and return to pre-admission level of function. Secondary outcomes were cost, length of stay, readmission and post-operative complications. Studies were excluded if they did not perform a CGA, they included patients under 65, the patients did not receive a surgical intervention, they were not admitted to an acute care hospital or they were not a randomized controlled trial. A Cochrane approved sensitive search strategy was employed, which identified nearly 15,000 articles to screen, from which 8 studies were included in the systematic review. Two authors reviewed all identified articles, performed bias assessment, extracted data and assessed the certainty of evidence.

Seven of the eight studies identified were in an orthogeriatric population (hip fracture) and one was in an elective surgical oncology population. Hip fracture studies were pooled and had a trend towards decreased mortality in the CGA arm and a significant improvement in discharge disposition. This means fewer people in the CGA arm were discharged to higher levels of care such as assisted living or long-term care. Length of stay was not statistically significant when all 5 studies that reported this outcome were pooled, however Prestmo *et al* reported that their CGA arm had a slightly longer length of stay but few patients required transfer to rehabilitation hospitals. They did not report cumulative length of stay that included the rehabilitation admission length. Consequently, we re-assessed length of stay with Prestmo *et al* removed; there was a significant decrease on length of stay in the CGA arm in the remaining 4 studies. Complications were reported by three studies, but due to the way they were reported, only two could be pooled. There was a significant reduction in complications when assessed with a fixed effect model, but this did not persist when a random effects model was used. Cost was reported by one study, while they did not find a significant decrease in cost, bootstrapping analysis suggested CGA was the economically dominant choice.

Because only one high quality study reported cost in our first review, we performed a second systematic review. This review again assessed CGA in surgical patients, however our primary outcome was cost and we excluded studies that did not report an economic outcome. We did not limit our study based on study quality, but did exclude studies that reported outcomes for non-surgical patients, included patients under 65 or did not complete a CGA. Our secondary outcomes were length of stay, return of premorbid function and mortality. A systematic search was conducted by a trained librarian; article screening, bias assessment, data extraction and economic evaluation quality assessment were performed independently by two authors. We identified 560 articles from which 8 studies were included. Only one study included in this review was included in the first systematic review. One study was in a non-orthopedic trauma population while the remaining 7 were in an orthogeriatric population.

Bias assessment revealed moderate to high risk of bias in all studies. There were two studies of high economic quality, four were of moderate quality and two were of low quality. Costs were decreased in the CGA arm in all 8 studies. Pooling of cost results was not performed due to the inherent challenges of adjusting for inflation, variation in currency valuation and differing techniques used for costing healthcare expenditures. Pooled analysis of the secondary outcomes in the orthogeriatric studies found significant decreases in length of stay, loss of function and mortality. This suggests pooled analysis has found CGA improves outcomes in a cost-effective manner. It cannot, however, prove CGA will be cost effective in other surgical populations.

Defining the distribution of cost by age is important to know before assessing a specific patient population. Assessment of the distribution of costs experienced within our health region by seniors compared to those under 65 was conducted along with a comparison of costs for scheduled and unscheduled procedures. A retrospective analysis of all inpatient general surgical procedures performed at the University of Alberta Hospital, Royal Alexandra Hospital, Misericordia Community Hospital and Grey Nuns Community Hospital over two fiscal years (2014/15 and 2015/16) was conducted. The data that was obtained was prospectively collected in a costing database operated by a private third party in four of the Edmonton zone's five major hospitals. Pooled analysis of mean cost by procedure from each of the four included hospitals was performed. Means were separate based on age groups (17-64, 65-79 and 80+), urgency (elective vs. unscheduled), and cost accrual timing (pre-operative, intra-operative and post-operative). Surgical procedures were divided into low, moderate and high risk.

There were 12,070 procedures included, representing 84% of all inpatient general surgical procedures in the region. Average cost was $4,351 for scheduled admissions and $4,054 for unscheduled admission. Only unscheduled admission costs were significantly increased in the older age cohorts. Costs more than doubled in the 80+ cohort for unscheduled surgery who underwent low and moderate risk procedures. This may suggest screening elective surgical patients allows effective medical optimization for those at increased risk resulting in decreased admission costs and that those at highest risk are being diverted to non-operative management.

