# The Determinants of Health Care Costs in Older Adults Undergoing Non-Elective Abdominal Surgery

by

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# DEDICATION

To my wife, Kristen, who has been my coach, role model, teammate and fan.

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# ABSTRACT

**BACKGROUND**

Health care spending in Canada has been increasing faster than the rate of gross domestic product (GDP). A disproportionate amount of the health care spending is allocated to care of older adults. Non-elective abdominal surgery is an expensive area of care for older adults. Despite this, the factors associated with cost in this patient population remain unclear.

**OBJECTIVES**

The primary objective of this study was to estimate the association between perioperative factors (age, American Society of Anesthetists (ASA) classification, operative severity (OS), frailty index (FI), complication severity) and health care costs among older adults undergoing non-elective abdominal surgery. The secondary objectives were: 1. to provide a comprehensive description of costs based on patient-level resource utilization; and 2. to examine the relationship between hospital costs and adverse events (non-fatal complication severity, mortality, and change in living arrangement).

**METHODS**

This study was an observational prospective cohort study. Over a 15 month period all patients 70 years or older who underwent non-elective abdominal surgery at the QEII Health Sciences Centre, Nova Scotia, were enrolled. Data were collected on patient demographics, investigations, treatments, and outcomes. Direct hospital health care costs (2012 $CAD) were calculated by tabulating patient-level resource use and assigning specific costs. The association between five perioperative factors and costs were analyzed using univariate non-parametric tests and multiple linear regression. The associations between adverse events and costs were assessed using univariate non-parametric tests and multiple linear regression.

**RESULTS**

During the study period, 212 patients who underwent abdominal surgery (median age 78 years (range 70-97)) were enrolled. The median costs of care were $9,166 (range $1,993-$104,403). The largest proportions of spending were non-procedural costs (65% [$2,176,875]) and intensive care costs (16% [$554,523]). The perioperative factors ASA classification ($p=0.0010$), OS ($p<0.0001$), FI ($p=0.0002$) and complication severity ($p<0.0001$) were all independently associated with health care costs, while age was not ($p=0.5330$). The following adverse events were independently associated with health care costs: non-fatal complication severity ($p<0.0001$), change in living arrangement ($p=0.0002$), and mortality ($p=0.0337$). Non-fatal complications had the strongest association with hospital costs (standardized $\beta$ coefficient = 0.3931).

**CONCLUSION**

Four perioperative factors (ASA, OS, FI and complication severity) are associated with costs; therefore, representing a potential cost prediction model for this patient group. This study is important for health care administrators, identifying targets for cost reduction. Cost reduction strategies and research should concentrate on mitigating or preventing complications and high cost areas, such as non-procedural costs and intensive care, in order to achieve cost savings.

## LIST OF ABBREVIATIONS USED

| | |
|---|---|
| ADLs | Activities of Daily Living |
| ASA | American Society of Anesthesiologists |
| BMI | Body Mass Index |
| CCI | Charlson Comorbidity Index |
| CAD | Canadian Dollars |
| CGA | Comprehensive Geriatric Assessment |
| Clavien | Clavien Complication Classification |
| CSHA | Canadian Study of Health and Aging |
| DRG | Diagnosis Related Groups |
| ERCP | Endoscopic Retrograde Cholangiopancreatography |
| FI-CGA | Frailty Index based on a Comprehensive Geriatric Assessment |
| GDP | Gross Domestic Product |
| ICU | Intensive Care Unit |
| IMCU | Intermediate Care Unit |
| IQR | Interquartile Range |
| IVC | Inferior Vena Cava |
| NLTCS | National Long Term Care Survey |
| LPN | Licensed Practical Nurse |
| NSQIP | National Surgical Quality Improvement Program |
| OS | Operative Severity |
| POSSUM | Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity |
| RN | Registered Nurse |
| TPN | Total Parenteral Nutrition |
| USD | United States Dollars |
| VIF | Variance Inflation Factor |

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# CHAPTER 1 INTRODUCTION

Health care spending in Canada has been increasing faster than economic growth. From 1999 to 2009 health care spending as a proportion of the national gross domestic product increased from 9% to 12% (1). In absolute terms, this represents an increase of over $90 billion CAD. This trend toward increased health care spending is consistent across Canadian provinces, and health care now accounts for the largest proportion of total provincial budgets (1, 2). Several factors have contributed to this phenomenon including health care sector price inflation, population aging, population growth, technological innovations and hospital-specific costs increasing in excess of general inflation (3).

While population aging has contributed to increased health care spending, there is concern that costs associated with care of older adults will increase substantially given the predicted future demographic trends (4). According to the United Nations World Population Prospects 2006 report, the number of individuals over the age of 60 years is projected to double by 2050 in developed countries while the number of individuals under the age of 60 years will decrease slightly (5). In 2005, 13.1% of the Canadian population was over the age of 65 years and 3.5% was over the age of 80 years. It is estimated that these percentages will increase to 28.5% and 10.8% by 2050, respectively (4). Care of older adults is an important area for cost analysis since it comprises a large portion of total health care expenditure in Canada. In 2009, 44% of total provincial and territorial health care spending was used to care for people older than 65 years, even though this group only accounted for 14% of the population (1). As the population continues to age it will likely place an increasing burden on our health care system.

Non-elective abdominal surgery is an area of health care for older adults that is associated with higher costs. Non-elective abdominal surgery for older adults is more expensive than both elective surgery for older adults and non-elective surgery for younger adults (6-12). The increased costs associated with non-elective surgery in older adult patients are relevant given that older adults are more likely to undergo non-elective surgery as they age. A recent analysis of the National Surgical Quality Improvement Program (NSQIP) database found that patients older than 65 years accounted for 26.2% of non-elective abdominal surgery procedures performed on 68,000 patients in 168 hospitals, even though adults 65 years or older only account for 13% of the US population (13). While only 15% of surgeries are performed on an non-elective basis for those 65 to 74 years, this proportion increases to 69% for those over 90 years (14). The proportion of older adults admitted to general surgery services on an non-elective basis has also increased over time (15). These age trends hold true for subsets of non-elective abdominal surgery including colorectal surgery and trauma admissions (11, 16).

Given the increasing health care expenditures and the call for improved fiscal restraint from the federal and provincial governments in Canada (17, 18), understanding the factors associated with health care costs will become increasingly important; particularly in high cost areas such as non-elective abdominal surgery for older adults. This study examined the relationship between perioperative factors, adverse events and direct in-hospital health care costs among older adults undergoing non-elective abdominal surgery. This thesis is divided into a background review, two manuscripts and a general conclusion. The background reviews the determinants of health care costs that have been previously identified in the surgical literature. The first manuscript examines the strength of association between five perioperative factors (age, American Society of Anesthesiologists' classification, operative severity, frailty index and complication severity) and hospital costs. It also provides a comprehensive description of health care costs according to component costs. The second manuscript assesses the relationship between adverse events (non-fatal complication severity, change in living arrangement, and in-hospital mortality) and hospital costs; and also examines the costs associated with unnecessary days in hospital. Given the interrelated nature of perioperative factors and adverse events, there is some overlap between the two manuscripts. The general conclusion outlines implications for future research and policy makers, discussing the limitations of the study results.

# CHAPTER 2 BACKGROUND

## 2.1 Determinants of Health Care Costs

Although non-elective abdominal surgery in older adult patients is expensive, the factors that contribute to costs remain unclear. Several studies have examined factors that may be associated with increased health care costs in older adults undergoing surgery, whether elective or non-elective. Understanding how these factors relate to health care costs has many practical applications. Individual factors can be used as targets for cost reduction. For example, it was estimated that a 5% relative reduction in postoperative complications for older adults undergoing general and vascular surgery could result in an annual cost reduction of $31 million in the United States (19). Factors can also be combined to create cost prediction and health risk models: the former are used for insurance underwriting, budgetary planning and population stratification and the latter are used for provider performance comparisons and provider payment decisions (20). The following sections discuss the numerous studies that have examined the impact of individual factors on hospital costs in abdominal surgery populations including age, comorbidities, ASA classification, frailty, operative severity, complications and mortality.

### 2.1.1 Age

An association between age and health care costs has been found in multiple settings, including community and surgical samples (10, 12, 21-23). For example, in a study of 358,091 older adults undergoing cholecystectomy, the average direct in-hospital health care costs were $11,675 for patients 50 to 64 years, increasing to $13,977 for patients 65 to 79 years and $17,039 for patients 80 years or older (24) (Table 2.1). However, this relationship may be mediated by other factors, which become more common as patients age. For example, as people age they are diagnosed with more chronic conditions, they become more frail, and they experience a higher rate of postoperative complications (25-27). In studies that have adjusted for these factors, age was no longer associated with health care costs in multivariate analyses (28).

### 2.1.2 Comorbidities

The impact of comorbidities on health care costs has been studied with varying results. The Charlson Comorbidity Index (CCI) is a scoring system used to estimate the burden of comorbidity. Originally developed in 1987 as a risk prediction scale for death among breast cancer patients, the CCI has become the most common standardized method of categorizing burden of comorbidity in the surgical literature aside from a simple count of comorbidities (29). The CCI uses weighted values for certain diseases to calculate a single numeric value for each patient. The index can also be combined with age to calculate a Combined Comorbidity-Age Risk Scale. The CCI has been shown to predict total one year Medicare charges in an older adult outpatient population and Medicare charges rose steadily with increasing number of comorbidities (30) (Table 2.1). Subsequent studies involving general surgery procedures have found similar results. The number of comorbidities has been associated with direct hospital costs in older adult patients undergoing laparoscopic cholecystectomy and laparoscopic appendectomy (9, 24). Similarly, the CCI was found to be associated with hospital costs in a sample of patients undergoing elective general surgery procedures (28). However, this may not apply to other surgical populations. The CCI did not significantly predict hospital health care costs in two studies of neurosurgery and thoracic surgery patients (31, 32).

### 2.1.3 American Society of Anesthetists (ASA) Classification

The American Society of Anesthetists (ASA) classification is a five point pre-operative risk prediction scale. This scale is assigned by the anesthetist prior to surgery based on their general impression of the patient's overall disease burden (33, 34). It has become routinely used by anesthetists in all surgical specialties. Previous studies have assessed the relationship between the ASA classification and direct hospital health care costs. One cohort study of patients undergoing laparoscopic cholecystectomy found that ASA classification was associated with increased length of hospital stay (35). Two other studies found that ASA classification was associated with hospital costs. Vonlanthen and colleagues found that ASA was significantly associated with hospital costs in a sample of major general surgery procedures (28). Davenport and colleagues assessed this relationship using the National Surgical Quality Improvement Program (NSQIP) database, including 5,878 patients undergoing a broad range of surgical procedures (36).

They also found that ASA was related to hospital costs, with the largest increase between categories III and IV (Table 2.1). However, ASA only accounted for 18.6% of the variability in costs on its own. So, although ASA is related to health care costs, it has limited ability to explain variations in cost.

### 2.1.4 Frailty

Frailty has been defined as an accumulation of deficits leading to a loss of physiological reserve, making a person more susceptible to physiological stressors (25). It can be thought of as a continuum where the state of being frail becomes more likely as deficits accumulate (25). Although there is overlap with the concepts of disability and comorbidity, frailty represents a separate entity. There are currently two main methods of operationalizing frailty. One method, published by Fried and colleagues, uses mainly objective measures of physical performance to quantify frailty (37). They defined frailty as the presence of three or more of unintentional weight loss, self-reported exhaustion, weak hand grip, slow walking speed and low physical activity (37). Some of these variables have been used independently to predict poor outcomes in older adults, such as weak hand grip (38) and slow walking speed (39). A second method of defining frailty, devised by Rockwood and colleagues, is the Frailty Index based on a Comprehensive Geriatric Assessment (FI-CGA) (40). The CGA identifies deficits in health in multiple domains based on an interview and physical examination. The FI-CGA is calculated by dividing the number of deficits present in the individual by the total number of measured deficits. Therefore, possible scores range from 0.00 to 1.00, but previous studies have shown that scores plateau at a maximum score of approximately 0.70 (40-42). Generally a FI-CGA will include a large number of deficits; it is recommended that at least 30 potential deficits are included to make the measure reliable (43). The FI-CGA was found to be independently predictive of poor clinical outcomes in older adult populations in outpatient settings (25, 40, 42, 44, 45).

There is evidence that frailty can be used to estimate health care costs in older adult populations. An item from the Fried frailty score was used to independently predict health care utilization (39). A group of 1,388 older adult male veterans who had been admitted to hospital were followed for one year to determine if walking speed was associated with health care costs. The study found that decreased walking speed was associated with longer hospital stay and increased costs. However, this may not be applicable in an acute care surgery setting. Other studies have also found a relationship between costs and a frailty index. The National Long Term Care Survey (NLTCS) consists of repeated surveys of people over the age of 65 years. Using data from the NLTCS, Yashin and colleagues showed that a frailty index was associated with total direct health care costs obtained from Medicare billing data (22). Additionally, in a prospective cohort study, Robinson and colleagues examined the association between a frailty index and health care costs in a sample of older adult patients undergoing elective colorectal surgery (46). In that study they divided patients into three groups depending on the presence of frailty traits: not frail, pre-frail and frail. Costs were significantly higher for frail patients with mean direct hospital health care costs increasing from $27,731 (+/-$15,693) and $29,776 (+/-$12,782) to $76,363 (+/-$48,595) for not frail, pre-frail and frail patients respectively (Table 2.1).

