THORACIC AORTIC DISEASE IN NOVA SCOTIA: EFFECT OF SOCIOECONOMIC STATUS AND REMOTENESS FROM TERTIARY CENTRE ON DISEASE OUTCOMES

by

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Table of Contents

List of Tables

List of Figures

Abstract:

The effect of socioeconomic status and remoteness from the tertiary care centre on outcomes in patients with thoracic aortic disease is unknown. This thesis sought to determine the effect of socioeconomic deprivation and geographic factors on outcomes in patients undergoing thoracic aortic aneurysm (TAA) and type A aortic dissection (TAAD) repair in Nova Scotia. A retrospective cohort study from 2005-2015 of patients presenting to the Maritime Heart Centre for elective or emergency thoracic aortic repair was performed. The Concentration index (C) of inequality and multivariable logistic regression were used to determine the effect of socioeconomic deprivation and geographic variables on in-hospital outcomes, while the C and Cox proportional hazard modeling were used to determine the effect of socioeconomic deprivation and geographic variables on long-term mortality. A total of 476 patients were included. There was no effect of SES or increased remoteness from the tertiary care centre on in-hospital mortality or discharge disposition. Prolonged length of stay, however, was more concentrated in more materially deprived patients, and patients from Eastern Zone were at greatest risk for this outcome, while patients from social deprivation quintiles 2 and 3 were at greatest risk of composite in-hospital complications. With respect to long-term outcomes, patients from Northern Zone and from ≥1 hour travel time from the tertiary centre were at increased risk for long-term mortality. Based on these results, barriers to discharge and causes of increased in-hospital composite complications among more deprived patients should be explored. Furthermore, gaps in care following surgery should be identified and mitigated through expansion of follow-up services to address inequalities in long-term mortality.

List of Abbreviations Used

AAA: Abdominal Aortic Aneurysm

AAS: Acute Aortic syndrome

COPD: Chronic Obstructive Pulmonary Disease

CPB: Cardiopulmonary Bypass

CT: Commuted Tomography

EF: Ejection Fraction

HDNS: Health Data Nova Scotia

ICD-10: International Classification of Disease Version 10

INSPQ: Institut National de Santé Publique du Québec

IRAD: International Registry of Acute Aortic Dissection

MHC: Maritime Heart Centre

SES: Socioeconomic Status

STS: Society of Thoracic Surgeons

TAA: Thoracic Aortic Aneurysm

TAAD: Type A Aortic Dissection

TBAD: Type B Aortic Dissection

WHO: World Health Organization

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Chapter 1: Introduction

1.1 Disease of the Thoracic Aorta

Thoracic aortic disease represents a silent disease with lethal consequences and costs the healthcare system tens of thousands of dollars per admission (McClure et al., 2020). Thoracic aortic aneurysm (TAA) is a dilation of all layers of the thoracic aortic wall caused by weakening of the aortic wall by either age-related degeneration or genetic predisposition (Goldfinger et al., 2014). Aortic aneurysms can exist undetected due to the often asymptomatic nature of the disease. Further aneurysmal wall changes can lead to disruptions of the integrity of the aortic wall, potentially resulting in either rupture of the aorta or tearing of the innermost layer of the aorta (referred to as aortic dissection). Dissections originating before the aortic arch are referred to as Type A aortic dissections (TAAD), and typically require emergent surgery. Those that originate within or after the arch are referred to as Type B aortic dissection (TBAD) and are often treated with medical management (Lombardi et al., 2020; Svensson et al., 1999; Tsai et al., 2009).

The incidence of TAA, both in Canada and internationally, has been estimated to be low at 8.5 to 10.9 per 100 000 person-years but has been increasing since first estimates in the 1950's (Clouse et al., 1998; Lodewyks et al., 2020; Olsson et al., 2006). The incidence of TAA rupture is around 3.5 to 5 per 100 000 person-years (Clouse et al., 2004; Johansson et al., 1995). The incidence of TAAD and TBAD is estimated to be 2.9 to 6 per 100,000 person-years (Clouse et al., 2004; Howard et al., 2013; Lodewyks et al., 2020; Meszaros et al., 2000). Operative mortality for elective thoracic aorta aneurysm repair ranges from 2.2%-3.4% vs 15.4%-31% for emergent TAAD repair (Wallen et al., 2019; J. B. Williams et al., 2012), making detecting aneurysms and providing surgery electively an important strategy for managing this disease.

1.2 Non-Clinical Determinants of Cardiovascular Outcomes

Although equity is a major policy objective in the Canadian healthcare system, health inequities based on socioeconomic status (SES) have been described in the Canadian general population (Hajizadeh et al., 2016; Pampalon, Hamel, Gamache, et al., 2009), and specifically among patients with cardiovascular disease (Blais et al., 2012; Lee et al., 2009), abdominal aortic aneurysms (AAA) (Al Adas et al., 2019), and aortic dissection (Kabbani et al., 2016; Zimmerman et al., 2016). To date, the effect of SES on outcomes in patients who undergoing elective TAA repair has not been described and the effect of SES on outcomes in TAAD repair has not been examined in the Canadian context.

In addition to SES, where a patient lives in relation to tertiary health services can play a role in health outcomes in cardiac surgery patients (Cote et al., 2015). It can be challenging to separate the independent effects of SES and remoteness as more deprived populations tend to live in more remote areas. Nonetheless, any exploration of SES on health outcomes should consider geographic variables, and vice versa. To date, no studies have examined the effect of increased remoteness from the nearest tertiary centre on outcomes in elective TAA repair. An exploration of these non-clinical risk factors will potentially allow for more equitable resource planning for this patient population in Nova Scotia.

1.3 Nova Scotia Context

Nova Scotia offers a unique opportunity to study the effects of SES and remoteness from the tertiary care on outcomes in thoracic aortic disease as it is one of the few jurisdictions with a completely centralized care model for thoracic aorta disease. Additionally, all patients who undergo surgical treatment of their thoracic aortic disease are automatically enrolled in the MHC clinical registry, a prospective registry that collects preoperative, intraoperative and in-hospital postoperative data on all patients undergoing cardiac surgery in Nova Scotia. This registry, in conjunction with administrative data available through Health Data Nova Scotia (HDNS) allows for a complete analysis of this disease process in Nova Scotians.

1.4 Objectives

The objectives of this study are to describe the incidence of TAA repair and TAAD repair in Nova Scotia, describe in-hospital and long-term outcomes of Nova Scotians with thoracic aortic disease, and to determine the effect of socioeconomic and remoteness variables on these outcomes.

1.5 Implications

Analyzing thoracic aortic disease in Nova Scotia will help to address gaps in the literature left by studies that have relied on administrative data without use of detailed, observational data from clinical registries. This knowledge will also allow for improved Nova Scotia-specific resource planning, such as increased and more equitable distribution of screening programs, access to specialized thoracic aortic disease clinics, and targeted initiatives to reach underserved patients with this disease. This will also allow for better allocation of resources to increase elective repair rates and thus reduce rates acute emergencies, leading to improved patient outcomes and overall healthcare savings in the province.

The remainder of this thesis is organized into 6 chapters. Chapter 2 gives the reader an overview of thoracic aortic disease. Chapter 3 provides a review of the literature relevant to SES and remoteness from the tertiary care on outcomes in cardiovascular disease. Chapter 4 describes the methodology used, and

Chapter 5 provides results. Chapter 6 provides a discussion of findings and implications for resource planning for the province, limitations, and further areas for research. Chapter 7 provides a conclusion.

Chapter 2: Thoracic Aortic Disease

2.1 Definition of Thoracic Aortic Disease

The normal aortic diameter is dependent on the patient's sex and body size. Dilations can occur anywhere in the aorta, from the aortic root as it leaves the heart to the ascending aorta, to the aortic arch where the head and upper extremity branches come off, and to the descending thoracic aorta. Thoracic aortic aneurysms typically remain a silent disease until they either rupture or evolve into acute aortic syndromes (AAS). AAS encompasses 5 different entities including aortic dissection (class 1), intramural hematoma (class 2), intimal tear without dissection (class 3), penetrating atherosclerotic ulcer (class 4), and iatrogenic aortic dissection (class 5) (Svensson et al., 1999; Tsai et al., 2009; Vilacosta & San Roman, 2001). AAS can be either a manifestation of aneurysmal disease or can occur without aneurysm as a result of aortic wall pathology. Recommendations for replacing the aneurysmal aorta electively, prior to AAS developing, depend on the extent of dilation, the location of the dilation and the patient's associated risk factors (Boodhwani et al., 2014; Erbel et al., 2014; Hiratzka et al., 2010).