To assess the cost of care, patients were prospectively enrolled in the EASE study while costs were obtained retrospectively. Hospitalization costs were calculated using Alberta Health Services (AHS) microcosting database, which allows patient level cost analysis, the gold standard in health economics. The primary outcome was total government cost (costs covered by the government health insurance program) during the entire enrollment period. Costs were adjusted for inflation to 2016 Canadian Dollars (CAD). Univariate generalized linear regression was used to assess the association of individual demographic and clinical variables with cost. Multivariate generalized linear regression was then used to model the effect on cost by the variables identified in univariate analysis.

Examination of individual level cost data including microcosted data, in AHS databases costs identified frailty, post-operative complications and ASA score as important predictors of increasing cost of surgical care in the elderly. Total insured cost increases 27% for each increase on the CFS scale, additionally, a major complication led to a doubling of costs over 6-months of care. Identifying frailty and developing specific interventions, such as CGA, are critical to improving the care of our increasingly large elderly population and to tame our growing healthcare costs.

Finally, examination of costs that patients accrue following discharge was performed. Using the validated Health Resource Utilization Inventory (HRUI), the cost that patients experience following discharge from acute abdominal surgery was assessed. The patients were enrolled as part of the Elder-friendly Approaches to the Surgical Environment (EASE) study in Edmonton and Calgary. Patients were excluded if they underwent non-operative management, were under 65, were dependent on others for more than two activities of daily living or were admitted for a trauma. Enrolled patients were followed for 6-months following discharge. The HRUI was administered at the final follow-up and gathers patient-reported resource use since discharge including medications, healthcare services and lost employment or volunteer hours (lost productive hours). Costs were calculated from the responses, log transformed to normalize distributions and then regression analysis was performed.

The HRUI was completed by 150 patients with a median 6-month total cost of $496 (Interquartile range $140-1,948). The cost experienced by patients were highly skewed. Generalized linear regression models were used for most cases, and when excess zeros were present zero-inflated negative binomial analysis was used. Frailty independently predicted increasing cost of healthcare services and medical products but predicted decreased cost from lost productive hours. When exploring the data further, we found that as frailty increased, fewer people were working and those that were working were working fewer hours. This meant there was a lower maximum cost ceiling for higher frailty patients. Additionally, complications did not independently predict costs for any category. Interventions in the elderly should consider patient born costs and lost productivity in less frail patients.

Summary of findings and future research

This thesis has sought to present a roadmap to improving the care of elderly surgical patients. The aging baby-boom generation will increasingly need surgical interventions over the coming decades. If we do not change current surgical practice, we risk ever increasing costs for surgical care and continued poor outcomes for this vulnerable population.

Both systematic reviews have identified CGA as a tool to improve outcomes in this population when they undergo surgical repair of hip fractures. There is not enough evidence yet to say whether CGA will be similarly beneficial in other surgical populations or if it will be beneficial in elective surgical settings. They do however highlight a promising direction of future research. CGA has been shown to be effective at reducing morbidity and mortality in both acute medical and orthopedic admissions, and we have also shown that it is cost effective in orthopedic trauma patients. Implementation of CGA in other surgical populations may lead to a similar reduction in morbidity and mortality. One clinical parameter assessed by CGA is frailty; management of frailty is an important component of the care plan developed by the geriatricians during CGA. This suggests that frailty is a reasonable target for intervention to improve outcomes.

Our analysis of the cost of surgical care within the Edmonton region suggests that the best target for cost reduction is seniors admitted for non-elective procedures. Our finding that the cost of care, after adjusting for surgical risk, is no different between younger and older patients suggests current screening and optimization may already be having some effect. Screening is not possible in unscheduled surgery; developing assessment tools to identify and treat those at increased risk who are presenting for unscheduled surgery is critical. CGA is one such tool. Despite a reasonable correlation between age and frailty, many studies of frailty versus age as a predictor of outcomes and cost have found frailty to be superior. Additionally, increasing frailty has been shown to lead to increased cost of surgical care in several small studies. The EASE study is examining CGA in the unscheduled general surgery population. Analysis of total government costs accrued by patients in the EASE study found that, after adjusting for age, pre-operative independence, complications and ASA, there was a significant increase in cost associated with increasing frailty. Additionally, patients continue to accrue higher healthcare services cost and out-of-pocket or insured medical product cost following discharge as frailty increases.