### 2.1.5 Operative Severity

Operative severity is another factor that has been studied in relation to health care costs in surgical populations. The severity of illness at presentation to hospital and the severity of the subsequent operation may have a large impact on resource utilization and length of stay translating to changes in hospital health care costs. The Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM) is one method of assessing the severity of illness and operative severity using preoperative investigations and operative characteristics (47). Only two studies have examined the relationship between POSSUM and health care costs. One study involving patients undergoing elective and non-elective abdominal surgery, found that POSSUM was associated with complications and that complications were in turn related to costs, but failed to assess the relationship directly (48). A second study assessed this relationship directly, finding that POSSUM was significantly associated with hospital health care costs, as well as other markers of resource utilization such as need for intensive care and length of stay in hospital (49). The sample was divided into quintiles based on the predicted chance of experiencing a postoperative complication. Costs significantly increased with increasing quintile (49) (Table 2.1).

2.1.6 Complications

A complication following surgery is defined as any deviation from the normal postoperative course (50). The severity of postoperative complications can vary from a simple superficial wound infection to organ failure resulting in death. The most common method to describe the severity of complications in the surgical literature is the Clavien Classification (50). Originally published in 1992 as a four level ordinal scale to classify the severity of complications, the Clavien Classification was modified in 2004 to a five level scale. The scale categorizes severity of a complication based on the type of therapy required to treat the complication.

Complications have been associated with costs in several studies involving major surgery. Dimick and colleagues showed that in a cohort of 1,008 adult general and vascular surgery patients, costs increased significantly if patients experienced a complication (51). The mean costs for a patient who experienced a major complication ($28,356) after surgery was double the costs for a patient experiencing a minor complication ($14,094) and six times the costs of patients who had an uncomplicated recovery ($4,487; costs in 2001 USD). Similarly, complications were associated with hospital charges in a cohort of 1,200 adults undergoing major abdominal surgery (28). Charges increased with each level of the Clavien classification. In a cohort of older adult patients undergoing elective and non-elective general and vascular surgery in the United States, Lawson and colleagues found that after risk adjustment complications were associated with increased readmissions to hospital and increased hospital costs during readmissions (19). Complications have been found to be associated with increased hospital costs in appendectomy, colorectal resection and trauma populations (23, 52, 53). However, some of the following evidence makes this association less clear. Using multivariate regression, Sartorelli and colleagues found that length of stay in hospital and length of intensive care stay were the main predictors of direct health care costs in older adult trauma patients (11). While complications likely lead to the increase in length of stay and length of intensive care stay, this was not reported and the presence or absence of complications alone was not a major predictor of costs.

2.1.7 Death

The relationship between mortality and costs is also unclear. Intuitively, deaths early in the course of a hospital stay may be associated with lower overall costs; however, several studies have found an association between mortality and increased costs. In Payne and colleagues' study of older adults in the community, mortality was associated with increased health care costs (21). Additionally, they described a time trend whereby costs associated with mortalities increased while costs associated with those who lived decreased over a ten year period, suggesting that the cost of interventions prior to death was increasing over time. Numerous retrospective studies have found that proximity to death is strongly associated with increased health care costs (54). Large population-based database studies in the United States, United Kingdom and Canada have all found that health care expenditures increase with increasing proximity to death (55-57). A recent review article reported that most studies have found that proximity to death has a stronger association with health care costs than does age (54). However, only two studies have directly assessed the relationship between death and health care costs following abdominal surgery procedures. These two studies from the United States found hospital costs to be greater in cases where the patient died in hospital (6, 7).

## 2.2 Limitations of the Literature

While previous research has led to an improved understanding of the factors associated with cost of care, there are several limitations associated with the existing literature. Although multiple factors have been associated with costs of care, most studies have examined factors in isolation or a limited number of factors. Commonly, studies have assessed the relationship between pre-operative risk factors and costs or post-operative complications and costs, but not usually both together. Studying both together can help untangle the potential association of postoperative complications and death with health care costs.

One of the major limitations of previous studies is the quality of cost estimation. The majority of studies assessing determinants of health care costs in surgical populations are based on administrative data, which limits the accuracy of clinical outcomes and cost estimation. There are three main methods for health care costs estimation: hospital charges, payment schedules and patient-level resource tracking (58). At the end of a hospital stay in a private for profit health care system, the patient or payer (public or private) is charged a fee based on the type of care that was received by the patient. These charges can be multiplied by a cost-to-charge ratio specific to the ward or hospital to estimate hospital costs for that patient. This generally allows costs to be estimated to within 10% of the actual costs incurred (58, 59). Using payment schedules is a more complex method of estimating costs. This method uses Diagnosis Related Groups (DRGs) to estimate costs based on the main diagnoses responsible for hospital admission. This method underestimates costs for patients who have a hospital admission complicated by long hospital stays, intensive care treatment or resource intense investigations and treatment (58). Although payment schedules are generally more accurate, cost-to-charge ratios may be more accurate if patients fall into several DRGs. The most complex and most accurate method of cost estimation is to track resource utilization for each patient, multiplying by a unit cost for each resource. This method is not often used because it is labor intensive unless the hospital has an existing electronic resource tracking system.

Finally, few Canadian costing studies involving older adults undergoing abdominal surgery have been published. The vast majority of surgical costing studies come from American centers or databases. Given that practice patterns, reimbursement of health care workers and equipment costs vary greatly between countries, results from American studies have limited generalizability to Canadian centers (60).

## 2.3 Purpose

Given the high costs associated with non-elective abdominal surgery in older adult patients and a lack of literature specifically examining costs associated with caring for this patient population, the purpose of this study was to provide a comprehensive analysis of health care costs including the association between perioperative factors and costs, a detailed breakdown of costs, and the relationship between adverse events and costs for older adults (70 years or older) undergoing non-elective abdominal surgery using patient-level resource tracking.

## 2.4 Objectives

### 2.4.1 Primary Objective

The primary objective was to determine the strength of association between five perioperative factors (age, ASA classification, operative severity, frailty index and complication severity) and direct hospital health care costs among patients ≥70 years undergoing non-elective abdominal surgery.

### 2.4.2 Secondary Objectives

1. To provide a comprehensive description of resource utilization and health care costs according to component costs (operative costs, non-operative procedure costs, non-procedural costs, radiology costs, and intensive care costs).
2. To determine the relationship between adverse outcomes (non-fatal complication severity, in-hospital mortality, and change in living arrangement) and direct hospital health care costs in older patients undergoing non-elective general surgery.

Table 2.1 The magnitude of increase in health care costs associated with perioperative factors in the surgical literature.

| Factor | Number | Population | Costs by level of factor* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Age** | | | 50-64 years | 65-79 years | ≥80 years | | | | |
| Kuy et al (2011) | 358,091 adults/older adults | Cholecystectomy | $11,675 | $13,977 | $17,039 | | | | |
| **Comorbidity** | | | 1 | 2 | 3 | 4 | 5 | 6 | ≥7 |
| Charlson et al (2008) | 5,861 adults | Primary care | $2,250 | $4,317 | $5,986 | $5,551 | $6,521 | $7,867 | $13,326 |
| **ASA classification** | | | I | II | III | IV | V | | |
| Davenport et al (2006) | 5,878 adults | Surgery | $1,986 | $3,211 | $5,384 | $18,359 | $22,889 | | |
| **Operative severity** | | | <20% | 20-40% | 40-60% | 60-80% | >80% | | |
| Pratt et al (2008) | 326 adults | Pancreatic resection | NR | $19,951 | $22,079 | $25,908 | $31,281 | | |
| **Frailty** | | | Non frail | Prefrail | Frail | | | | |
| Robinson et al (2011) | 60 older adults | Colorectal surgery | $27,731 | $29,776 | $76,363 | | | | |
| **Complication** | | | No complication | I | II | IIIa | IIIb | IV | |
| Vonlanthen et al (2011) | 1,200 adults | Major abdominal surgery | $27,946 | $30,739 | $42,338 | $53,388 | $97,001 | $159,345 | |
| Dimick et al (2004) | 1,008 adults | General or vascular surgery | $4,487 | $14,094 | | | $28,356 | | |
| **Mortality** | | | Discharged alive | Died in hospital | | | | | |
| Gardner & Palasti (1990) | 304 adults | General surgery | $5,465 | $12,207 | | | | | |
| Munoz et al (1994) | 13,600 adults | General surgery | $6,837 | $29,314 | | | | | |

* Costs listed above are from varying years. Therefore, the magnitude of costs can only be compared within studies but not between studies.

# CHAPTER 3

# THE ASSOCIATION BETWEEN PERI-OPERATIVE FACTORS AND HEALTH CARE COSTS FOR OLDER ADULTS UNDERGOING NON-ELECTIVE ABDOMINAL SURGERY

## ABSTRACT

**BACKGROUND**

Health care spending in Canada has been increasing faster than the rate of economic growth, with a large proportion allocated to care of older adults. A rapidly aging population has exacerbated concerns about health care spending. Understanding the factors associated with increased health care costs will support cost forecasting and cost containment strategies, particularly in high cost areas such as non-elective abdominal surgery.

**OBJECTIVES**

The objective of this study was to examine the relationship between perioperative factors (age, American Society of Anesthetists (ASA) classification, operative severity (OS), frailty index (FI), complication severity) and health care costs among older adults undergoing non-elective abdominal surgery, while providing a comprehensive description of costs based on patient-level resource tracking.

**METHODS**

This study was an observational prospective cohort study. Over a 15 month period all patients 70 years or older who underwent non-elective abdominal surgery at a tertiary care teaching hospital were enrolled. Patient demographics, perioperative factors and outcomes were extracted from the medical record. Direct hospital health care costs (2012 $CAD) were calculated by tabulating patient-level resource use and assigning specific costs. The association between five perioperative factors and costs were analyzed using univariate non-parametric tests and multiple linear regression. Hospital costs were broken down into component costs to provide a comprehensive description.

**RESULTS**

During the study period 212 patients underwent non-elective abdominal surgery (median age 78 years (range 70-97)). The median costs of care was $9,166 (range $1,993-$104,403). The largest proportions of spending were non-procedural costs (65% [$2,176,875]) and intensive care costs (16% [$554,523]). On multiple linear regression ASA score ($p=0.0010$), OS ($p<0.0001$), FI ($p=0.0002$) and in-hospital complication severity ($p<0.0001$) were all independently associated with health care costs, while age was not ($p=0.5330$).

**CONCLUSION**

This study indicates four perioperative factors (ASA, OS, FI and complication severity) associated with health care costs are potentially useful to improve cost forecasting. The findings of this study have implications for health care administrators, providing targets for cost reduction and a potential cost prediction model. Complication severity was most strongly associated with costs; therefore, reducing complication rates is an important target for cost reduction. Cost reduction research should focus on high cost areas, such as non-procedural bed costs and intensive care. Reducing or eliminating unnecessary days in hospital would reduce costs.

## 3.1 Introduction

Health care spending in Canada has been increasing faster than the growth of Gross Domestic Product (GDP) over the last decade (61). There are concerns that this pattern of spending is not sustainable, prompting government health care spending restraint. A large proportion of health care spending is used to care for older adults. While those over 65 years account for only 14% of the population, they account for 44% of health care spending (61). By 2050 the population 65 years or older is expected to have doubled and the population 80 years or older is expected to have tripled (4). Accordingly there is substantial concern that health care spending will become unmanageable as the population ages.

Certain areas of health care for older adults are associated with higher costs. One example of this is non-elective abdominal surgery. Non-elective abdominal surgery for older adults is more expensive than both elective surgery for older adults and non-elective surgery for younger adults (6-12). Unfortunately the need for non-elective abdominal surgery increases as patients age and proportion of older adults admitted for abdominal surgery on a non-elective basis has increased over time (13, 15, 27). An analysis of the National Surgical Quality Improvement Program (NSQIP) database found that 26% of all non-elective abdominal surgery was performed on older adult patients even though they all account for 13% of the population (13).

Although non-elective abdominal surgery in older adult patients is expensive, the factors that contribute to costs remain unclear. Several studies have examined factors that may be associated with increased health care costs in older adult patient undergoing surgery, whether elective or non-elective. Understanding how these factors relate to health care costs has many practical applications. In the surgical literature several perioperative factors have been associated with health care costs including age (9, 23, 24), frailty (22, 62), American Society of Anesthesiologists (ASA) classification (28, 36), operative severity (48) and complications (28, 51, 63). However, very little literature has specifically examined non-elective abdominal surgery in older adults and many past studies use administrative data, limiting the accuracy of cost estimates. Given the high costs associated with such care, a better understanding of the factors that contribute to costs in this patient population may have implications for cost reduction and resource planning. Therefore, the purpose of this study was two fold: 1. to examine the relationship between perioperative factors (age, ASA classification, operative severity, frailty index and complications) and health care costs for older adults (70 years or older) undergoing non-elective abdominal surgery. 2. to provide provide a comprehensive description of health care costs according to component costs using patient-level resource tracking.