The most common type of AAS is aortic dissection, so most treatment recommendations are extrapolated from the aortic dissection population (Lansman et al., 2010). AAS in the ascending aorta typically requires surgical intervention, whereas AAS occurring more distally are amenable to strict medical control of blood pressure and serial imaging, with stent graft repair for complicated cases (Appoo et al., 2016; Lombardi et al., 2020). Aortic dissection is subclassified into Type A Aortic Dissection (TAAD) (starting in the ascending aorta) and Type B Aortic Dissection (TBAD) (starting in the aortic arch or distally) (Lombardi et al., 2020). TAAD represents a very lethal condition with mortality approaching 1% per hour without surgical intervention (Hirst et al., 1958), whereas the mainstay of management for TBAD is medical management with stent graft repair of complicated cases (Lombardi et al., 2020).

2.2 Incidence of Thoracic Aortic Disease

The epidemiology of thoracic aortic aneurysms (TAAs) is challenging to study as TAAs typically remain silent until they are detected incidentally or when they present as a rupture or AAS. Population-based cohort studies internationally have shown that the incidence of TAA has increased over time from about 5.9 per 100 000 person-years in the 1950’s to over 10.9 per 100 000 person-years in the 1990’s, while the incidence of rupture has decreased from about 5.0 per 100 000 person-years to 3.5 per 100 000 person-years over the same time period (Bickerstaff et al., 1982; Clouse et al., 1998, 2004; Johansson et al., 1995). Using administrative data it has been estimated that the incidence of asymptomatic TAA has been increasing in Canada over the past two decades from 3.5 to 10.9 per 100 000, whereas the rate of rupture is stable around 1.0 to 1.5 per 100 000 person-years (Lodewyks et al., 2020; McClure et al., 2018). The prevalence of TAA is difficult to estimate as many patients remain asymptomatic until the aneurysm is found incidentally. In Manitoba, using a novel approach combining diagnosis codes along with timing of Computed Tomography (CT) scans (as would be used for routine follow-up), the prevalence was found to have increased from 58 per 100,000 in 1998 and 243 per 100,000 in 2016 (Lodewyks et al., 2020).

Estimates of the incidence of TAAD vary widely due to the inclusion or exclusion of pre-hospital deaths and range from 2.5 to 15.3 per 100 000 (Landenhed et al., 2015; Melvinsdottir et al., 2016). In Ontario, the incidence of TAAD and TBAD was estimated at 1.9 per 100 000 person-years and 2.7 per 100 000 person-years, respectively (McClure et al., 2018), whereas in Manitoba. the combined incidence of TAAD and TBAD was found to be 3.0 per 100 000 person-years (Lodewyks et al., 2020). Both studies found the incidence to be stable over time.

2.3 Outcomes in Thoracic Aortic Disease

The goal of aortic screening is to detect aneurysms at the asymptomatic phase and the goal of aortic surgery is to resect the affected aorta to minimize risk of developing an AAS. Outcomes of operations on the ascending aorta vary widely based on the extent of repair (Achneck et al., 2007; Idrees et al., 2016), the presence of connective tissue disease (Gott et al., 1999), and the acuity of the operation (Gott et al., 1999; J. B. Williams et al., 2012). Operative outcomes have been tracked through notable databases, including the Society of Thoracic Surgeons (STS) National Database which was created as a quality improvement and patient safety initiative and now has over 1000 participating institutions. In a report from the STS database from 2004 to 2009, which included 45,894 proximal aortic operations, operative mortality was 3.4% for elective cases and 15.4% for emergent cases (J. B. Williams et al., 2012). In a subsequent STS database study of only elective aortic root replacement operations, operative mortality was 2.2% (Wallen et al., 2019).

The first comprehensive description of the natural history of medically managed TAAD described TAAD to have a mortality of 1-2% per hour after the dissection occurs (Hirst et al., 1958). Studies including pre-hospital deaths have estimated pre-hospital mortality to range from 18% to 38% (Clouse et al., 2004; Kurz et al., 2017; Melvinsdottir et al., 2016; Meszaros et al., 2000). The International Registry of Acute Aortic Dissection (IRAD) was created in 1996 to combine efforts to create a multi-centre registry for aortic dissection. In their most recent report, with over 20 years of patient enrolment, IRAD has demonstrated a decrease in mortality from TAAD from 31% in the 1990’s to 22% in the 2010-2013 era, mainly driven by a decrease in surgical mortality of 25% to 18.4% (Evangelista et al., 2018). Several non-IRAD studies have reported longer-term centre-specific outcomes over time. Ten-year survival has improved from only 55% in the 1980's and 1990's to closer to 70% in the 2000's (Fann et al., 1995; Sabik et al., 2000; Tan et al., 2005).

2.4 Summary

Thoracic aortic aneurysms represent occult disease that manifest as acute aortic catastrophes with high mortality. The incidence of TAA is increasing over time, likely owing to increased detection, while the incidence of TAAD has remained stable. The principles of managing thoracic aortic disease include detection of TAA with surgical intervention when operative risk is lower prior to rupture or AAS occurring. Surgical management of both TAA and TAAD has improved over time, with improvements in long-term survival in this disease.

Chapter 3: Literature Review

While there are many clinical risk factors for adverse outcomes in patients with cardiovascular disease, this literature review will focus on the effects of SES and remoteness on health outcomes in general, in patients with coronary disease, in patients undergoing cardiac surgery, and in patients with abdominal aortic aneurysms. There is a paucity of literature on SES and remoteness and outcomes in elective thoracic aortic aneurysms. Evidence from patients undergoing cardiac surgery, treatment for aortic dissection, and abdominal aortic aneurysm repair builds a foundation for exploring SES and remoteness in the TAA population.

3.1 Socioeconomic Status & Remoteness and Health Outcomes

"The social determinants of health are the conditions in which people are born, grow, live, work and age. These circumstances are shaped by the distribution of money, power and resources at global, national and local levels. The social determinants of health are mostly responsible for health inequities – the unfair and avoidable differences in health status seen within and between countries." (World Health Organization, 2008).

The social determinants of health are clearly linked to adverse health outcomes. In a report by the World Health Organization (WHO), the authors outline the theories by which the social determinants of health lead to adverse health outcomes and give recommendations on how to best measure differences in health outcomes (Health, 2008). When measuring differences in health within a population, one can measure the health difference or health gap between two populations, or look at the gradient across the population, allowing for identification of inequalities at all levels of the society (Bonnefoy et al., 2007).

Patients from rural and remote locations experience decreased access to primary care and geographic barriers to accessing specialized services (Douthit et al., 2015; Humphries & Van Doorslaer, 2000). This translates into increasing chronic disease mortality with increasing relative remoteness (Chondur et al., 2014). Both SES and remoteness play a significant role in adverse health outcomes in developed countries, and separating the independent effect of each can be challenging as more rural and remote populations have increasing socioeconomic disadvantage (Chondur et al., 2014; Subedi et al., 2019).

3.1.1 Socioeconomic Status and Health Outcomes in Canada

Lower income has consistently been shown to be related to poor health outcomes among Canadians (Humphries & Van Doorslaer, 2000; Jiménez-Rubio et al., 2008; McGrail et al., 2009; Safaei, 2007). Income-related health inequity has been shown in all Canadian provinces and is increasing over time (Hajizadeh et al., 2016; Safaei, 2007). Composite measures of socioeconomic status (which also account for education, occupation, social support), have shown increased premature mortality among Canadians with increasing socioeconomic deprivation (Pampalon, Hamel, & Gamache, 2009; Shahidi et al., 2020).

3.1.2 Remoteness from Tertiary Care and Health Outcomes in Canada

"Remoteness" can be defined as "distant or far away geographically", and "accessibility" can be defined as "the ease of approach from one location to another measured in terms of distance travelled, the cost of travel, or the time taken" (Higgs et al., 2003). In Canada, increased remoteness is associated with increased mortality (Subedi et al., 2019). It is challenging to separate the effect of one's distance from the healthcare facility from the effect of the social determinants of health on health outcomes as patients who live in more remote areas tend to experience exacerbation of socioeconomic disparities (Smith et al., 2008). Certainly, there are socioeconomic barriers that can amplify the effect of geographic distance to health services, and both must be accounted for.

3.2 Socioeconomic Status & Remoteness and Cardiovascular Outcomes

3.2.1 Cardiovascular Risk Factors and Cardiac Disease

Both material and social deprivation, as well as increased distance from tertiary care centres have been shown to affect cardiovascular disease outcomes in high-income countries (Schultz et al., 2018). Within Canada, the prevalence of cardiovascular disease risk factors are concentrated in more socially disadvantaged regions (Lee et al., 2009). In a recent comprehensive meta-analysis of 19 studies examining the effect of SES on several outcomes following acute myocardial infarction in Canada, if was found that lower socioeconomic measures, predominantly measured as income, with some studies including education and occupation, was associated with a 48% increase in short-term mortality, a trend toward increased 1-year mortality, a 20% decrease in access to invasive cardiac services, and a 24% decrease in odds of revascularization (Moledina & Tang, 2021).