Overall, we have found that CGA is a cost-effective intervention in unscheduled orthogeriatric patients and that elderly patients presenting for unscheduled general surgery are at increased risk of high post-operative care costs. Additionally, we have shown that inpatient, total government, post-discharge healthcare services and post-discharge medical product costs are all increased with higher frailty in a prospective elderly acute general surgery population. Examining CGA in these patients, and implementing a program of CGA if it is proven to be effective, is critical to improve the sustainability of our single-payer public healthcare system.

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Appendix

Chapter 2

1. Geriatric Assessment/
2. geriatric assessment*.tw,kf.
3. Health Services for the Aged/
4. or/1-3
5. comprehensive health care/
6. Patient Care Planning/
7. Progressive Patient Care/
8. patient care team/
9. patient-centered care/
10. "delivery of health care, integrated"/
11. or/5-10
12. (frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or (old* adj (people or person* or resident* or adult* or patient*))).tw,kf.
13. 11 and 12
14. limit 11 to "all aged (65 and over)"
15. 4 or 13 or 14
16. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (assess* or evaluat* or apprais* or function or functioning or comprehensive* or patient care team or patient* education or interprofession* or inter-profession* or interdisciplin* or inter-disciplin* or multi-disciplin* or multidisciplin* or rehab*)).tw,kf.
17. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (manage* care program* or Critical Pathway* or Program* Evaluation or case manag*)).tw,kf.
18. (geriatric adj3 (evaluation or management or program* or modif* or friendly or intervention or coordinat* or co-ordinat*)).tw,kf.
19. (elder* adj3 (program* or modif* or friendly or intervention* or coordinat* or co-ordinat*)).tw,kf.
20. or/16-19
21. 15 or 20
22. exp Specialties, Surgical/
23. exp surgical procedures, operative/
24. su.fs.
25. Surgery Department, Hospital/
26. perioperative care/ or intraoperative care/ or perioperative nursing/ or postoperative care/ or preoperative care/
27. Trauma Centers/ or General Surgery/
28. (((surgery or surgical) adj (unit* or department* or area*)) or (operating adj (room* or theatre* or theater* or suite*))).mp.
29. (surgery or surgical or trauma or operation or operating or operative).ti.
30. (surgery or surgical or trauma or operation or operating or operative).kf.
31. (surgery or surgical or trauma or operation or operating or operative).ab. /freq=2

32. (perioperative or peri operative or intraoperative or intra operative or postoperative or post-operative).ti,ab,kf.
33. or/22-32
34. (surgery or surgical or trauma or operation or operating or operative).mp.
35. hospital*.mp.
36. 34 and 35
37. 33 or 36
38. (acute care for elders or acute care for the elderly or Nurses Improving Care for Healthsystem Elders or modified Hospital Elder Life Program or mHELP or hospitali?ed elder life program*).tw,kf.
39. (geriatrician* or geriatric specialist* or geriatric nurse* or geriatric physician*).tw,kf.
40. (geriatric unit* or geriatric ward*).tw,kf.
41. 39 or 40
42. 37 and 41
43. 21 and 37
44. geriatric trauma*.mp.
45. 42 or 43 or 44
46. randomized controlled trial.pt.
47. controlled clinical trial.pt.
48. multicenter study.pt.
49. pragmatic clinical trial.pt.
50. (randomis* or randomiz* or randomly).ti,ab.
51. groups.ab.
52. (trial or multicenter or multi center or multicentre or multi centre).ti.
53. (intervention? or effect? or impact? or controlled or control group? or (before adj5 after) or (pre adj5 post) or ((pretest or pre test) and (posttest or post test)) or quasiexperiment* or quasi experiment* or pseudo experiment* or pseudoexperiment* or evaluat* or time series or time point? or repeated measur*).ti,ab.
54. non-randomized controlled trials as topic/
55. interrupted time series analysis/
56. controlled before-after studies/
57. or/46-56
58. exp animals/
59. humans/
60. 58 not (58 and 59)
61. review.pt.
62. meta analysis.pt.
63. news.pt.
64. comment.pt.
65. editorial.pt.
66. cochrane database of systematic reviews.jn.
67. comment on.cm.
68. (systematic review or literature review).ti.
69. or/60-68
70. 57 not 69
71. 45 and 70