## 3.2 METHODS

### 3.2.1 Design

This study was an observational prospective cohort study assessing the relationship between perioperative factors and direct hospital health care costs.

### 3.2.2 Selection criteria

All patients 70 years or older who were admitted to an acute care surgery service at a tertiary care teaching hospital (QEII Health Sciences Centre, Halifax) between July 1, 2011 and September 30, 2012 and underwent non-elective abdominal surgery procedures were prospectively enrolled in this study. Only patients with intra-abdominal or abdominal wall conditions were included in the study. Patients who required treatment for a complication resulting from a prior elective procedure were excluded. Patients who were transferred from or transferred to an acute care hospital bed in an outlying hospital were excluded from this study due to an inability to track resource utilization in those hospitals.

### 3.2.3 Data Collection

Patients were enrolled within 48 hours of admission to hospital. At that time a Comprehensive Geriatric Assessment (CGA) was completed. The CGA captures information on patient demographics, Frailty Index based on a Comprehensive Geriatric Assessment (FI-CGA) (40) and living arrangement. Following the patients' discharge from hospital, a standardized, comprehensive review of the inpatient medical record was performed to collect data regarding their course in hospital, operative variables, complications and resource utilization.

Data were collected regarding five perioperative factors including age, ASA classification, operative severity, frailty, and complication severity. Age at admission to hospital was treated as a continuous variable in all analyses. The ASA classification was determined for each patient (grade one to five) by the attending anesthetist. For this study the ASA classification was obtained directly from the anesthetist's preoperative record. The severity of each operation was graded by one of the investigators (JB or PD) using the scale created by Saxton and Velanovich. This classifies procedures on a three level ordinal scale based on invasiveness and benign versus malignant disease (64). A Frailty Index was calculated for each patient based on the CGA (FI-CGA), using the Videx© tool (Kenneth Rockwood Inc.) (40-42). The FI-CGA is calculated by dividing the number of deficits a patient has accumulated by all measured deficits. Therefore, possible scores ranged from 0.00 to 1.00 on a continuous scale. A postoperative complication was defined as any deviation from the normal postoperative course. Complications were categorized based on the Clavien Classification, placing complications on a five level ordinal scale (50). Complications were identified and graded by one of the study investigators (JB or PD) based on a review of the medical record. Only in-hospital complications were used in this study.

### 3.2.4 Cost Calculation

Direct medical costs calculated from the perspective of the hospital (payer) were included. Direct medical costs borne by the patient and indirect (lost productivity) costs were excluded. Costs were estimated by patient-level resource tracking (tracking resource utilization and multiplying by a unit cost for each resource). The episode of care for this study was defined as being from admission to the acute care surgical service until either discharge from hospital, 90 days following admission, or death. Only costs incurred during the episode of care were calculated. Costs incurred after 90 days were truncated. It was not feasible to obtain costs due to readmission at outlying hospitals therefore, to limit measurement bias, only costs from the index hospitalization were used in this analysis. All costs were in 2012 Canadian Dollars ($CAD).

The majority of unit cost estimates were based on an exact count. When this was not possible or feasible cost estimates were based on time intervals. During the review of the medical record, the exact number of resources used in each of the following categories was counted: diagnostic imaging, laboratory investigations, non-operative interventional procedures, blood products, consultations, physician fees, antibiotics, anticoagulants and operative disposables. These counts were later double checked for errors in extraction or transcription.

The following cost estimates were assigned based on units of time. Bed costs for ward, intermediate care and intensive care were assigned on a daily basis; bed costs included direct supplies (dressings, saline, other ward stock) and compensation (Registered Nurses (RN), Licensed Practical Nurses (LPN), unit aids, booking clerks). Operating room facility costs were assigned using a base rate (for pre-admission nursing, preoperative nursing, the patient attendant, the anesthesia technician, anesthesia supplies and post-anesthetic care unit nursing) and an hourly rate (for intra-operative nursing). Medication costs for analgesics and antiemetics outside of the operating room, and intensive care infusions were assigned on a daily basis. Daily averages for these medications were calculated by performing an exact count of medication dosages for the first 25 patients.

Specific unit costs that were dependent on institutional agreements with private companies or unions were obtained from department managers and from the central finance department (such as capital acquisition costs, staff wages and disposable equipment). Laboratory investigation prices were taken from the Capital District Health Authority Laboratory Test Price List, which are used to bill the Nova Scotia government for insured persons (65). Prices for blood products were obtained directly from Canadian Blood Services (66, 67). Physicians' fees were taken directly from the Nova Scotia Medical Services Insurance physician billing manual, which is used to determine physician billing in the province of Nova Scotia (68). Bed costs were based on a top down estimate from the central finance department. Medication costs were obtained from the pharmacy department.

The costs of unnecessary patient-days was also estimated. The number of unnecessary days in hospital was defined as the difference between the actual discharge date and the date when the clinical team documented in the chart that the patient was medically ready to leave hospital. The same definition was used for the intermediate care unit (IMCU) and the intensive care unit (ICU). By definition, no medical treatment was necessary after the patient was deemed medically ready for discharge. Therefore, the excess cost of unnecessary days on the ward was estimated by multiplying the number of patient-days by the ward bed costs. The excess costs for unnecessary IMCU patient-days were estimated using the difference between IMCU bed costs and ward bed costs, since all other hospital costs were the same. Similarly, the excess costs for unnecessary ICU patient-days were estimated using the difference between ICU bed costs and IMCU bed costs.

### 3.2.5 Statistical Analysis

The univariate relationship between five perioperative factors and costs was examined individually using simple linear regression. Age and frailty index were treated as continuous variables. The normality of the distribution of non-categorical variables was assessed using the Shapiro-Wilk test. Costs, age and frailty index were transformed on a lognormal scale. This allows the relationship between continuous factors to be interpreted as a percentage change (e.g. x percent increase in age is associated with a y percent increase in costs) (69, 70). Exponentiating a 1% increase in the perioperative factor by the β coefficient is equal to the expected percentage change in costs ($\Delta costs\% = 1.01^{(coefficient)}$). The ASA classification, OS and the Clavien classification were treated as ordinal variables. The relationship between ordinal factors can be interpreted as an increase in the exponentiated β coefficient of costs (e.g. x unit increase in ASA classification results in exp(coefficient) increase in costs) (69-71). An alpha level of 5% was used to determine statistical significance.

To assess for independent associations between the perioperative factors and costs, multiple linear regression was used. Tolerance and variance inflation factor (VIF) were used to assess for collinearity in the model. Tolerance <0.2 and VIF >5 were considered to indicate collinearity. Standardized β coefficients were calculated to assess the relative importance of each of the perioperative factors when describing the variations in costs. The amount of variation in costs explained by the model was assessed by calculating the coefficient of determination ($R^2$).

A combination of descriptive statistics and nonparametric tests was used to describe resource utilization and costs associated with specific aspects of hospital care. Hospital costs of care were broken down into operative costs, non-operative procedure costs, non-procedural costs, radiology costs and intensive care costs. Operative costs include surgeons' fee, anesthetists' fee, facility costs per hour for the operating room and costs of disposable equipment. Non-operative procedural costs include costs associated with endoscopy procedures and interventional radiology procedures, including physician fees, support staff salaries, disposable equipment, non-disposable equipment, and dialysis. Non-procedural costs include physician consultation fees, physician attending fees, allied health care personnel salaries, ward/intermediate care bed costs (which includes nursing and support staff salaries), medication costs, total parenteral nutrition costs, laboratory costs and blood product costs. Radiology costs include any radiological test ordered from the time of presentation in the emergency department to the time of discharge from hospital. Intensive care costs include only those costs specific to the intensive care unit; specifically, physician fees, intensive care bed costs (which includes nursing and support staff salaries), and medication costs for infusions. The distribution of each component of hospital health care costs (operative costs, non-operative procedure costs, non-procedural costs, radiology costs and intensive care costs) was described using medians, inter-quartile ranges and ranges. The distributions of each component were then compared using Wilcoxon signed rank test.

### 3.3 RESULTS

During the 15 month study period, 520 patients aged 70 years and older were admitted to the acute care surgery service (Figure 3.1). Fifty four patients (10.4%) were excluded because they met one of the following exclusion criteria: admitted on an elective basis, presenting with a complication from elective surgery, did not have intra-abdominal or abdominal wall pathology. Twenty seven patients (5.2%) were excluded because they were transferred from an outlying hospital, leaving 439 eligible for the study. Forty two patients (9.6%) did not consent to participate. Seven patients (1.6%) were missed because they were either discharged or died in less than 24 hours from admission. One hundred seventy eight (45.6%) patients did not undergo surgery. The final cohort consisted of 212 patients who underwent non-elective abdominal surgery during the study period.

Patient characteristics are presented in Table 3.1. Most patients had an ASA classification (181 [85.4%]) of II or III and most patients had a procedure for benign disease (185 [87.2%]) giving an operative severity of 1 or 2. The median length of stay was 8.0 days (IQR 4.0-16.5). The total number of days in hospital for all patients was 3,127, with 2,742 (87.7%) patient-days on the ward, 224 (7.2%) patient-days in the intermediate care unit (IMCU) and 161 (5.1%) patient-days in the intensive care unit (ICU). The number of unnecessary patient-days (defined as days after being determined medically ready for discharge until actual discharge from hospital) was 386/2,742 (14.1%) on the ward, 12/224 (5.4%) in the IMCU and 8/161 (5.0%) in the ICU. During their hospital stay, 105 (49.5%) patients experienced a non-fatal complication (68 [32.1%] minor and 37 [17.5%] major) and 14 (6.6%) patients died in hospital.

3.3.1 Breakdown of costs

The median total direct hospital health care costs was $9,166 (range $1,993-$104,403; Table 3.2). Of the five main cost categories, non-procedural costs contributed the largest amount to total costs (median $5,447), followed in descending order by operative, radiological, non-operative procedural and intensive care costs. Each cost category was significantly different from the other cost categories (Figure 3.2). Within the non-procedural cost category, bed costs were the largest cost subcategory (median $4,410). Unnecessary days in the ward and IMCU accounted for an estimated cost of $170,226 (5.0%) and $3,708 (0.1%), respectively. Although total parenteral nutrition (TPN) and blood products were associated with high costs for some patients (maximum $5,819 and $21,914, respectively), they did not materially contribute to the median costs for the cohort as a whole. The subcategory of operative costs accounting for the largest proportion of the total operative costs was the surgeon and resident fees (median $602). Non-operative procedures and intensive care costs did not materially contribute to the median costs for the cohort as a whole, but for some patients, the costs in these areas were high. The non-operative procedures with the highest maximum costs were angioembolization (maximum $5,594), followed by ERCP (maximum $2,623), colonic stenting (maximum $2,348), IVC filter insertion (maximum $1,788), and percutaneous drainage (maximum $1,699).

For the 46 patients who were admitted to the intensive care unit (ICU), non-procedural costs (median $10,224) accounted for the largest proportion of the total costs (median $24,286). ICU-specific costs were the second largest cost category (median $8,101; Table 3.2). The largest cost subcategory within ICU-specific costs was bed costs (median $6,300). Unnecessary days in ICU accounted for an estimated excess cost of $10,800 (0.3%).

### 3.3.2 Perioperative factors and health care costs

All non-categorical variables were significantly right skewed (age [p<0.0001], frailty index [p=0.0023], total costs [p<0.0001]). Therefore, these variables were log transformed to meet the assumptions of linear regression and allow for interpretation of the relationship between factors and costs as percentage changes in costs. In univariate analysis, all perioperative factors except for age were significantly associated with total hospital costs (age [p=0.4884], ASA [p<0.0001], OS [p<0.0001], FI-CGA [p<0.0001] , Clavien [p<0.0001]). Similarly, in multivariate analysis ASA classification, operative severity, frailty index and complications were independently associated with total hospital health care costs; however, age was not (Table 3.3). Using the coefficients produced from the multiple linear regression, increases of 1 level in ASA classification, operative severity and Clavien classification were associated with a 24%, 40% and 25% increase in total costs, respectively. A 20% increase in frailty index was associated with a 13% increase in total cost. Standardized β coefficients showed that complication severity was the most important factor in accounting for variations in total costs. Overall, the four factors explained 57% of the variation in total hospital costs ($R^2 = 0.5680$). There was no signficant collinearity between variables as indicated by tolerance >0.2 and VIF <5.

## 3.4 Discussion

Understanding the determinants and distributions of health care utilitization is essential to developing strategies to control costs; particularly in high cost and common areas of health care. This study identified four perioperative factors (ASA, OS, FI-CGA and complications) that were associated with health care costs among older adults undergoing non-elective abdominal surgery. While the relationship between these factors and cost has been studied before, no investigators have reported factors associated with costs in this patient population. Furthermore, previous research has typically considered factors in isolation.