Cardiac diseases can manifest as acute emergencies, such as acute myocardial infarction, which requires immediate treatment to limit myocardial damage. Urgent transfer to tertiary care is often initiated. Even in a small geographic area of New Jersey, small increases in distance from place of residence resulted in decreased use of invasive cardiac services following myocardial infarction (Gregory et al., 2000). Living in remote areas can affect access to invasive cardiac services following acute myocardial infarction in Quebec, Alberta, and Nova Scotia (Boyd et al., 2018; Hassan et al., 2009; Rodrigues et al., 2002; Seidel et al., 2004). Current society guidelines focus on timely access to invasive services for cardiac revascularization in patients experiencing myocardial infarction (Wong et al., 2019). After treatment of acute cardiac events, patients at increased distance from the treating hospital are also less likely to attend follow-up clinics and are more likely to be readmitted for a subsequent cardiac diagnosis (Piette & Moos, 1996).

In patients undergoing cardiac surgery, social disadvantage has been associated with adverse health outcomes in several high-income countries (Butt et al., 2019; Charles et al., 2019; Coyan et al., 2020; Dalén et al., 2015; Gibson et al., 2009; Koch et al., 2010; Nielsen et al., 2019; Pagano et al., 2009; Taylor et al., 2003). In the United States, patients from rural areas are at higher risk of prolonged hospital length of stay and in-hospital mortality compared to patients from urban areas (Dao et al., 2010). In a comprehensive analysis of the STS database, the distressed communities index, which accounts for 7 socioeconomic measures, suggested that patients from more distressed communities were more likely to experience morbidity and mortality following coronary artery bypass grafting (Mehaffey et al., 2020). In Canada, after adjusting for socioeconomic status, increased distance from the tertiary care centre has been associated with worse 30-day outcomes following cardiac surgery (Cote et al., 2015).

3.2.2 Socioeconomic Status and Aortic Disease

Although risk factor profiles are similar between the cardiac and the aortic disease patient populations, the access to diagnosis and management differ widely. For patients presenting with myocardial infarction, symptomatology is predictable, diagnostic criteria are reliable, and rapid treatment algorithms are well established and evidence based. Patients with aortic aneurysms, however, do not have symptoms until they present urgently, and many urgent presentations are initially misdiagnosed. Patients presenting with acute TAAD to non-tertiary institutions experience delays in diagnosis and treatment (Harris et al., 2011).

With respect to patients with AAAs, SES has been shown to have a negative effect on access to less invasive endovascular surgery (Faulds et al., 2013). SES has also been shown to be associated with worse short-term surgical outcomes in five studies (Al Adas et al., 2019; Boxer et al., 2003; Khashram et al., 2017; Lemaire et al., 2008; Ultee et al., 2015), although two studies showed no association between SES and short-term outcomes (Agabiti et al., 2008; Durham et al., 2011). Al Adas et al. (2019) and Kashram et al (2017) showed socioeconomic deprivation to be associated with decreased long-term survival. Interestingly, patients with descending TAA who are visible minorities or from lower income households actually experience increased access to endovascular aneurysm repair (Johnston et al., 2013). The only study to date on SES in outcomes in elective TAA repair showed no effect of payer status (Medicaid vs not), on outcomes in endovascular repair of descending TAA (Murphy et al., 2010). No studies have examined the effect of SES on outcomes in patient undergoing elective ascending aortic repair.

For patients presenting emergently with aortic dissection, one study of hospital administration discharge records of 212 aortic dissections in the United States showed lower SES to be associated with worse long-term survival, but not short-term mortality (Kabbani et al., 2016). Another study using clinical registry data involving 334 acute TAAD repairs at a single United States institution also demonstrated that income quartile was not associated with increased 30-day mortality or stroke following acute TAAD repair (Altomare, 2015). In contrast, a retrospective analysis of administrative data in the United States of 15,641 records showed patients with lower median income and those whose primary payer is Medicare had worse in-hospital mortality with TAAD repair (Zimmerman et al., 2016). No studies investigating SES and TAA and TAAD in a publicly funded healthcare system currently exist.

3.2.3 Remoteness and Aortic Disease

Following aortic surgery, patients require routine follow-up to ensure there is no further aneurysmal change of the remaining aorta. No studies to date have examined the effects of increased distance to the tertiary care centre on outcomes in elective TAA repair or aortic dissection. In patients presenting for elective AAA repair, rural and remote patients from Australia experienced equivalent long-term survival (Golledge et al., 2020), and rural patients from the United States actually experience improved in-hospital outcomes as a result of increased referral to high-volume centers (Mell et al., 2012). Similarly, in a study of 136 patients at a single institution in the United States, patients at increased distance from the tertiary centre experienced equivalent follow-up and long-term survival following endovascular AAA repair (Sarangarm et al., 2010). Whether or not distance to the tertiary care centre is associated with decreased survival in patients undergoing aortic surgery has not been studied in the Canadian context, and specifically in the ascending TAA population has not been studied in any jurisdiction.

3.3 Summary

While studies have shown that SES and remoteness can have an effect on outcomes in patients with cardiovascular diseases, gaps exist at the intersection between SES, distance to tertiary care and thoracic aortic disease, especially in a publicly funded system. The centralized care for TAA and TAAD in Nova Scotia provides a unique opportunity to fill this void in the current literature.

Chapter 4: Methods

4.1 Data Sources

Patients were identified through the Maritime Heart Centre (MHC) Registry. The MHC registry is a detailed clinical database that captures preoperative, intraoperative, and postoperative data on all patients undergoing cardiac surgery at the Queen Elizabeth II Health Science Centre. These in-hospital, observational patient data were then linked to administrative data from the Health Data Nova Scotia (HDNS), a data repository that provides access to administrative data including patient's geographic coordinates, dissemination area and Vital Statistics data. Dissemination areas are the smallest geographical unit for which census level data are available and are comprised of populations of 400 to 700 persons (Statistics Canada, 2019). Vital statistics data includes patient's date of death as well as immediate cause and supporting causes of death based on International Classification of Diseases version 10 (ICD-10) coding (Dalhousie University, n.d.).

4.2 Study Population

A retrospective cohort study was performed on all patients from Nova Scotia who underwent ascending TAA repair from January 1st, 2005 to December 31st, 2015. Any patient who had undergone any form of aortic surgery involving the ascending aorta or aortic arch was included. This included repair of TAAD, aortic root repair (with or without valve replacement), ascending aneurysm repair, and/or aortic arch repair, either in isolation or in combination with other cardiac surgery procedures. Both elective and emergent patients were included in the cohort. Patients with descending thoracic aneurysm, thoracoabdominal aneurysm, abdominal aortic aneurysm were excluded as were patients who underwent aortic interventions resulting from traumatic injury. Patients undergoing root enlargement or aortic root repair for endocarditis were excluded. Patients under the age 18 and non-residents of Nova Scotia were also excluded.

4.3 Ethics Review

Approval for this study was granted by the Nova Scotia Health Authority Research Ethics Board (No. 1021911).

4.4 Variables

4.4.1 Outcome Variables

Outcome variables of interest were in-hospital mortality, composite in-hospital complications, hospital length of stay, discharge disposition to another institution or nursing home, and long-term survival (Table 4.1). The outcome of length of stay was dichotomized into prolonged (≥10 days) vs. normal length of stay (<10 days).