72. remove duplicates from 71

Chapter 3

MEDLINE Search

1. Geriatric Assessment/
2. geriatric assessment*.tw,kf.
3. Health Services for the Aged/
4. or/1-3
5. comprehensive health care/
6. Progressive Patient Care/
7. patient-centered care/
8. "delivery of health care, integrated"/
9. or/5-8
10. (frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or (old* adj (people or person* or resident* or adult* or patient*))).tw,kf.
11. 9 and 10
12. limit 9 to "all aged (65 and over)"
13. 4 or 11 or 12
14. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (assess* or evaluat* or apprais* or comprehensive* or patient care team or patient* education or interprofession* or inter-profession* or interdisciplin* or inter-disciplin* or multi-disciplin* or multidisciplin* or rehab*)).tw,kf.
15. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (manage* care program* or Critical Pathway* or Program* Evaluation or case manag*)).tw,kf.
16. (geriatric adj3 (evaluation or management or program* or modif* or friendly or intervention or coordinat* or co-ordinat*)).tw,kf.
17. (elder* adj3 (program* or modif* or friendly or intervention* or coordinat* or co-ordinat*)).tw,kf.
18. or/14-17
19. 13 or 18
20. exp Specialties, Surgical/
21. exp surgical procedures, operative/
22. su.fs.
23. Surgery Department, Hospital/
24. perioperative care/ or intraoperative care/ or perioperative nursing/ or postoperative care/ or preoperative care/
25. Trauma Centers/ or General Surgery/
26. (((surgery or surgical) adj (unit* or department* or area*)) or (operating adj (room* or theatre* or theater* or suite*))).mp.
27. (surgery or surgical or trauma or operation or operating or operative).ti.
28. (surgery or surgical or trauma or operation or operating or operative).kf.
29. (surgery or surgical or trauma or operation or operating or operative).ab. /freq=2

30. (perioperative or peri operative or intraoperative or intra operative or postoperative or post-operative).ti,ab,kf.
31. (orthop?edic or orthogeriatric).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]
32. or/20-31
33. (surgery or surgical or trauma or operation or operating or operative).mp.
34. hospital*.mp.
35. 33 and 34
36. 32 or 35
37. (acute care for elders or acute care for the elderly or Nurses Improving Care for Healthsystem Elders or modified Hospital Elder Life Program or mHELP or hospitali?ed elder life program*).tw,kf.
38. (geriatrician or geriatric specialist* or geriatric nurse* or geriatric physician*).tw,kf.
39. (geriatric unit* or geriatric ward*).tw,kf.
40. 38 or 39
41. 36 and 40
42. 19 and 36
43. 41 or 42
44. exp Economics/
45. value of life/
46. Quality-adjusted life years/
47. models, economic/
48. markov chains/
49. monte carlo method/
50. decision tree/
51. ec.fs.
52. economic*.ti,kf.
53. economic*.ab. /freq=2
54. (economic evaluat* or economic analys* or economic study or economic studies or economic assess* or economic consequence*).mp.
55. (cost? or costing? or costly or costed).ti,kf.
56. (cost? or costing? or costly or costed).ab. /freq=2
57. ((cost-benefit or benefit-cost or cost effectiv* or cost utility) adj2 (analys* or evaluat* or assess* or study or studies or ratio*)).mp.
58. (cost minimization or cost minimisation or cost consequence* or cost offset*).mp.
59. ((cost or costs) adj2 analys*).mp.
60. ("cost of illness" adj4 (analys* or evaluat* or assess* or study or studies or framework*)).mp.
61. (price? or pricing?).tw.
62. (pharmacoeconomic? or (pharmaco adj economic?)).tw,kf.
63. budget*.tw,kf.
64. expenditure*.tw,kf.
65. (value adj1 (money or monetary)).tw,kf.
66. (fee or fees).tw,kf.
67. "Quality adjusted life year*".tw,kf.
68. qaly*.tw,kf.

69. cba.tw,kf.
70. cea.tw,kf.
71. cua.tw,kf.
72. markov*.tw,kf.
73. monte carlo.tw,kf.
74. (decision adj2 (tree* or analys* or model*)).tw,kf.
75. or/44-74
76. 43 and 75