The ASA classification has previously been identified as explaining some variations in costs in elective and non-elective surgical populations (28, 35, 36). For example in an elective surgical cohort involving 5,878 patients, Devonport and colleagues found that ASA accounted for 18.2% of the variability in costs (36). Operative severity, as measured by the POSSUM scale, has also been associated with health care costs (48, 49). However, POSSUM includes multiple variables which are not routinely measured during a surgical admission, limiting its utility in costing studies, particularly those using administrative data (72). In contrast, the operative severity classification by Saxton and Velanovich can be straightforwardly applied using the diagnosis and surgical procedure. However neither the ASA classification nor operative severity are modifiable factors. They represent the disease state of the patient prior to surgery and therefore are not a target for cost containment by themselves. Rather, these factors could be used to develop predictive models, identifying those who are likely to have resource intense hospital admissions where other cost containment strategies might be implemented (20).

Frailty is an established concept in the literature but is just emerging as a perioperative factor related to postoperative outcomes and costs (46, 73, 74). Frailty has been defined as an accumulation of deficits leading to a loss of physiological reserve, making a person more susceptible to physiological stressors (25). Several investigators have suggested that increasing frailty is associated with higher costs in elective surgical patients (62, 75, 76). In the present study we found that the FI-CGA measured at the time of admission was significantly associated with costs, such that a 20% increase in FI-CGA score was associated with a 13% increase in hospital costs. The median FI-CGA of 0.30 was high in comparison to previous studies involving older adults that were not hospitalized (25, 40). This may have resulted from the patients' acute illnesses since the frailty index was measured at admission. Simlar to the ASA score and operative severity, frailty is not modifiable in the acute setting (77) but could be used to develop predicitive models of costs. While many of the items in the FI-CGA are not routinely measured during admission to a surgical service, a frailty index can be created using data from administrate databases given that there are enough available deficits measured (22, 43, 75).

Complications are consistently found to be associated with increased health care costs across a variety of settings (28, 48, 51, 63); this study was no exception. The presence and severity of complications, categorized by the Clavien classification system, was found to be the most important factor explaining the variation in costs in older adults undergoing non-elective abdominal surgery. Therefore, reduction of complications has the greatest potential for reducing costs. The primary argument for limiting complications is the benefit to the patient. An added benefit to decreasing complication rates is the reduction in health care costs incurred by the health care system and ultimately society. There are many examples in the surgical and geriatric literature of interventions aimed at decreasing complication rates, either in the form of single interventions or bundled interventions (78, 79). The varying levels of success seen with many of these interventions are accompanied by inconsistent uptake and adherence (80, 81). One example is the Enhanced Recovery After Surgery (ERAS) protocol, which has been shown to decrease length of stay, complication rates and hospital costs in elective colorectal surgery (82, 83). Implementation and adherence was highly variable between centers (80). There is evidence that even a modest reduction in complication rates could result in significant cost reduction. A US study estimated that a 5% relative reduction in postoperative complications would be associated with an annual decrease of $31 million (0.008%) in Medicare payments due to readmissions for general surgery patients (19). If health care costs allocated to the care of older adults (65 years and older) were reduced by the same proportion in Canada, the total annual cost reduction would be approximately $6.6 million (2009 CAD). The potential to decrease complications and costs in this patient population is unclear and further research is required.

Interestingly, age was not associated with costs when controlling for other factors. Increasing age has been shown to be associated with increasing health care costs in other studies of patients undergoing abdominal surgery (9, 10, 12, 23, 24). However, another study found that age was no longer associated with health care costs once they adjusted for multiple other factors (28). This suggests age is a marker for other factors that contribute to increased costs, such as increased frailty or ASA classification. In the present study, age was not associated with health care costs in either univariate or multivariate analyses. It may be that the age range in this study was too narrow to demonstrate an effect of age on costs. If younger adult patients were included we would expect to see an association between age and costs; however that association may be diminished when taking other factors into consideration.

The four perioperative factors associated with costs in this study together explained 57% of the variation in costs for this patient population. These factors represent a potential cost predictor model, which could be used for cost forecasting during budgetary planning and for stratifying patient populations based on expected resource use intensity (20). An analytic approach to cost forecasting using expected patient characteristics and outcomes can improve forecasting accuracy, leading to more efficient allocation of resources (84, 85). Identifying patients within surgical departments who are likely to have higher health care costs can help to focus cost containment strategies (20, 85). For example, it is more efficient to use cost containment strategies only for those patients who are predicted to have a resource intense hospital admission; not for patients expected to have low cost admissions (85). These four perioperative factors are not suited to use as a health risk model, because the model includes operative severity and complications which are influenced by practice patterns. Health risk models can be used to adjust for factors unrelated to provider proficiency or efficiency, allowing for an adjusted comparison of provider performance and adjusted provider payment (20).

Breaking down costs allows administrators and researchers to identify higher cost areas to target for efficiency assessment and development of cost control strategies. The largest proportion of hospital costs in this cohort was non-procedural costs. This includes physician consultation fees, physician attending fees, allied health care personnel salaries, ward/intermediate care bed costs (which includes nursing and support staff salaries), medication costs, total parenteral nutrition costs, laboratory costs and blood product costs. By far the largest subcategory of costs was bed costs. Unnecessary days on the ward accounted for 4.8% of the total hospital costs in this patient cohort. Therefore, reducing the number of unnecessary days in hospital would result in decreased costs and improved efficiency. This may be accomplished by using fast track protocols for those patients who are predicted to have resource intense hospital stays. Fast track protocols have been shown to significantly reduce length of stay, complication rates and hospital costs in elective colorectal surgery (82, 83). Further research is required to determine whether the same results would be found in a non-elective setting.

Intensive care costs contributed considerably less to the median cost per patient; however, costs were highly variable, with a small number of patients incurring high costs. Only 6.1% of patient-days were spent in the intensive care unit, but 17% of total costs were incurred there. Again, the largest cost subcategory for intensive care costs was bed costs. It may be that a reduction in the rate of postoperative complications would decrease the need for intensive care, but this would require further research into the relationship between complications and intensive care while controlling for other patient factors. This study did not include identification of predictors of clinical outcomes. A clinical predictive model could be paired with the proposed cost prediction model to identify patients that are likely to have poor outcomes and high costs to inform clinical decision making, including end-of-life decision making (86). However, the question of the appropriateness of intensive care among high risk individuals, is an ethical issue and outside the scope of this paper (87).

### 3.4.1 Limitations

This study represents a heterogenous population of older adult patients. This study includes a spectrum of procedures from low morbidity procedures such as laparoscopic cholecystectomy and laparoscopic appendectomy to high morbidity procedures such as exploratory laparotomy for severe trauma or septic shock due to large bowel perforation. Thus, expected rates of complication and mortality vary greatly between diagnosis groups. While potentially advantageous when considering the entire acure care surgery service, caution should be used when applying the results of this study to one particular diagnosis group.

To calculate the FI-CGA a standardized, validated Comprehensive Geriatric Assessment was administered shortly after admission. Nevertheless, patients may have attempted to overestimate their health due to a response bias. Attempts were made to limit this bias by acquiring collateral information from family members and the medical record when possible. Complications were identified and categorized prior to calculation of patient-level costs in order to limit measurement bias.

Patient-level resource tracking is the most accurate method of estimating health care costs (58); however, some measurement bias and error still exist when calculating hospital health care costs. Bed costs are top down estimates calculated taking the annual costs of nursing remuneration and ward stock (disposable supplies stocked on the ward) for a particular ward and dividing by the number of patients cared for on that ward in the previous year. Because the bed costs are average costs they tend to underestimate the daily costs of a patient who requires intensive nursing care or large amounts of ward stock. Conversely, bed costs overestimate the daily costs of patients requiring little nursing care or ward stock. Also, patients being transferred from or transferred to hospitals outside of the health region was excluded from the study since it was impractical to track resource utilization at these other hospitals. Since the costs of readmission were not included, the study underestimated the costs of patients who were readmitted to the study hospital.

### 3.5 Conclusions

This study examined perioperative factors associated with total direct hospital health care costs and identified high cost aspects of care for older adult patients undergoing non-elective abdominal surgery. ASA classification, operative severity, frailty and complications are perioperative factors most strongly associated with health care costs. Together they could be useful to forecast costs in similar patient populations and are important factors to consider in identifying patients with high predicted resource utilization. Reducing complication rates is an important target for cost reduction. Reducing or eliminating unnecessary days in hospital would reduce costs.

Figure 3.1 Patient selection and recruitment flowchart for patients admitted to the acute care surgery service, QEII Health Sciences Centre, July 2011 to September 2012.

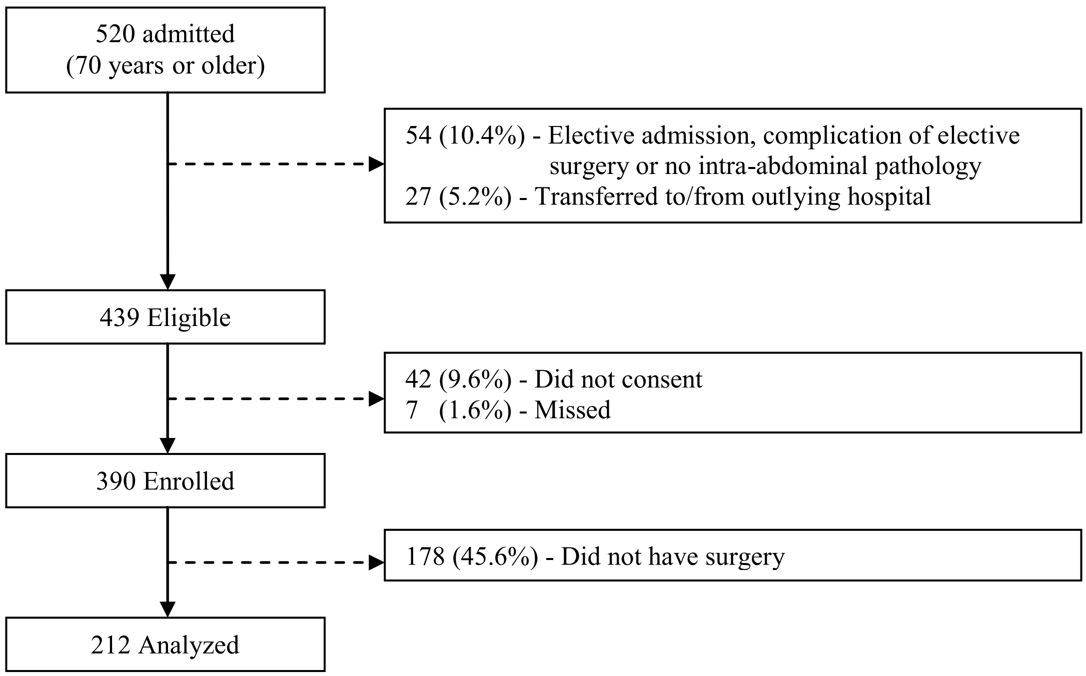
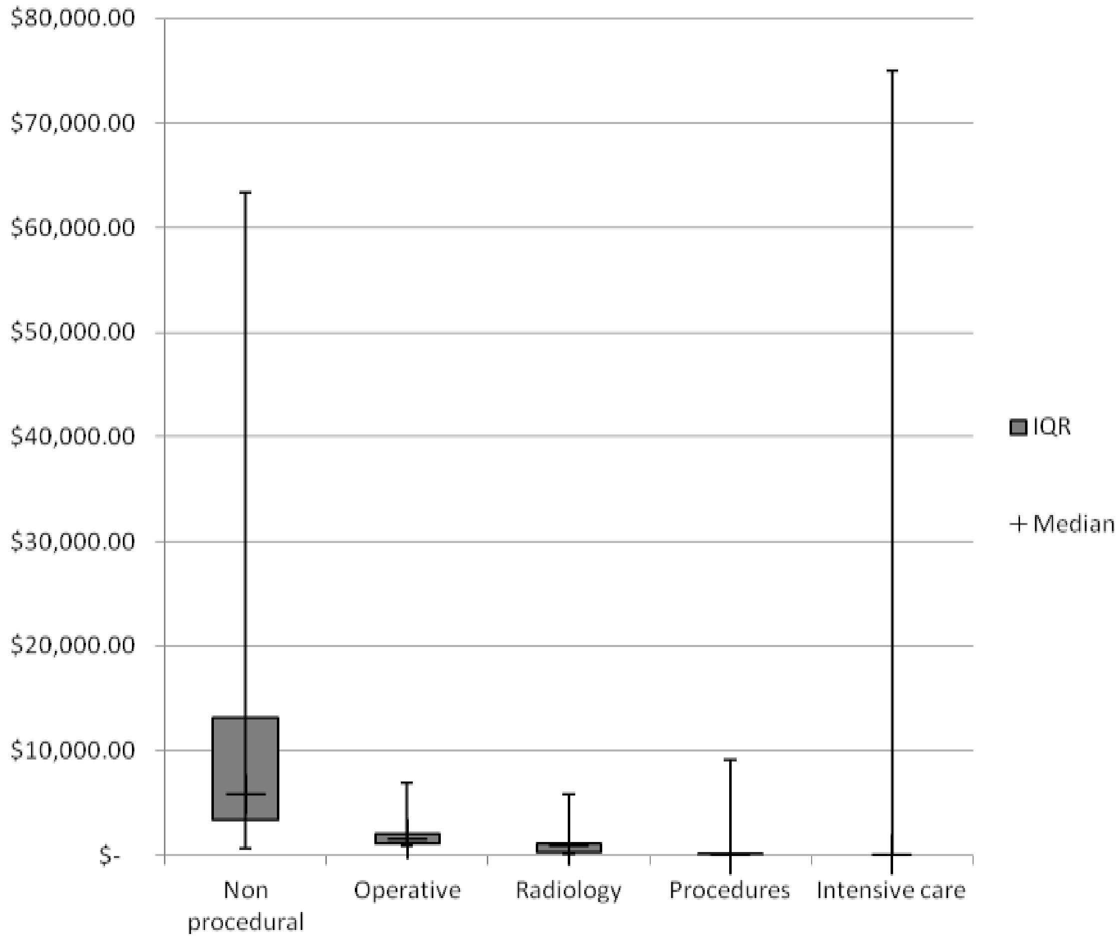


Figure 3.2 Box and whisker plot of cost categories showing median, interquartile range, minimum and maximum values for non-elective abdominal surgery patients in QEII Health Sciences Centre, July 2011 to September 2012 (2012 $CAD).