4.4.2 Independent Variables

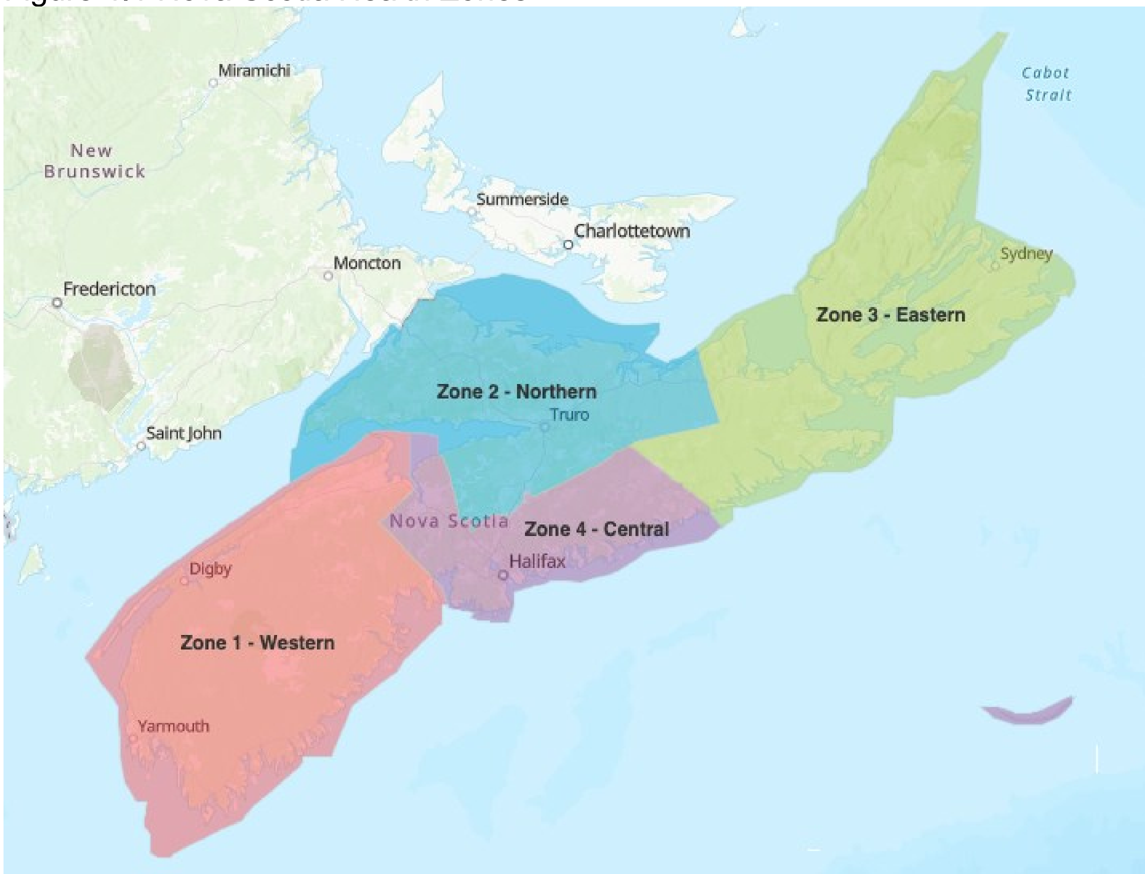
Socioeconomic Status

Socioeconomic variables were derived from patient's dissemination area. The Pampalon Index of Deprivation uses Canadian Census Data to estimate material and social deprivation corresponding to dissemination areas. This index measures material deprivation from the proportion of individuals age 15 years and older with less than high school education, average household income, and the ratio of employment/population. Social deprivation, on the other hand, is measured from the proportion of individuals age 15 years and older living alone, proportion of individuals age 15 years and older who are separated, divorced, or widowed, and the proportion of single-parent families within a dissemination area. The application of this index allowed the separation of dissemination areas into socioeconomic quintiles, with quintile 1 representing the most privileged population and quintile 5 the least (Pampalon et al., 2012). The Pampalon Index of Deprivation has been validated in Canada (Pampalon et al., 2014). Deprivation quintiles were obtained from the 2006 Canadian Census data using the Institut National de Santé Publique du Québec (INSPQ), which publishes publicly available data files linking dissemination areas to their calculated deprivation quintiles (Institut national de santé publique du Québec, 2017).

Remoteness Variables

Remoteness variables of interest include patient's estimated travel time to the tertiary care centre and patient's corresponding health zone. Travel time from geographical coordinates corresponding to the patients' place of residence to the tertiary hospital in Halifax was calculated using commercially available geographic information system (GIS) software (ArcMAP, ESRI). Nova Scotia is a rural province and straight-line distance might underestimate estimate geographic barriers to the tertiary care center due to the sparseness of rural road infrastructure. Nova Scotia Health Authority has 4 health zones for delivery of health services (Figure 4.1) (Statistics Canada, 2015). Patient's health zone based on place of residence was also recorded (Table 4.1).

Figure 4.1 Nova Scotia Health Zones



Note: Data Source: Statistics Canada Health Regions: Boundaries and Correspondence with Census Geography, (Table 82-402-x). Created using ArcGIS, ESRI).

Baseline Characteristics

Clinical characteristics of interest included age, sex, clinical comorbidities, and operative characteristics (Table 4.1)

Table 4.1: Definitions and Sources of Variables Used in the Study

Variable	Definition	Source
Outcome Variables		
In-Hospital Mortality	Death before discharge	Maritime Heart Centre Registry
Composite In-Hospital Complication	Any cardiac complication (low cardiac output, cardiac arrest, arrhythmia, myocardial infarction, valvular complication), neurological complication (stroke, seizure, coma or delirium), pulmonary complication (prolonged ventilation, pulmonary edema, pneumonia, pneumothorax, thoracentesis, embolism, reintubation), vascular complication (dissection, clot, rupture), acute kidney injury (rise in creatinine ≥176mmol/L that is new), readmission to intensive care, or in-hospital mortality	Maritime Heart Centre Registry
Hospital Length of Stay	Days from operation to discharge	Maritime Heart Centre Registry
Discharge Disposition	Discharge to other institution or nursing home	Maritime Heart Centre Registry
All-Cause Mortality	Death until end of follow-up March 31, 2016	Vital statistics
Socioeconomic Status		
Median Household Income	Median income ($) per household in the dissemination area corresponding to the patient's place of residence	Health Data Nova Scotia
Social Deprivation Quintile	Quintile 1 through 5, with quintile 1 (5) being least (most) deprived based on the proportion of individuals aged 15 years and older living alone, who were separated, divorced or widowed, and single-parent families of the dissemination area corresponding to the patient's place of residence.	Health Data Nova Scotia & Institute National Santé Québec
Material Deprivation Quintile	Quintile 1 through 5, with quintile 1 (5) being least (most) deprived based on the proportion of people age 15 and older with no high school diploma, percentage employment, and the average income of the dissemination area corresponding to the patient's place of residence.	Health Data Nova Scotia & Institute National Santé Québec

Table 4.1: Definitions and Sources of Variables Used in the Study *(Continued)*

Variable	Definition	Source
Geographical Variables		
Longitude and Latitude	Coordinates associated with patient's address	Health Data Nova Scotia
Estimated Driving Time to Tertiary Care Centre	Estimated driving time (minutes) from place of residence to tertiary care centre	Calculated using longitude and latitude
Health Zone	Zone 1 = Western Zone 2 = Northern Zone 3 = Eastern Zone 4 = Central	Health Data Nova Scotia
Clinical Variables		
Age	Patient age	Maritime Heart Centre Registry
Sex	Female or Male	Maritime Heart Centre Registry
Smoking History	Any tobacco or cannabis smoking	Maritime Heart Centre Registry
Hypertension	History of blood pressure exceeding 140/90, a history of high blood pressure, or the need for ani-hypertensive medication	Maritime Heart Centre Registry
Diabetes	A history of diabetes, regardless of duration	Maritime Heart Centre Registry
Hypercholesterolemia	Any history of dyslipidemia, treated or untreated	Maritime Heart Centre Registry
Pre-operative Renal Failure	Serum creatinine level >176 μmol/L	Maritime Heart Centre Registry
Cerebrovascular Disease	Any transient ischemic attack, any prior stroke, or any carotid artery disease	Maritime Heart Centre Registry
Peripheral Vascular Disease	Any history of aneurysm and/or occlusive disease with or without extra-cardiac vascular procedure	Maritime Heart Centre Registry
Chronic Obstructive Pulmonary Disease (COPD)	Requires pharmacologic therapy for the treatment of chronic pulmonary compromise, or has Forced Expiratory Volume 1 <75% of predicted value	Maritime Heart Centre Registry

Table 4.1: Definitions and Sources of Variables Used in the Study *(Continued)*

Variable	**Definition**	**Source**
Clinical Variables *(Continued)*		
Ejection Fraction	Based on pre-operative cardiac catheterization or echo if no catheterization available	Maritime Heart Centre Registry
Angina	History of angina, can be stable or unstable	Maritime Heart Centre Registry
Status Urgent or Emergent	Surgery within 24 hours of admission	Maritime Heart Centre Registry
Combined Operation	Coronary bypass or valve replacement	Maritime Heart Centre Registry
Aortic Dissection	Type A Aortic Dissection at time of operation	Maritime Heart Centre Registry
Chronic Aortic Dissection	Aortic Dissection that has stabilized with medical management prior to the operation	Maritime Heart Centre Registry
Cardiopulmonary Bypass Time	The time (minutes) the patient was on the heart-lung machine	Maritime Heart Centre Registry
Cross-Clamp Time	The time (minutes) blood flow to the heart was stopped to facilitate the operation	Maritime Heart Centre Registry

Note: Variable definitions as per Health Data Nova Scotia Data Dictionary (Dalhousie University, n.d.) and Maritime Heart Centre Data Coding Guide (Maritime Heart Centre, 2017)

4.5 Statistical Analysis

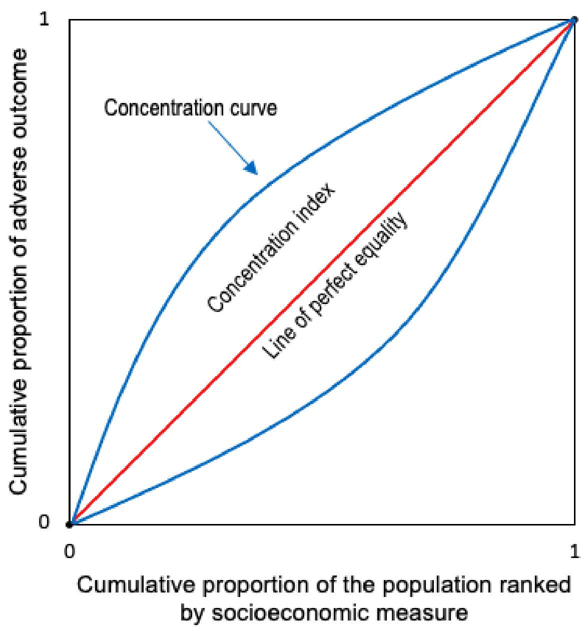
4.5.1 Descriptive Analysis

The age-adjusted incidence of TAA repair and TAAD repair was calculated for each sex based on Canadian census estimates and adjusted to the 2012 Canadian standard population (Statistics Canada, 2020). Weighted linear regression was performed to analyze trends in incidence over time. Standard descriptive statistics was used to summarize outcomes, socioeconomic status variables, remoteness variables, and clinical variables used in the study. Continuous variables were described using mean and standard deviation for normally distributed variables and median and inter-quartile range (IQR) for non-normally distributed variables. Categorical variables were described using the number and percentage of patients with that variable of interest.