EMBASE Search

1. geriatric assessment/
2. geriatric assessment*.tw,kw.
3. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (assess* or evaluat* or apprais* or comprehensive* or patient care team or disability evaluation or patient* education or interprofession* or inter-profession* or interdisciplin* or inter-disciplin* or multi-disciplin* or multidisciplin* or rehab*)).tw,kw.
4. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (manage* care program* or Critical Pathway* or Program* Evaluation or case manag*)).tw,kw.
5. (geriatric adj3 (management or program* or modif* or friendly or intervention or coordinat* or co-ordinat*)).tw,kw.
6. (elder* adj3 (program* or modif* or friendly or intervention* or coordinat* or co-ordinat*)).tw,kw.
7. or/1-6
8. exp surgery/
9. (surgery or surgical or trauma or operation or operating or operative).ti,kw.
10. general surgery/
11. perioperative period/
12. intraoperative period/
13. perioperative nursing/
14. postoperative care/
15. preoperative care/ or preoperative period/
16. (((surgery or surgical) adj (unit* or department* or area*)) or (operating adj (room* or theatre* or theater* or suite*))).tw,kw.
17. (surgery or surgical or trauma or operation or operating or operative).ab. /freq=2
18. (perioperative or peri operative or intraoperative or intra operative or postoperative or post-operative).ti,kw.
19. (perioperative or peri operative or intraoperative or intra operative or postoperative or post-operative).ab. /freq=2
20. (orthop?edic or orthogeriatric).mp.
21. or/8-20
22. (acute care for elders or acute care for the elderly or Nurses Improving Care for Healthsystem Elders or modified Hospital Elder Life Program or mHELP or hospitali?ed elder life program*).tw,kw.

23. (geriatrician* or geriatric specialist* or geriatric nurse* or geriatric physician*).mp.
24. (geriatric unit* or geriatric ward*).mp.
25. 22 or 23 or 24
26. 7 and 21
27. 21 and 25
28. 26 or 27
29. economic evaluation/ or "cost benefit analysis"/ or "cost effectiveness analysis"/ or "cost minimization analysis"/ or "cost utility analysis"/
30. "cost of illness"/
31. (economic evaluat$ or economic analys$ or economic study ornsequence$).mp.
32. "cost of illness"/
33. economic*.ti.
34. economic*.ti,kw.
35. economic*.ab. /freq=2
36. (economic evaluat* or economic analys* or economic study or economic studies or economic assess* or economic consequence*).mp.
37. (cost? or costing? or costly or costed).ti,kw.
38. (cost? or costing? or costly or costed).ab. /freq=2
39. ((cost-benefit or benefit-cost or cost effectiv* or cost utility) adj2 (analys* or evaluat* or assess* or study or studies or ratio*)).mp.
40. (cost minimization or cost minimisation or cost consequence* or cost offset*).mp.
41. ((cost or costs) adj2 analys*).mp.
42. ("cost of illness" adj4 (analys* or evaluat* or assess* or study or studies or framework*)).mp.
43. (price? or pricing?).tw.
44. (pharmacoeconomic? or (pharmaco adj economic?)).tw,kw.
45. budget*.tw,kw.
46. expenditure*.tw,kw.
47. (value adj1 (money or monetary)).tw,kw.
48. (fee or fees).tw,kw.
49. "Quality adjusted life year*".tw,kw.
50. qaly*.tw,kw.
51. cba.tw,kw.
52. cea.tw,kw.
53. cua.tw,kw.
54. markov*.tw,kw.
55. monte carlo.tw,kw.
56. (decision adj2 (tree* or analys* or model*)).tw,kw.
57. or/29-56
58. 28 and 57

NHS EED Search

1. Geriatric Assessment/
2. geriatric assessment*.mp.

3. ((frail* or sarcopeni* or elder* or senior* or gerontolog* or geriatric* or veteran* or old* people or old* person* or old* resident* or old* adult* or old* patient*) adj3 (assess* or evaluat* or apprais* or comprehensive* or patient care team or patient* education or interprofession* or inter-profession* or interdisciplin* or inter-disciplin* or multi-disciplin* or multidisciplin* or rehab*)).mp.
4. (geriatric adj3 (evaluation or management or program* or modif* or friendly or intervention or coordinat* or co-ordinat*)).mp.
5. (elder* adj3 (program* or modif* or friendly or intervention* or coordinat* or co-ordinat*)).mp.
6. (acute care for elders or acute care for the elderly or Nurses Improving Care for Healthsystem Elders or modified Hospital Elder Life Program or mHELP or hospitali?ed elder life program*).mp.
7. (geriatrician* or geriatric specialist* or geriatric nurse* or geriatric physician*).mp.
8. (geriatric unit* or geriatric ward*).mp.
9. or/1-8
10. (surg* or operation or operating or operative).mp.
11. 9 and 10