IQR = Interquartile Range

Table 3.1 Characteristics of patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Characteristic | N=212 | |
|---|---|---|
| Age (median,range) | 78 | (70-97) |
| Sex (n, % female) | 112 | (52.8) |
| Frailty Index at admission (median,range) | 0.30 | (0.16-0.51) |
| ASA classification (n, %) | | |
| I | 5 | (2.4) |
| II | 82 | (38.7) |
| III | 99 | (46.7) |
| IV | 22 | (10.4) |
| V | 4 | (1.9) |
| Operative severity (n, %) | | |
| Grade 1 | 77 | (36.3) |
| Grade 2 | 108 | (50.9) |
| Grade 3 | 27 | (12.7) |
| Common Diagnoses (n, %) | | |
| Acute cholecystitis | 36 | (17.0) |
| Small bowel obstruction (adhesive) | 27 | (12.7) |
| Large bowel obstruction (malignant) | 18 | (8.5) |
| Pancreatitis (gallstone) | 14 | (6.6) |
| Incarcerated groin hernia | 13 | (6.1) |
| Common procedures (n, %) | | |
| Laparascopic cholecystectomy | 48 | (22.6) |
| Right hemicolectomy | 28 | (13.2) |
| Lysis of adhesions | 27 | (12.7) |
| Inguinal hernia repair | 18 | (8.5) |
| Small bowel resection | 12 | (5.7) |

ASA = American Society of Anesthesiologists

Table 3.2 Breakdown of mean, median and total direct hospital costs (2012 $CAD) by cost category for patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Cost Category | n | Hospital costs per patient | | | Total for all patients | |
|---|---|---|---|---|---|---|
| | | Mean $CAD | Median $CAD, (IQR) | | $CAD, (%) | |
| Total costs | 212 | 16,536 | 9,166 | (13,241) | 3,372,703 | (100) |
| Non procedural | 212 | 10,268 | 5,447 | (9,356) | 2,176,875 | (65) |
| Resident | | 137 | 85 | (96) | 28,975 | (1) |
| Consultant fees | | 130 | 0 | (146) | 27,662 | (1) |
| Allied Health | | 299 | 97 | (304) | 63,370 | (2) |
| Bed costs (Ward/Intermediate care)* | | 7,961 | 4,410 | (6,351) | 1,687,749 | (50) |
| Medications | | 177 | 76 | (119) | 37,463 | (1) |
| Total parenteral nutrition | | 131 | 0 | 0 | 27,702 | (1) |
| Laboratory investigations | | 629 | 364 | (468) | 133,286 | (4) |
| Blood products | | 805 | 0 | (146) | 170,707 | (5) |
| Operative | 212 | 1,717 | 1,484 | (835) | 364,063 | (11) |
| Room costs† | | 383 | 333 | (120) | 81,188 | (2) |
| Disposables | | 230 | 218 | (393) | 48,815 | (1) |
| Surgeon/resident fees | | 695 | 602 | (181) | 147,276 | (4) |
| Anesthetist fees | | 409 | 320 | (258) | 86,784 | (3) |
| Radiology | 212 | 1,026 | 884 | (922) | 217,597 | (6) |
| Procedures | 212 | 281 | 0 | (154) | 59,644 | (2) |
| Intensive care | 212 | 2,942 | 0 | 0 | 554,523 | (16) |
| Intensive care (only ICU patients) | 46 | 12,054 | 8,101 | (7,118) | | |
| Attending physician /resident | | 2,515 | 1,741 | (758) | 115,687 | (3) |
| Bed costs* | | 9,450 | 6,300 | (6,300) | 434,700 | (13) |
| ICU infusions | | 90 | 60 | (60) | 4,136 | (0) |

* Bed costs included direct supplies (dressings, saline, other ward stock) and compensation (Registered Nurses (RN), Licensed Practical Nurses (LPN), unit aids, booking clerks)

† Operating room facility costs were assigned using a base rate (for pre-admission nursing, preoperative nursing, the patient attendant, the anesthesia technician, anesthesia supplies and post-anesthetic care unit nursing) and an hourly rate (for intra-operative nursing)

$ CAD = Canadian Dollars

IQR = Interquartile Range

ICU = Intensive Care Unit

Table 3.3 Univariate and multivariate associations between perioperative factors and hospital health care costs (2012 $CAD) for non-elective abdominal surgery patients in QEII Health Sciences Centre, July 2011 to September 2012.

| Perioperative Factors | n | Univariate Hospital costs Median $CAD, (IQR) | | Multivariate Adjusted hospital costs† Median $CAD, (IQR) | | p value | Standardized β coefficient |
|---|---|---|---|---|---|---|---|
| Age* | | | | | | | |
| 70-79 | 142 | 8,101 | (12,529) | 10,954 | (1,433) | 0.5330 | -0.0258 |
| 80-89 | 58 | 13,566 | (14,350) | 10,127 | (2,124) | | |
| >90 | 12 | 11,501 | (13,727) | 11,574 | (5,301) | | |
| ASA | | | | | | | |
| I | 5 | 6,647 | (1,537) | 10,515 | (7,569) | 0.0010 | 0.1856 |
| II | 82 | 6,266 | (3,886) | 8,789 | (1,619) | | |
| III | 99 | 11,966 | (14,837) | 11,622 | (1,827) | | |
| IV | 22 | 24,436 | (24,441) | 15,803 | (5,574) | | |
| V | 4 | 35,755 | (59,530) | 12,230 | (10,209) | | |
| Operative Severity | | | | | | | |
| Grade 1 | 77 | 5,061 | (2,813) | 7,584 | (1,383) | <0.0001 | 0.2486 |
| Grade 2 | 108 | 13,566 | (16,367) | 13,156 | (1,964) | | |
| Grade 3 | 27 | 12,512 | (11,483) | 13,001 | (3,794) | | |
| FI-CGA* | | | | | | | |
| <0.24 | 40 | 5,389 | (3,601) | 7,467 | (1,911) | 0.0002 | 0.2068 |
| 0.24-0.27 | 44 | 7,464 | (6,140) | 10,139 | (2,409) | | |
| 0.28-0.32 | 42 | 7,376 | (12,119) | 10,532 | (2,502) | | |
| 0.33-0.37 | 43 | 14,204 | (14,033) | 12,106 | (2,866) | | |
| >0.37 | 43 | 20,643 | (31,585) | 14,542 | (3,822) | | |
| Clavien | | | | | | | |
| No complication | 95 | 5,845 | (4,316) | 7,861 | (1,366) | <0.0001 | 0.4060 |
| Grade I | 34 | 9,937 | (9,819) | 9,219 | (2,467) | | |
| Grade II | 34 | 18,819 | (17,384) | 13,584 | (3,590) | | |
| Grade III | 12 | 16,978 | (9,104) | 14,178 | (6,279) | | |
| Grade IV | 25 | 31,402 | (52,550) | 23,113 | (7,356) | | |
| Grade V | 12 | 21,472 | (24,962) | 15,807 | (7,530) | | |

* Age and Frailty Index were treated as log transformed continuous variables in linear regression models

† Adjusted for the other four perioperative factors

ASA = American Society of Anesthesiologists Classification

FI-CGA = Frailty Index based on a Comprehensive Geriatric Assessment. Listed as quintiles in this table.

Clavien = Clavien Complication Classification

$CAD = Canadian Dollars

IQR = Interquartile range

# CHAPTER 4

# THE IMPACT OF ADVERSE EVENTS ON HEALTH CARE COSTS FOR OLDER ADULTS UNDERGOING NON-ELECTIVE ABDOMINAL SURGERY

## ABSTRACT

**BACKGROUND**

There is concern about the increase in health care spending in Canada as a proportion of the gross domestic product (GDP). A large proportion is allocated to care of older adults and the rate of population aging is expected to increase. Older adults are more likely to experience adverse events after non-elective surgery than younger patients and adverse events after surgery are associated with increased health care costs among older adult patients. The strength of the association between adverse events and hospital costs for older adults undergoing non-elective surgery remains unclear.

**OBJECTIVE**

The primary objective of this study was to examine the relationship between in-hospital costs and adverse events (postoperative complications, mortality and change in living arrangement).

**METHODS**

This study was an observational prospective cohort study. Over a 15 month period all patients 70 years or older who underwent non-elective abdominal surgery were enrolled. Data were collected regarding patient demographics, investigations, treatments and outcomes. Patient-level resource tracking was used to calculate direct hospital health care costs (2012 $CAD). The associations between adverse events and costs were assessed using univariate non-parametric tests and multiple linear regression.

**RESULTS**

During the study period 212 patients underwent abdominal surgery (median age 78 years (range 70-97)). The median costs of care were $9,166 (range $1,993-$104,403). The number of unnecessary patient-days was 386/2,742 (14.1%) on the ward, 12/224 (5.4%) in the intermediate care unit and 8/161 (5.0%) in the intensive care unit. When controlling for age, American Society of Anesthetists (ASA) classification, operative severity and frailty using multivariate analysis non-fatal complication ($p<0.0001$), a change in living arrangement ($p=0.0002$), and mortality ($p=0.0337$) were independently associated with health care costs. The estimated median costs attributable to experiencing a grade I to IV complication were $2,441, $5,956, $8,918, and $16,916, respectively, with all levels accounting for 31% of the total costs in this cohort. A 46% increase in costs for patients experiencing a change in living arrangement was estimated to have attributable costs of $6,325, accounting for 11% of the total costs in this cohort. In-hospital mortality was associated with a 44% increase in costs, with attributable costs of $7,123, which accounts for 4% of the total costs in this cohort. Patients who required a change in living arrangement at discharge had significantly more unnecessary days in hospital (median 1.5 days versus 0.0 days, $p<0.0001$).

**CONCLUSION**

Accurate cost estimates help health administrators to estimate the magnitude of cost reduction expected with proposed strategies. Complications and need for a change in living arrangement were strongly associated with costs. Decreasing major complications and reducing unnecessary days in hospital, particularly for patients who require a change in living arrangement at discharge, could lead to a significant reduction in costs.

## 4.1 INTRODUCTION

The Canadian population is aging with the proportion of adults 65 years or older expected to double and the proportion 80 years or older expected to triple by 2050 (4). There is concern that this will place considerable strain on the health care system since a large proportion of the health care budget is allocated care of older adults. In 2009, 44% of the total health care budget was spent on care of people 65 years or older although they accounted for only 14% of the population (61). Certain areas of health care are associated with higher costs. One of those areas is emergency abdominal surgery in older adults, which is associated with higher costs than both elective surgery in older adults and emergency surgery in younger adults (6-9, 24). This is relevant since older adults are more likely to undergo emergency abdominal surgery as they age (27). A recent analysis of the National Surgical Quality Improvement Program (NSQIP) database found that patients 65 years or older accounted for 26.2% of emergency abdominal surgery procedures, although they accounted for only 14% of the population (13).

The increased costs associated with emergency abdominal surgery in older patients may be due to postoperative adverse events. Several studies have found that adverse events, such as postoperative complications, mortality, and change in living arrangement, are more common after non-elective surgery in older adults, compared to older adults undergoing elective surgery (6, 7, 27, 88) or younger adult patients undergoing non-elective surgery (13, 89-91). Complications have consistently been associated with increased health care costs across a variety of settings (28, 48, 51, 63). However the relationship between adverse events and costs in the setting of non-elective abdominal surgery in older adults has not been well studied. Prior surgical costing studies have typically utilized administrative data, which limits the accuracy of cost estimation and clinical information (92). Additionally, studies often consider adverse events in isolation without adjusting for other relevant perioperative factors. Lastly, few studies have specifically studied older adults or non-elective surgery. Therefore, the purpose of the present study was to examine the relationship between postoperative adverse events (complications, in-hospital mortality, and change in living arrangement at discharge) and hospital health care costs for older adults undergoing non-elective abdominal surgery.