4.5.2 Concentration Index

The Concentration index (C) approach was used to measure inequalities in adverse outcomes (in-hospital mortality, composite in-hospital complication, prolonged length of stay, discharge disposition other than home, and all-cause long-term mortality). The C is a validated measure of inequality in a health variable as determined by the Concentration curve (Jui-fen et al., 2007). To generate the Concentration curve, patients are ranked from lowest to highest socioeconomic (or remoteness) measure along the horizontal axis with cumulative share of total adverse health outcomes on the vertical axis. If each patient had their equal share of adverse outcomes, the Concentration curve would follow a perfect 45˚ line, known as “perfect equality”. If the burden of adverse outcomes is more concentrated in patients from lower ranked socioeconomic status (or remoteness variable), the curve would sit above the line of perfect quality. Conversely, if the burden of adverse outcomes is more concentrated in patients from higher ranked socioeconomic status (or remoteness variable), the curve would sit below the line of inequality. The magnitude of inequality was quantified using the Concentration curve, equal to twice the area between the curve and the line of perfect equality, expressed as a value of -1 to +1 (Figure 4.2). Binary outcome variables create minimum and maximum values bounded by the positive and negative mean, rather than the (-1, +1) range. To overcome this, the C can be normalized by multiplying it by 1/(1-mean) (Wagstaff, 2005). All outcome variables in this study were binary variables and were normalized. The C for each outcome variable was measured using three measures of socioeconomic status variables (median household income, material deprivation, social deprivation) and one measure of remoteness (travel time).

Figure 4.2: An Example of the Concentration Curve



Note: If the Concentration curve lies above (below) the line of perfect equality, the resulting Concentration index is negative (positive).

4.5.3 Regression Analysis

For regression analysis, continuous variables were dichotomized into categorical variables. Age (<60 years and ≥60 years), cardiopulmonary bypass (CPB) time (<180 and ≥180 minutes), cross-clamp time (<127.5 and ≥127.5 minutes) and estimated travel time (<1 hour and ≥1 hour) were dichotomized to values approximate to the median value in the study population. Ejection fraction (EF) (<60% and ≥60%) was dichotomized to low EF (<60%) and normal EF (≥60%).

To determine risk factors for outcomes of interest (in-hospital mortality, composite in-hospital complication, prolonged length of stay, discharge disposition to another institution or nursing home) univariable logistic regression analysis was performed. Risk factors for adverse outcomes with $p \leq 0.1$ were included in multivariable analysis, with sex, socioeconomic deprivation and estimated travel time variables included a priori. Median household income was not used in logistic regression as income is a component of material deprivation, and hence adjusted for a priori. If two variables were found to be highly correlated ($R \geq 0.5$), the more clinically significant variable was chosen. Multivariable analyses were repeated using health zone to determine the independent effect of this factor.

4.5.4 Survival Analysis

Kaplan Meier survival estimates were created to estimate long-term survival. Long-term survival was compared across social and material deprivation quintiles, estimated travel time <1 hour and ≥1 hour, and health zone using log-rank test. Cox proportional hazard modeling was performed to determine the independent effect of socioeconomic variables and estimated travel time for the outcome of all-cause mortality during follow-up. Risk factors for adverse outcomes with $p \leq 0.1$ were included in multivariable analysis, with sex, socioeconomic deprivation and estimated travel time variables included a priori. If two variables were found to be highly correlated ($R \geq 0.5$), or felt to have significant clinical overlap, the more clinically significant variable was chosen. Multivariable analysis was repeated using health zone to determine the independent effect of this factor.

A sensitivity analysis was performed by repeating all analyses on only elective patients. Statistical analysis was performed using Stata, version 14 (College Station, TX).

Chapter 5: Results

5.1 Baseline Characteristics

A total of 476 patients underwent elective and emergent ascending TAA and TAAD repair at the Maritime Heart Centre from January 1st, 2005 to December 31st, 2015. Mean age was 59.1 years (Standard Deviation [SD] ±13.3 years) and 107 (22.5%) were female. Baseline characteristics of the 476 patients are presented in Table 5.1.

Table 5.1: Baseline and Operative Characteristics

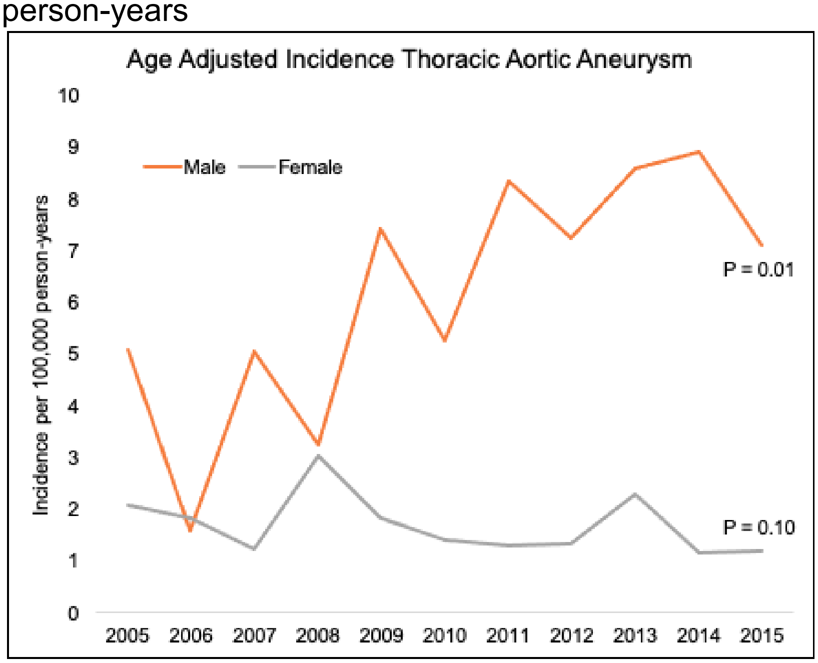
Characteristics	**All Patients n=476**	**Elective Patients n=393**	**Emergent Patients n=83**
Clinical Characteristics			
Age, years (mean ±SD)	59.1 ±13.3	58.5 ±13.3	61.7 ±12.9
Female Sex	107 (22.5%)	91 (23.2%)	16 (19.3%)
Hypertension	271 (56.9%)	219 (55.7%)	52 (62.7%)
Diabetes	48 (10.1%)	42 (10.7%)	6 (7.2%)
Dyslipidemia	189 (39.7%)	167 (42.5%)	22 (26.5%)
Smoking history	258 (54.2%)	213 (54.2%)	45 (54.2%)
Chronic Kidney Disease	12 (2.5%)	6 (1.5%)	6 (7.2%)
Cerebrovascular Disease	31 (6.5%)	21 (5.3%)	10 (12.1%)
Peripheral Vascular Disease	160 (33.6%)	126 (32.1%)	34 (41.0%)
COPD	52 (10.9%)	47 (12.0%)	5 (6.0%)
Ejection Fraction, % (mean ±SD)	53.6 ±14.8	55.0 ±14.5	42.8 ±13.3
Angina	131 (27.5%)	97 (24.7%)	34 (41.0%)
Operative Characteristics			
Urgent Status	83 (17.4%)	0	83 (100%)
Combined Operation (Coronary bypass and/or valve)	332 (69.8%)	296 (75.3%)	36 (43.4%)
Coronary artery bypass	71 (14.9%)	60 (15.3%)	11 (13.3%)
Valve	309 (64.9%)	278 (70.7%)	31 (37.4%)
Aortic Dissection	85 (17.9%)	9 (2.9%)	72 (86.8%)
Chronic Aortic Dissection	11 (2.3%)	9 (2.3%)	<5 (<4%)
CPB Time, minutes (median, [IQR])	180 [141-232]	175 [135-223.5]	216 [173-273]
Cross-Clamp time, minutes (median, [IQR])	127.5 [91-170]	129 [92-171]	119 [87-154]