## 4.2 METHODS

### 4.2.1 Design

This study was an observational prospective cohort study assessing the relationship between adverse events and direct inpatient health care costs.

### 4.2.2 Selection criteria

All patients 70 years or older who were admitted to an acute care surgery service at a tertiary care teaching hospital (QEII Health Sciences Centre, Halifax) between July 1, 2011 and September 30, 2012 and underwent non-elective abdominal surgery procedures were prospectively enrolled in this study. Only patients with intra-abdominal or abdominal wall conditions were included. Patients who required treatment for a complication resulting from a prior elective procedure were excluded. Patients that were transferred from or transferred to an acute care hospital bed in an outlying hospital were also excluded from this study due to an inability to track resource utilization in those hospitals.

### 4.2.3 Perioperative factors and adverse events

Patients were enrolled within 48 hours of admission to hospital. At the time of enrollment a comprehensive geriatric assessment (CGA) was completed. The CGA captures information on patient demographics, Frailty Index based on a Comprehensive Geriatric Assessment (FI-CGA) (40) and living arrangement. Following the patients' discharge from hospital, a standardized, comprehensive review of the inpatient medical record was performed to collect data regarding course in hospital, operative variables (American Society of Anesthiologists (ASA) classification and operative severity), complications and resource utilization. ASA classification was taken from the anesthesiologist's preoperative assessment (33, 34). Operative severity (OS) was categorized according to the Saxton and Velanovich classification (64). This classifies procedures on a three level ordinal scale based on invasiveness and benign versus malignant disease (64).

Complications were defined as any deviation from the normal postoperative course and categorized according to the Clavien classification system (50). The scale categorizes complication severity from one to five based on the type of therapy initiated in response to the complication. Complications were identified and graded by one of the study investigators (JB or PD) based on a review of the medical record. Only in-hospital complications were used in this study.

Pre-admission living arrangement was divided into five categories (living alone, living with others, semi-independent housing, nursing home and inpatient greater than two weeks). Discharge destination was recorded from the medical record. At discharge living arrangement was divided into six categories (living alone, living with others, semi-independent housing and nursing home, restorative care [inpatient physiotherapy/occupational therapy] and continued hospitalization). Change in living arrangement was defined as inability to return to the patient's pre-admission living arrangement and need for increased assistance, representing a loss of independence (e.g a change from living alone to living with others, a change from semi-independent housing to nursing home).

4.2.4 Cost Calculation

Direct medical costs calculated from the perspective of the hospital (payer) were included. Direct medical costs borne by the patient and indirect (lost productivity) costs were excluded. Costs were estimated by patient-level resource tracking (tracking resource utilization and multiplying by a unit cost for each resource). The episode of care for this study was defined as being from admission to the acute care surgical service until either discharge from hospital, 90 days following admission, or death. Only costs incurred during the episode of care were calculated. Costs incurred after 90 days were truncated. It was not feasible to obtain costs due to readmission at outlying hospitals therefore to limit measurement bias, only costs from the index hospitalization were used in this analysis. All costs were in 2012 Canadian Dollars ($CAD).

The majority of unit cost estimates were based on an exact count. When this was not possible or feasible cost estimates were based on time intervals. During the review of the medical record, the exact number of resources used in each of the following categories was counted: diagnostic imaging, laboratory investigations, non-operative interventional procedures, blood products, consultations, physician fees, antibiotics, anticoagulants and operative disposables. These counts were later double checked for errors in extraction or transcription.

The following cost estimates were assigned based on units of time. Bed costs for ward, intermediate care and intensive care were assigned on a daily basis; bed costs included direct supplies (dressings, saline, other ward stock) and compensation (Registered Nurses (RN), Licensed Practical Nurses (LPN), unit aids, booking clerks). Operating room facility costs were assigned using a base rate (for pre-admission nursing, preoperative nursing, the patient attendant, the anesthesia technician, anesthesia supplies and post-anesthetic care unit nursing) and an hourly rate (for intra-operative nursing). Medication costs for analgesics and antiemetics outside of the operating room, and intensive care infusions were assigned on a daily basis. Daily averages for these medications were calculated by performing an exact count of medication dosages for the first 25 patients.

Specific unit costs that were dependent on institutional agreements with private companies or unions were obtained from department managers and from the central finance department (such as capital acquisition costs, staff wages and disposable equipment). Laboratory investigation prices were taken from the Capital District Health Authority Laboratory Test Price List, which are used to bill the Nova Scotia government for insured persons (65). Prices for blood products were obtained directly from Canadian Blood Services (66, 67). Physicians' fees were taken directly from the Nova Scotia Medical Services Insurance physician billing manual, which is used to determine physician billing in the province of Nova Scotia (68). Bed costs were based on a top down estimate from the central finance department. Medication costs were obtained from the pharmacy department.

The cost of unnecessary patient-days was also estimated. The number of unnecessary days in hospital was defined as the difference between the actual discharge date and the date when the clinical team documented in the chart that the patient was medically ready to leave hospital. The same definition was used for the intermediate care unit (IMCU) and the intensive care unit (ICU). By definition, no medical treatment was necessary after the patient was deemed medically ready for discharge. Therefore, the excess cost of unnecessary days on the ward was estimated by multiplying the number of patient-days by the ward bed costs. The excess cost for unnecessary IMCU patient-days was estimated using the difference between IMCU bed costs and ward bed costs, since all other hospital costs were the same. Similarly, the excess cost for unnecessary ICU patient-days was estimated using the difference between ICU bed costs and IMCU bed costs.

### 4.2.5 Statistical Analysis

The differences in costs between binary adverse outcomes (mortality and change in living arrangement) were compared using Wilcoxon rank sums test. The Kruskal-Wallis test was used to compare cost distributions between each Clavien complication level (grade one to four). Then to assess the relationship between these adverse outcomes a multiple linear regression was performed, controlling for other factors (age, American Society of Anesthesiologists [ASA] classification, operative severity [OS] and Frailty Index based on a Comprehensive Geriatric Assessment [FI-CGA]). These were factors that have previously been identified in the literature as being significantly associated with health care costs (10, 12, 22, 24, 28, 36, 48, 49, 62). The multiple linear regression included a binary or ordinal variable for each of the adverse outcomes (Cost = age + ASA classification + operative severity + FI-CGA + change in living arrangement (yes/no) + complication (Clavien one to four) + in-hospital mortality (yes/no)). Adjusted median costs were calculated by exponentiating the least squares means of the log-transformed total costs using general linear models. Descriptive statistics were used to elaborate the severity and type of postoperative complications and cause of postoperative mortality.

The increase in costs associated with each level of an ordinal factor can be calculated by exponentiating the β coefficient (e.g. x unit increase in complication severity results in exp(coefficient) increase in cost) (69-71). Costs attributable to each adverse event were calculated using a regression based approach (93). For example, predicted costs were calculated for the subset of patients that experienced a complication using the β coefficients from the multiple linear regression described above. The predicted cost calculation was then repeated assuming that each patient did not experience a complication (Clavien=0). The difference between these two estimates represents the cost attributable to in-hospital complications.

## 4.3 Results

During the 15 month study period, 520 patients aged 70 years and older were admitted to the acute care surgery service (Figure 4.1). Fifty four patients (10.4%) were excluded because they met one of the following exclusion criteria: admitted on an elective basis, presenting with a complication from elective surgery, or did not have intra-abdominal or abdominal wall pathology. Twenty seven patients (5.2%) were excluded because they were transferred from an outlying hospital, leaving 439 eligible for the study. Forty two patients (9.6%) did not consent to participate. Seven patients (1.6%) were missed because they were either discharged or died in less than 24 hours from admission. One hundred seventy eight (45.6%) patients did not undergo surgery. The final cohort consisted of 212 patients who underwent non-elective abdominal surgery during the study period.

Patient characteristics are presented in Table 4.1. Most patients had an ASA classification (181 [85.4%]) of II or III and most patients had a procedure for benign disease (185 [87.2%]) giving an operative severity of 1 or 2. The median length of stay was 8.0 days (IQR 4.0-16.5). The total number of days in hospital for all patients was 3,127, with 2,742 (87.7%) patient-days on the ward, 224 (7.2%) patient-days in the intermediate care unit (IMCU) and 161 (5.1%) patient-days in the intensive care unit (ICU). The number of unnecessary patient-days (defined as days after being determined medically ready for discharge until actual discharge from hospital) was 386/2,742 (14.1%) on the ward, 12/224 (5.4%) in the IMCU and 8/161 (5.0%) in the ICU.

During their hospital stay, 110 (51.9%) patients experienced a non-fatal complication (69 [32.5%] minor and 41 [19.4%] major). This includes non-fatal complications experienced by the patients who later died in hospital. Fourteen (6.6%) patients died in hospital. In-hospital complications are listed by grade in Table 4.2. Of the 14 patients that died in hospital, 12 died due to a postoperative complication. The remaining two died due to pre-existing comorbidities and the presenting disease process. Major complications (Clavien three or four) were more common among the patients who died in hospital (43%) than patients who did not die in hospital (18%) (p=0.0326). Patients that died in hospital were admitted to the ICU (13 [93%] versus 33 [17%], p<0.0001) and spent significantly more days admitted in the ICU (median 2.0 days versus 0.0 days, p<0.0001) than patients who did not die in hospital.

Table 4.3 shows pre-admission and discharge living arrangements for the study cohort. Overall 48 patients (22.6%) experienced a change in living arrangement, indicating a loss of independence. Patients who required a change in living arrangement at discharge had a significantly longer median hospital stay (19.0 days versus 6.5 days, p<0.0001) and stayed significantly more unnecessary days in hospital (median 1.5 days versus 0.0 days, p<0.0001) than patients who returned to their pre-admission dwelling.

The median total direct hospital health care costs were $9,166 (range $1,993-$104,403). Hospital costs for the entire cohort of 212 patients totaled $3,372,703. Of the five main cost categories, non-procedural costs contributed the largest amount to total costs ($2,176,875), followed by intensive care costs ($554,523), operative costs ($364,063), radiology costs ($217,597) and non-operative procedural costs ($59,644). Unnecessary days in the ward, IMCU and ICU accounted for an estimated cost of $170,226 (5.0%), $3,708 (0.1%) and $10,800 (0.3%), respectively.

The median costs of care were significantly greater for patients who died in hospital ($21,472 versus $8,298, p=0.0002; Table 4.4). Likewise, median costs were increased for those that experienced a change in living arrangement ($20,650 versus $7,578, p<0.0001). The severity of complications graded by the Clavien classification was significantly associated with health care costs (p<0.0001; Table 4.4). Multivariate analysis confirmed this relationship between the Clavien classification and costs (p<0.0001), change in living arrangement and costs (p=0.0006), and mortality and costs (p=0.0337; Table 4.5). Exponentiating the β coefficient shows that, while controlling for other factors, each level of the Clavien classification from one to four was associated with a 27% increase in total health care costs. In-hospital mortality was associated with a 44% increase and a change in living arrangement was associated with a 46% increase in costs. The costs attributable to experiencing a complication, in-hospital mortality or a change in living arrangement are listed in Table 4.5. In terms of total costs this would amount to $1,030,339 (31%), $125,469 (4%) and $356,753 (11%) attributable to complications, in-hospital mortality and change in living arrangement in this cohort, respectively.

## 4.4 DISCUSSION

Given the aging population and increasing costs associated with care of older adults, strategies are needed to control health care spending and ensure that resources are used efficiently. Examining the relationship between adverse events and costs may help providers and administrators identify potential targets for cost reduction. Non-elective abdominal surgery in older adults is associated with higher health care costs and higher rates of adverse events than in younger patients, yet prior costing studies have not focused on this patient population. This study used patient-level cost data to examine the relationship between adverse events (complications, mortality, and change in living arrangement) and inpatient direct health care costs.

In this cohort complications were significantly associated with health care costs, even while controlling for other perioperative factors. This is in keeping with results from previous surgical studies involving adults of all ages undergoing elective abdominal surgery (28, 48). Dimick and colleagues used the hospital accounting system and adverse event data from the National Surgical Quality Improvement Program (NSQIP) database to determine attributable costs for several complications experienced by adults undergoing elective general and vascular surgery (51). They found that attributable costs were greatest for respiratory complications ($52,466 USD) followed by thromboembolic ($18,310), cardiovascular ($7,789), and infectious complications ($1,398) (51). The results of the present study were similar in that grade IV complications were associated with the greatest increase in costs and were most commonly (70%) due to respiratory failure.

Advanced age is a recognized risk factor for postoperative respiratory complications, but there are several strategies to reduce the risk of respiratory complications both from a surgery and anesthetic point of view (94, 95). These strategies include minimally invasive rather than open surgery, judicious use of respiratory depressant anesthetics and neuromuscular blocking agents, selective intraoperative nasogastric decompression and noninvasive ventilation when possible (94, 95). Avoiding excessive opioid use in the postoperative period may decrease the rate of respiratory depression (96). Similarly, there are strategies to reduce other complications that were common in the study group including ileus (96, 97), urinary tract infection (98), delirium (79), and wound infections (99, 100).

The estimated median costs attributable to experiencing a grade I to IV complication was $2,523, $5,913, $9,033, and $16,553, respectively, with all levels accounting for 30% of the total costs in this cohort. The cost of complications as a proportion of total costs for a surgical population has not been reported previously. However, a recent study of older adults (65 years or older) undergoing elective general and vascular surgery found that the readmission rate and cost of readmissions are significantly greater for patients who experienced a complication in hospital. They estimated that a 5% reduction in postoperative complications would result in a cost reduction of $31 million to the Medicare system in the US annually (0.008% of total Medicare payments in 2006) (19). If health care costs allocated to the care of older adults (65 years and older) were reduced by the same proportion, the total annual cost reduction would be approximately $6.6 million (2009 CAD). The potential to decrease complication and costs in this patient population is unclear and further research is required.

Previous studies examining the relationship between living arrangement and costs in the geriatric literature have focused on comparing costs between skilled nursing home care and home or community based care. While studies in the United States have found higher associated costs for nursing home care, they did not address how a change in living arrangement upon discharge from hospital might influence in-hospital health care costs (101, 102). One study examined costs associated with inpatient rehabilitation in a cohort where 70% of the patients were 65 years or older and found that a change in living arrangement was associated with increased inpatient rehabilitation costs while controlling for other patient and hospital factors (103). Although the present study did not consider the cost of rehabilitation services, hospital health care costs were significantly higher for patients that experienced a change in living arrangement (suggesting a loss of independence and a need for increased assistance), even when controlling for other factors including postoperative complications. This 46% increase in costs for patients experiencing a change in living arrangement was estimated to have median attritible costs of $6,325, accounting for 10% of the total costs in this cohort. A change in living arrangement was associated with a longer hospital stay and significantly more unnecessary days in hospital, suggesting that the increased costs were due to days spent waiting for their new dwelling to be made ready. It is possible that costs could be reduced by streamlining the organization of discharge living arrangement. However, it is unclear whether this delay is due to a deficiency of nursing and semi-independent care beds necessitating infrastructure development or due to an internal problem with coordinating consulting services in the hospital requiring early identification of patients likely to require a change in living arrangements. Further research will be needed to determine why this delay exists and how best to reduce delays.

The literature regarding the relationship between mortality and costs has been split in surgical studies. Early general surgery costing studies demonstrated a relationship between in-hospital mortality and costs (6, 7). A recent study of major elective abdominal surgery, found that costs associated with in-hospital mortality were significantly higher than complications requiring an invasive procedure but significantly lower than complications resulting in organ failure (28). An ecological study comparing costs between inpatient surgical departments of different hospitals found that mortality rates were not related to mean costs of care at a surgical department level (63). In the present study, in-hospital mortality was associated with significantly increased health care costs. This increase in cost was due in part to intensive care costs, with patients who died in hospital being admitted to the ICU more often and for a longer period of time than patients who did not die in hospital.

The increased costs associated with mortality suggest that the expectations regarding care at the end of life need to be re-evaluated. It is justifiable to pursue expensive treatments if there is a reasonable expectation of a meaningful recovery. However, while "the value of life is infinite or incalculable, only finite resources are available" (104). Social welfare can be maximized by allocating resources to the treatments that are most cost-effective and to those patients most likely to receive the greatest benefit. The problem is that providers do not yet have a reliable way to predict mortality early in each hospital admission (105). Mortality prediction models have been inadequate to use without substantial clinical judgement, leaving families and providers in a difficult situation (105). Patients in this study that died in hospital experienced significantly more major complications prior to passing away and significantly more time in the intensive care unit, which is a high cost area. If providers were able to predict in-hospital mortality or a functional outcome that was unacceptable to the patient earlier in the hospital admission, the focus of care could be shifted to palliation earlier leading to better palliation and coincidental cost reduction.

### 4.4.1 Limitations

This study represents a heterogenous population of older adult patients. This study includes a spectrum of procedures from low morbidity procedures such as laparoscopic cholecystectomy and laparoscopic appendectomy to high morbidity procedures such as exploratory laparotomy for severe trauma or septic shock due to large bowel perforation. Thus, expected rates of complication and mortality vary greatly between diagnosis groups. While potentially advantageous when considering the entire acute care surgery service, caution should be used when applying the results of this study to one particular diagnosis group.

To collect preoperative patient characteristics a standardized, validated Comprehensive Geriatric Assessment was administered shortly after admission. Nevertheless, patients may have attempted to overestimate their health due to a response bias. Attempts were made to limit this bias by acquiring collateral information from family members and the medical record when possible. Complications were identified and categorized prior to calculation of patient-level costs in order to limit measurement bias.

Patient-level resource tracking is the most accurate method of estimating health care costs (58); however, some measurement bias and error still exist when calculating hospital health care costs. Bed costs are top down estimates calculated taking the annual costs of nursing remuneration and ward stock (disposable supplies stocked on the ward) for a particular ward and dividing by the number of patients cared for on that ward in the previous year. Because the bed costs are average costs they tend to underestimate the daily costs of a patient who requires intensive nursing care or large amounts of ward stock. Conversely, bed costs overestimate the daily costs of patients requiring little nursing care or ward stock. Also, patients being transferred from or transferred to hospitals outside of the health region were excluded from the study since it was impractical to track resource utilization at other hospitals. Since the costs of readmission were not included, the study underestimated the costs of patients who are readmitted to the study hospital. Since only 8 (3.8%) patients were readmitted to the acute care surgery service during the 3 month follow up period, this underestimation would be relatively small in magnitude.

It was beyond the scope of this paper to develop a mortality or complication prediction model. Such a model would be necessary to influence decisions about when care should be focus on treatment or palliation. Similarly, it is beyond the scope of this study to develop specific interventions to decrease complications and decrease unnecessary days in hospital; this is an area for continued research and knowledge translation.

### 4.5 Conclusion

This paper examined the relationship between adverse events (complications, mortality, and change in living arrangement) and hospital health care costs for older adults undergoing non-elective abdominal surgery using patient-level data. Examining this relationship identified potential targets for cost reduction, such as reducing major complications and reducing unnecessary days in hospital, particularly for patients who require a change in living arrangement at discharge. Non-procedural cost was the largest contributor to total costs, followed by intensive care cost. Bed costs and unnecessary days admitted to the ward and ICU contributed substantially to both these categories. Accurate cost estimates help health administrators to estimate the magnitude of cost reduction expected with proposed strategies.

Figure 4.3 Patient selection and recruitment flowchart for patients admitted to the acute care surgery service, QEII Health Sciences Centre, July 2011 to September 2012.

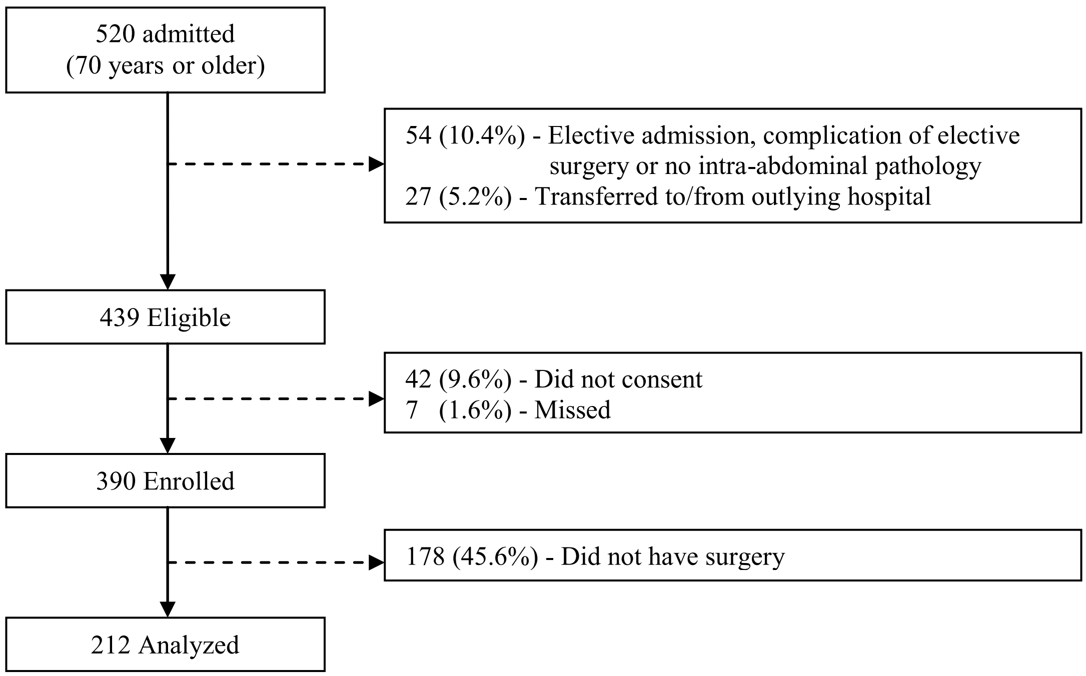


Table 4.1 Characteristics of patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Characteristic | N=212 | |
|---|---|---|
| Age (median,range) | 78 | (70-97) |
| Sex (n, % female) | 112 | (52.8) |
| Frailty Index at admission (median, range) | 0.30 | (0.16-0.51) |
| ASA classification (n, %) | | |
| I | 5 | (2.4) |
| II | 82 | (38.7) |
| III | 99 | (46.7) |
| IV | 22 | (10.4) |
| V | 4 | (1.9) |
| Operative severity (n, %) | | |
| Grade 1 | 77 | (36.3) |
| Grade 2 | 108 | (50.9) |
| Grade 3 | 27 | (12.7) |
| Common Diagnoses (n, %) | | |
| Acute cholecystitis | 36 | (17.0) |
| Small bowel obstruction (adhesive) | 27 | (12.7) |
| Large bowel obstruction (malignant) | 18 | (8.5) |
| Pancreatitis (gallstone) | 14 | (6.6) |
| Incarcerated groin hernia | 13 | (6.1) |
| Common procedures (n, %) | | |
| Laparascopic cholecystectomy | 48 | (22.6) |
| Right hemicolectomy | 28 | (13.2) |
| Lysis of adhesions | 27 | (12.7) |
| Inguinal hernia repair | 18 | (8.5) |
| Small bowel resection | 12 | (5.7) |

ASA = American Society of Anesthesiologists

Table 4.2 In-hospital complications by Clavien complication severity classification for patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Clavien Classification of Complication Severity | Complication | n | % |
|---|---|---|---|
| Grade I | | | |
| Any deviation from the normal postoperative course, without specific intervention | **Delirium** | **12** | **(35)** |
| | **Wound infection** | **6** | **(18)** |
| | **Ileus** | **4** | **(12)** |
| | Acute kidney injury | 2 | (6) |
| | Urinary retention | 2 | (6) |
| | Wound hematoma | 2 | (6) |
| | Line infection | 1 | (3) |
| | Supraventricular tachicardia | 1 | (3) |
| | Wound seroma | 1 | (3) |
| | Fall | 1 | (3) |
| | Upper gastrointestinal bleed | 1 | (3) |
| | Diarrhea | 1 | (3) |
| Grade II | | | |
| Requiring specific pharmacological intervention | **Urinary tract infection** | **10** | **(29)** |
| | **Artial fibrillation** | **8** | **(24)** |
| | **Pneumonia** | **6** | **(18)** |
| | Wound infection | 2 | (6) |
| | Diarrhea | 1 | (3) |
| | Myocardial infarct | 1 | (3) |
| | Supraventricular tachicardia | 1 | (3) |
| | High output ostomy | 1 | (3) |
| | Thrombophlebitis | 1 | (3) |
| | Pulmonary edema | 1 | (3) |
| | Artial flutter | 1 | (3) |
| | Deep venous thrombosis | 1 | (3) |
| Grade III | | | |
| Requiring surgical, endoscopic or radiological intervention | **Dehiscence** | **2** | **(17)** |
| | **Postoperative bleeding** | **2** | **(17)** |
| | **Urinary tract infection** | **2** | **(17)** |
| | Abscess | 1 | (8) |
| | Cystic duct leak | 1 | (8) |
| | Upper gastrointestinal bleed | 1 | (8) |
| | Gallstone ileus | 1 | (8) |
| | Rotator cuff injury | 1 | (8) |
| | Incarcerated inguinal hernia | 1 | (8) |
| Grade IV | | | |
| Life threatening complication involving organ dysfunction | **Respiratory failure** | **16** | **(64)** |
| | Acute renal failure | 2 | (8) |
| | Pneumonia | 2 | (8) |
| | Intra-abdominal sepsis | 2 | (8) |
| | Postoperative bleeding | 1 | (4) |
| | Pulmonary edema | 1 | (4) |
| | Meningoencephalitis | 1 | (4) |
| Grade V | | | |
| Complication resulting in death | **Intra-abdominal sepsis** | **4** | **(33)** |
| | **Pneumonia** | **2** | **(17)** |
| | Ischemic bowel | 2 | (17) |
| | Acute renal failure | 2 | (17) |
| | Postoperative bleeding | 1 | (8) |
| | Pulmonary embolism | 1 | (8) |