Notes: Data presented as number (%) unless otherwise specified. COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; IQR: Inter-Quartile Range; SD: Standard Deviation

5.2 Incidence

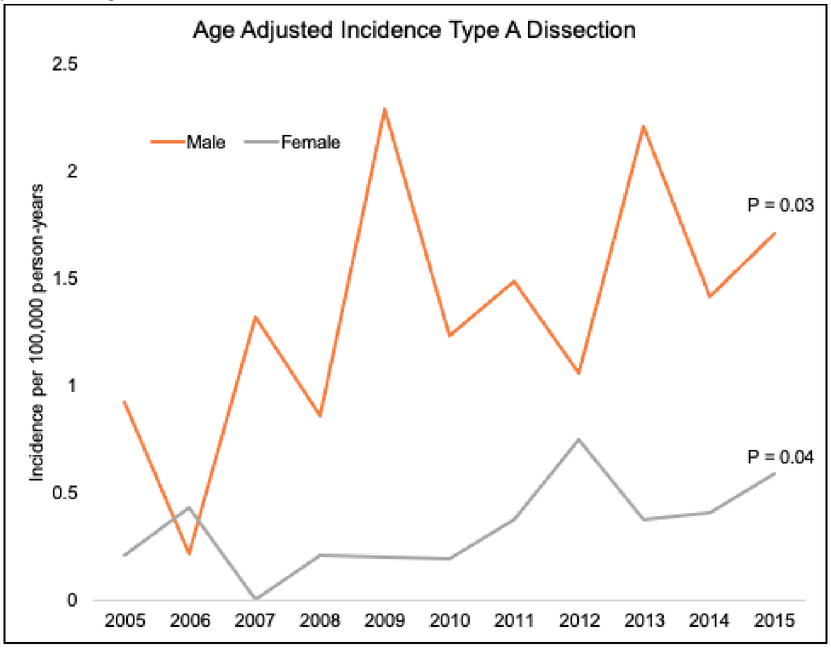
The incidence of elective TAA repair was 3.9 per 100,000 person-years (95% confidence interval [CI]: 3.5 to 4.3). The average incidence in males was 6.2 per 100,000 (95% CI: 5.9 to 6.5), whereas the average incidence in females was only 1.7 per 100,000 (95% CI: 1.5 to 1.9). The incidence in males increased over time (p=0.01), while there was no statistically significant trend over time (p=0.10) in females (Figure 5.1). With respect to TAAD, the average annual age-adjusted incidence of TAAD was 0.8 per 100,000 person-years (95% CI 0.65 to 1.01). The average incidence was 1.3 per 100,000 males (95% CI: 1.01 to 1.67) and 0.3 per 100,000 females (95% CI 0.18 to 0.50). This incidence increased in both males and females over time (Figure 5.2).

Figure 5.1: Age-Adjusted Incidence of Thoracic Aortic Aneurysm Repair per 100,000 person-years



Notes: Age and sex-adjusted incidence of thoracic aortic aneurysm repair adjusted to the 2012 Canadian Standard population. P for trend coefficients.

Figure 5.2: Age-Adjusted Incidence of Type A Aortic Dissection Repair per 100,000 person-years



Notes: Age and sex-adjusted incidence of type A aortic dissection repair adjusted to the 2012 Canadian Standard population. P for trend coefficients.

5.3 Non-Clinical Characteristics

Median household income was $46,856 (Inter-Quartile Range [IQR]: $39,199-$61,880.5] Canadian dollars. Median estimated travel time was 64.5 (IQR: 11.49-138.8) minutes. A total of 248 (52.1%) of patients resided ≥1 hour from the tertiary care centre. The majority of patients were from social deprivation quintiles 3 (24.7%) and 4 (24.2%). The most common material deprivation quintile was quintile 1 (26.6%), which is the least deprived quintile. The majority of patients (48.8%) came from Central Zone (Table 5.2).

Table 5.2: Non-Clinical Characteristics of Patients Who Underwent Ascending Aortic Surgery

Characteristics	All Patients n=476	Elective Patients n=393	Emergent Patients n=83
Median Household Income, $ (median, [IQR])	46,856 [39,199-61,880.5]	46,432 [39,163-62,031]	48,127 [39,235-59,862]
Social Deprivation Quintile			
1	77 (16.7%)	67 (17.5%)	10 (12.5%)
2	73 (15.8%)	53 (13.9%)	20 (25.0%)
3	114 (24.7%)	93 (24.4%)	21 (26.3%)
4	112 (24.2%)	100 (26.2%)	12 (15.0%)
5	86 (18.6%)	69 (18.1%)	17 (21.3%)
Material Deprivation Quintile			
1	123 (26.6%)	104 (27.2%)	19 (23.8%)
2	87 (18.8%)	71 (18.6%)	16 (20.0%)
3	93 (20.1%)	74 (19.4%)	19 (23.8%)
4	108 (23.4%)	89 (23.3%)	19 (23.8%)
5	51 (11.0%)	44 (11.5%)	7 (8.8%)
Estimated Travel Time, minutes (Median, [IQR])	64.5 [11.5-138.8]	65.0 [11.8-139.6]	48.51 [9.5-115.4]
Estimated Travel Time ≥1 hour	248 (52.1%)	211 (53.7%)	37 (44.6%)
Health Zone			
1 Western	96 (22.6%)	81 (23.0%)	15 (21.1%)
2 Northern	70 (16.5%)	60 (17.0%)	10 (14.1%)
3 Eastern	53 (12.5%)	45 (12.8%)	8 (11.3%)
4 Central	205 (48.4%)	167 (47.3%)	38 (53.5%)

Notes: Data presented as number (%) unless otherwise specified. IQR: Inter-Quartile Range

5.4 Outcomes

Overall, 25 (5.3%) of patients died in-hospital and 320 (67.2%) of patients experienced a composite in-hospital complication. Median length of stay was 10 days (IQR: 7-17 days). At discharge, 51 (10.7%) of patients were discharged to another hospital or nursing home. Of the patients who underwent elective surgery (n=393), in-hospital mortality was 2.3% and of the patients who underwent emergency surgery, in-hospital mortality was 19.3% (Table 5.3).

Table 5.3: Outcomes of All Patients Who Underwent Ascending Aortic Surgery

Outcome	**All Patients n=476**	**Elective Patients n=393**	**Emergent Patients n=83**
In-Hospital Mortality	25 (5.3%)	9 (2.3%)	16 (19.3%)
Composite Complication	320 (67.2%)	249 (63.4%)	71 (85.5%)
Hospital Length of Stay, days (median, [IQR])	10 [7-17]	9 [6-15]	17 [9-30]
Discharge Disposition to Another Institution or Nursing Home	51 (10.7%)	30 (7.6%)	21 (32.3%)
Long-Term All-Cause Mortality	73 (15.3%)	49 (12.5%)	24 (28.9%)

Notes: Data presented as number (%) unless otherwise specified. IQR: Inter-Quartile Range