The most common complications in each grade are bolded

Table 4.3 Pre-admission and discharge living arrangements for patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Pre-admission Living Arrangement | n | Discharge Destination n, (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Living Alone | Living with Others | Semi-independent Housing | Nursing Home | Restorative Care | Continued Hospitalization | Deceased |
| Living Alone | 59 | 31 (53) | **12 (20)** | **1 (2)** | **2 (3)** | **5 (8)** | **5 (8)** | 3 (5) |
| Living with Others | 135 | 3 (2) | 103 (76) | - | - | **14 (10)** | **4 (3)** | 11 (8) |
| Semi-independent Housing | 10 | - | - | 6 (60) | **2 (20)** | **1 (10)** | **1 (10)** | - |
| Nursing Home | 7 | - | - | - | 6 (86) | **1 (14)** | - | - |
| Inpatient >2 weeks | 1 | - | - | - | - | 1 (100) | - | - |

Bolded numbers indicate a change in living arrangement where available care was increased, representing a loss of independence

Table 4.4 Univariate comparison of costs (2012 $CAD) between those who did and did not experience an adverse event among patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Adverse Event | n | (%) | Hospital costs $CAD Median | (IQR) | Minimum | Maximum | p value |
|---|---|---|---|---|---|---|---|
| In hospital mortality | | | | | | | |
| No | 198 | (93) | 8,298 | (13,402) | 2,135 | 107,653 | 0.0002* |
| Yes | 14 | (7) | 21,472 | (27,823) | 11,221 | 98,769 | |
| Clavien | | | | | | | |
| No complication | 102 | (48) | 6,366 | (5,807) | 2,135 | 37,919 | <0.0001† |
| Grade I | 34 | (16) | 9,937 | (11,856) | 3,153 | 85,947 | |
| Grade II | 35 | (17) | 18,214 | (17,424) | 3,725 | 81,401 | |
| Grade III | 12 | (6) | 16,978 | (9,104) | 6,256 | 55,066 | |
| Grade IV | 29 | (14) | 31,447 | (52,550) | 9,886 | 107,654 | |
| Change in Living Arrangement | | | | | | | |
| No | 164 | (77) | 7,578 | (10,918) | 2,135 | 98,769 | <0.0001* |
| Yes | 48 | (23) | 20,650 | (23,237) | 3,966 | 107,653 | |

* Wilcoxon rank sum

† Kruskal-Wallis

Clavien = Clavien Complication Classification

$CAD = Canadian Dollars

IQR = Interquartile range

Table 4.5 Adjusted and attributable costs (2012 $CAD) associated with in-hospital mortality, Clavien classification of complication severity, and change in living arrangement for patients undergoing non-elective abdominal surgery in QEII Health Sciences Centre, July 2011 to September 2012.

| Adverse Events | n | (%) | Hospital costs (2012 $CAD) Adjusted costs* Median | (IQR) | Attributable costs† Median | (IQR) | p value ‡ | Standardized β coefficient† |
|---|---|---|---|---|---|---|---|---|
| In hospital mortality | | | | | | | | |
| No | 198 | (93) | 10497 | (1627) | - | - | 0.0337 | 0.1037 |
| Yes | 14 | (7) | 15140 | (9986) | 7123 | (8133) | | |
| Clavien | | | | | | | | |
| No complication | 102 | (48) | 8234 | (1912) | - | - | <0.0001 | 0.3931 |
| Grade I | 34 | (16) | 9321 | (3629) | 2441 | (1570) | | |
| Grade II | 35 | (17) | 13466 | (5067) | 5956 | (3493) | | |
| Grade III | 12 | (6) | 14563 | (9308) | 8918 | (6179) | | |
| Grade IV | 29 | (14) | 21873 | (9392) | 16916 | (12469) | | |
| Change in Living Arrangement | | | | | | | | |
| No | 164 | (77) | 9867 | (1709) | - | - | 0.0002 | 0.1813 |
| Yes | 48 | (23) | 14431 | (4914) | 6325 | (5603) | | |

* Adjusted for age, American Society of Anesthesiologists Classification, Frailty Index based on a Comprehensive Geriatric Assessment, operative severity

† Estimated based on predicted values using multiple linear regression model (Log costs = age + American Society of Anesthesiologists Classification + Frailty Index based on a Comprehensive Geriatric Assessment + operative severity + Clavien classification of complication severity + Change in living arrangement + In-hospital mortality)

‡ Multiple linear regression model adjusting for age, American Society of Anesthesiologists Classification, Frailty Index based on a Comprehensive Geriatric Assessment, operative severity, Clavien classification of complication severity, change in living arrangement, in-hospital mortality

Clavien = Clavien Complication Classification

$CAD = Canadian Dollars

IQR = Interquartile range

# CHAPTER 5 CONCLUSION

A rapidly aging population has raised concerns about health care spending and an interest in understanding the factors associated with increased health care cost, particularly in high cost areas such as non-elective abdominal surgery (24, 62, 106). This study examined the relationship between perioperative factors (age, ASA, OS, FI-CGA), adverse events (complication severity, mortality and change in living arrangement) and cost, providing a detailed description of high cost areas of care.

The presence and severity of complications had the strongest association with costs among older adult patients undergoing non-elective abdominal surgery. Furthermore, of the four factors associated with cost, the severity of postoperative complications is the only potentially modifiable factor related to costs. Therefore, strategies to mitigate or prevent post-operative complications may achieve cost reduction. Although this relationship has been studied before, it has never been studied in the context of non-elective surgery for older adults. Accurate estimates of costs attributable to complications in this patient population helps administrators estimate the cost reduction possible with strategies aimed at decreasing complication rates. While the development and implementation of strategies to reduce complications is outside the scope of this study, numerous studies have presented strategies that have achieved significant reduction in complications (94-99). Even modest reductions in complications could achieve substantial cost reduction on a national level (19).

Mortality was associated with increased health care costs, even when taking other factors into consideration. Patients who died in hospital were admitted to the intensive care unit more often and stayed longer than those who were discharged alive. It is possible that this escalation of treatment prior to death could be avoided, shifting to care focused on palliation at an earlier stage. This would provide better palliation for dying patients, coincidentally reducing cost. However, mortality prediction was outside the scope of this study. Regardless, although predetermined criteria to decide when to limit life-sustaining treatment are standard in some other countries, such criteria have not been implemented in Canada (86).

Loss of independence, as indicated by a need for a change in living arrangement at discharge, was independently associated with health care costs. Much of this was related to unnecessary time in hospital. Strategies to reduce the need for a change in living arrangement could potentially reduce costs depending on the costs associated with such an intervention. Even if the same proportion of patients required a change in living arrangement, streamlining the process at discharge would reduce unnecessary days in hospital and costs. This may require better coordination among hospital personnel early in the patient's stay to initiate appropriate discharge planning. Additionally there is a shortage in the number of long term care beds in the province; however, this was outside the scope of this study.

This study found four perioperative factors (ASA classification, operative severity, frailty index and severity of complications) that represent a potential cost prediction model. If validated in a separate sample of older adults undergoing non-elective abdominal surgery, such a model could be used for budgetary planning, insurance underwriting or to identify groups of patients that are likely to have resource intense hospital stays (i.e. population stratification) (20). Since major treatment decisions are rarely based on costs in Canada, this type of population stratification would not be used to determine whether or not someone received treatment. Rather, programs designed to control costs could be triggered when a patient is predicted to have a resource intense hospital stay. For example, since the largest proportion of costs in this study was due to bed costs (nursing salaries, support staff salaries, ward supplies), strategies to limit the number of unnecessary days spent in hospital, or in resource intense environments (ICU and IMCU) could reduce hospital costs.

### 5.1 LIMITATIONS

Threats to internal validity are addressed in the individual papers above; limitations in generalizability and scope are addressed here. First, this study was designed to estimate costs from the hospital-provider perspective, not from a societal perspective. The study did not include rehabilitation or longterm care costs. Likewise, this study did not consider income lost by care givers after discharge. Reducing the rate of change in living arrangement may result in increased need for care at home, leading to loss of income by care givers, increased at-home nursing and overall increased costs to society (107, 108).

Although this study described the types of postoperative complications, it was not designed to determine the reasons for postoperative complications or change in living arrangement. Determining the reasons for these adverse events is a complicated issue, often dependent on many upstream factors, and is therefore outside the scope of this study; this is an area for continued research and knowledge translation. Likewise, it was beyond the scope of this paper to develop a mortality or complication prediction model. Such a model would be necessary to influence decisions about when care should be focused on treatment or palliation.

This study took place in a tertiary referral hospital and therefore may limit generalizability to small community hospitals. Likewise, this study has limited generalizability to centres outside of Canada since personnel costs, equipment costs and practice patterns often vary greatly between countries (60).

### 5.2 Implications for Future Research

This study identified four perioperative factors that were significantly associated with hospital costs. Future cost-effectiveness or health technology assessment studies involving older adults undergoing surgery should measure and control for these perioperative factors (ASA, OS, FI-CGA and Clavien). This is particularly true for frailty, which is an emerging concept in the literature and has only been considered in one surgical costing study to date (62). Canada has expanded its health technology assessment organizations since 2003, suggesting that this will be an important area of research in the near future (17).

The cost prediction model proposed in this study is classified as such because it includes factors that reflect practice patterns (OS) and practice performance (Clavien) (20). Cost prediction models can be used for budgetary planning, insurance underwriting or to identify groups of patients that are likely to have resource intense hospital stays (i.e. population stratification). In contrast, health risk models include health risk or disease severity factors and patient compliance factors but not factors reflecting the provider's cost-effectiveness. By constructing health risk models in this way, they can provide an adjusted comparison of provider performance, controlling for factors outside the provider's control. Health risk models can therefore be used to calculate performance-based provider reimbursement. This type of reimbursement plan would incentivize treatment of patients with higher health risk or disease severity (i.e. "sicker" patients) (20). Validating a health risk model for this patient population was outside the scope of this study, but is an important line of future research. Future studies should develop and validate health risk models for older adults that can be used broadly in the Canadian health care system. Canada, Germany, France and the United Kingdom are all moving towards activity-based hospital payments (17). In Ontario, some performance-based reimbursement policies have been introduced for general practitioners (17). Performance-based reimbursement may be on the horizon for both hospitals and surgeons.

Finally, the reasons for postoperative complications and change in living arrangment and the development of strategies to reduce these adverse events were outside the scope of this study. This represents a large body of work yet to be completed. Although many studies have proposed methods to reduce specific complications very few are specific to older adults undergoing non-elective surgery. Future research should focus on a bundled intervention to decrease major complications in this patient population. Research should also address how to limit the financial impact of complications when they cannot be prevented. Specifically, research should focus on preventing respiratory complications since this was the most common reason for intensive care admission. This study found that patients who die in hospital have longer intensive care stays. More accurate mortality prediction models may allow care to shift toward palliation earlier in a hospital stay for patients at very high risk.

### 5.3 Implications for Policy Makers

This study found that costs attributable to postoperative complications and a change in living arrangement accounted for 31% ($1,030,339) and 11% ($356,753) of the overall hospital costs for this patient population over a 15 month period. Funding further research to develop and evaluate interventions to decrease these adverse events could lead to cost reduction.

The largest proportion of spending in this study was in the areas of non-procedural costs ($2,176,875 [65%]) and intensive care costs ($554,523 [16%]). In both cases, bed costs (nursing salaries, support staff salaries and ward supplies) accounted for the majority of those costs. Assessing efficiency in these high cost areas could lead to cost reduction. The health region where the study hospital is located, Capital District Health Authority, is currently implementing a system to track employee hours as part of the Case Costing Initiative. Systems to track how employees spend salaried hours would inform efficiency assessments and cost containment strategies.

Policy makers within the Canadian health care system control costs using a number of mechanisms, including budget shifting, budget setting and direct or indirect controls of health care supply (17). Although mechanisms vary by province, soft budget caps are generally set for hospitals and health regions (17). Hospital administrators are then responsible for the allocation of funds to individual departments (109). Once validated, the cost prediction model proposed in this paper or individual factors could be used for budget projections based on the patient population from the previous year.

A validated cost prediction model would allow health care administrators and providers to identify groups of patients that are likely to have resource intense hospital stays (i.e. population stratification). This could be used to focus interventions to reduce hospital cost, such as an intervention to reduce the number of unnecessary days spent in hospital by mobilizing personnel involved in discharge planning early in the patient's hospital stay.

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