5.5 The Concentration Index

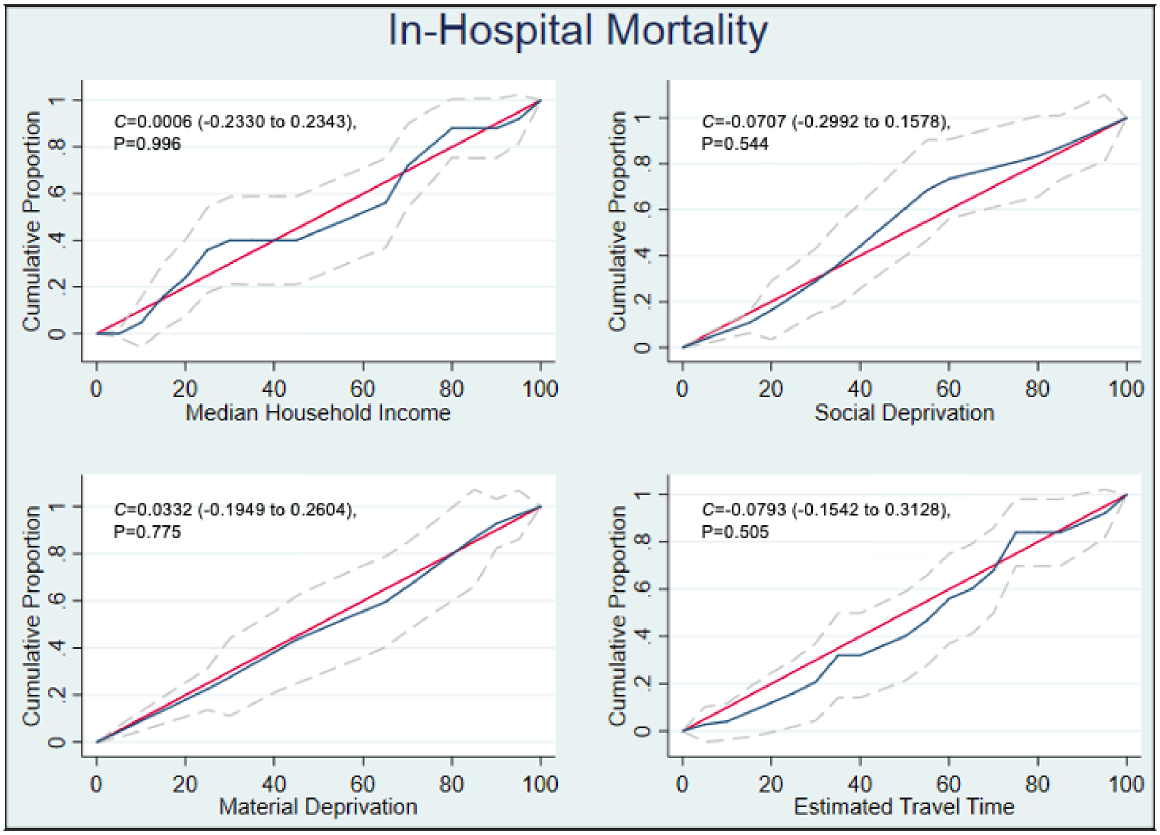
Calculation of the C for each outcome by median household income, social deprivation, material deprivation and estimated travel time revealed no significant inequality for the outcomes of in-hospital mortality, composite in-hospital complication, or discharge disposition. Prolonged length of stay was more concentrated among patients with lower median household income and more material deprivation. Long-term all-cause mortality was more concentrated among patients who live further from the tertiary care centre, however this did not reach statistical significance (Table 5.4). The Concentration curves by each ranking variable are graphically represented in Figures 5.3-5.7.

Table 5.4: The Concentration Indices for Outcomes

Outcome	**Median Household Income**	**Social Deprivation Quintile**	**Material Deprivation Quintile**	**Estimated Travel Time**
In-Hospital Mortality	0.0006 (-0.2330 to 0.2343)	-0.0707 (-0.2992 to 0.1578)	0.0332 (-0.1949 to 0.2604)	-0.0793 (-0.1542 to 0.3128)
Composite In-Hospital Complication	-0.0516 (-0.1631 to 0.0599)	-0.0094 (-0.1195 to 0.1006)	0.0399 (-0.0700 to 0.1497)	-0.0220 (-0.1334 to 0.0895)
Prolonged Length of Stay	-0.1107 (-0.2177 to -0.0035)*	0.0502 (-0.0561 to 0.1566)	0.1076 (0.0018 to 0.2133)*	0.0866 (-0.0205 to 0.1937)
Discharge Disposition	-0.0578 (-0.2284 to 0.1178)	-0.0224 (-0.1910 to 0.1463)	0.1052 (-0.0628 to 0.2732)	0.1170 (-0.0991 to 0.3331
All-Cause Mortality During Follow-up	-0.0585 (-0.2040 to 0.0870)	0.0144 (-0.1282 to 0.1570)	0.0700 (-0.0722 to 0.2122)	0.1359 (-0.0082 to 0.2801)

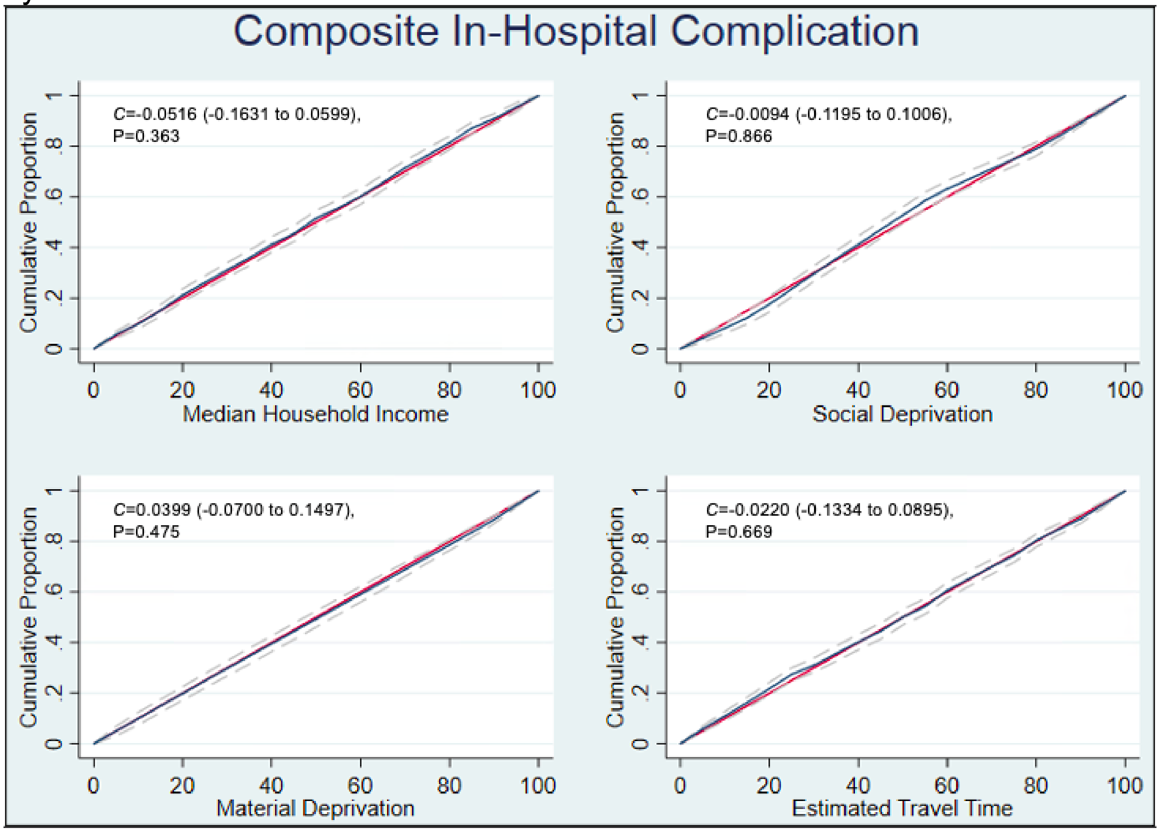
Notes: 95% Confidence Intervals are in brackets. Asterisks indicate statistical significance at 95% confidence interval

Figure 5.3: The Concentration Curves for Outcome of In-Hospital Mortality by Socioeconomic Variables and Remoteness



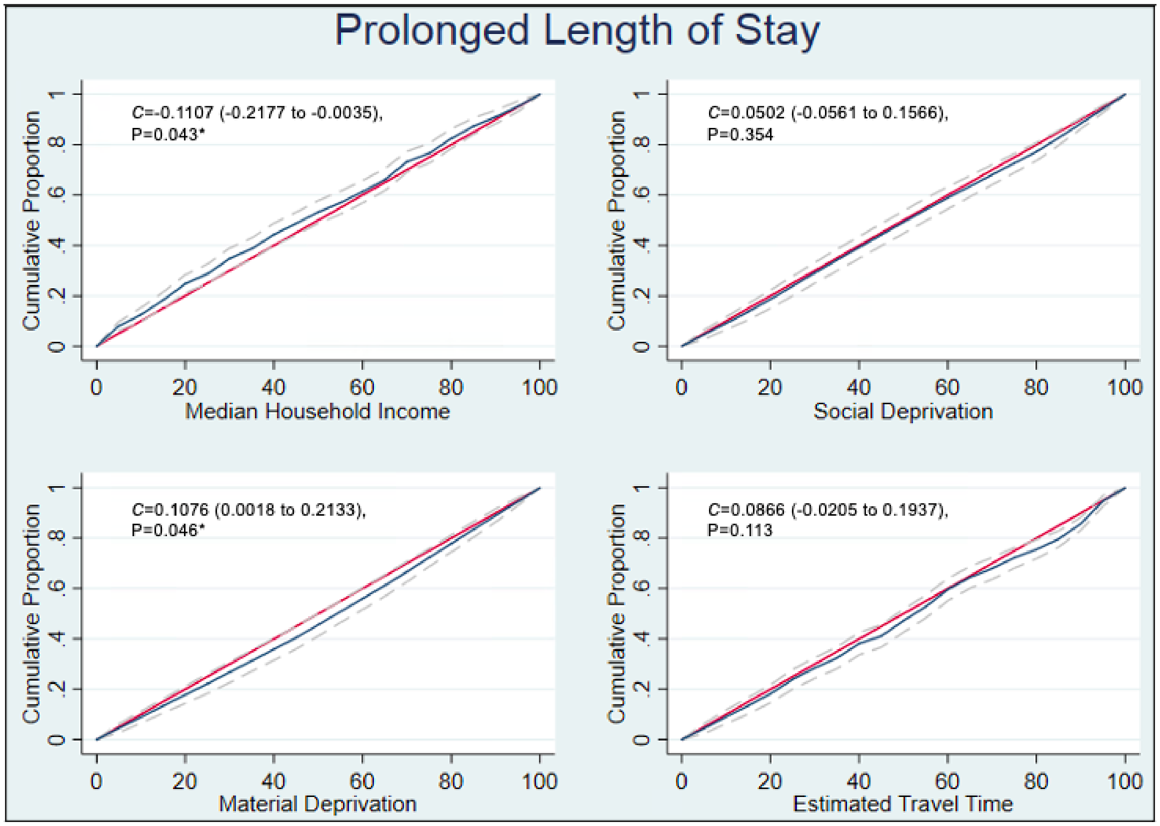
Notes: Concentration curves demonstrating cumulative proportion of in-hospital mortality ranked by median household income, social deprivation, material deprivation and estimated travel time. Dashed lines represent 95% Confidence Intervals.

Figure 5.4: Concentration Curves for Outcome of Composite In-Hospital Complication by Socioeconomic Variables and Remoteness



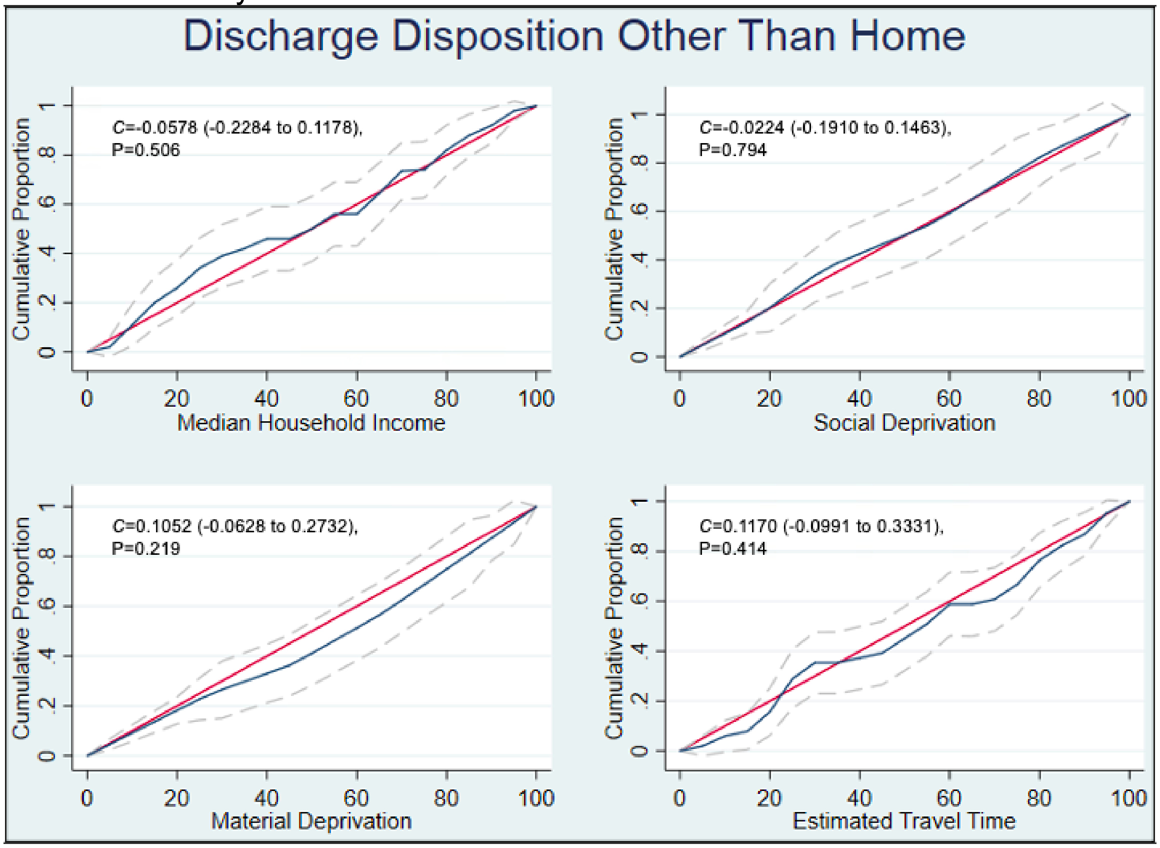
Notes: The Concentration curves demonstrating cumulative proportion of composite in-hospital complications ranked by median household income, social deprivation, material deprivation and estimated travel time. Dashed lines represent 95% Confidence Intervals.

Figure 5.5: The Concentration Curves for Outcome of Prolonged Length of Stay by Socioeconomic Variables and Remoteness



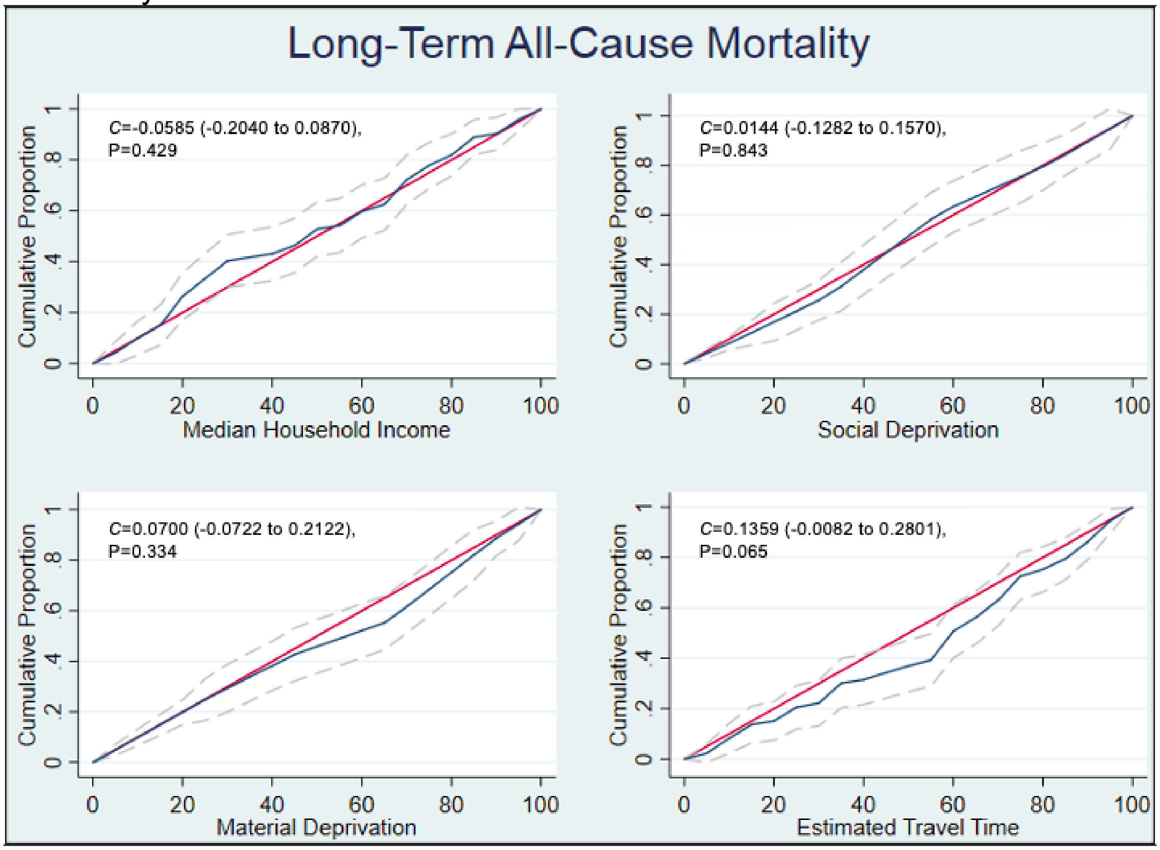
Notes: The Concentration curves demonstrating cumulative proportion of prolonged length of stay ranked by median household income, social deprivation, material deprivation and estimated travel time. Dashed lines represent 95% Confidence Intervals.

Figure 5.6: The Concentration Curves for Outcome of Discharge Disposition Other Than Home Ranked by Socioeconomic Variables and Remoteness



Notes: The Concentration curves demonstrating cumulative proportion of outcome of discharge disposition other than home ranked by median household income, social deprivation, material deprivation and estimated travel time. Dashed lines represent 95% Confidence Intervals.

Figure 5.7: The Concentration Curves for Outcome of Long-Term All-Cause Mortality Ranked by Socioeconomic Variables and Remoteness



Notes: The Concentration curves demonstrating cumulative proportion of outcome of long-term all-cause mortality ranked by median household income, social deprivation, material deprivation and estimated travel time. Dashed lines represent 95% Confidence Intervals.

5.6 Logistic Regression of In-Hospital Outcomes

5.6.1 In-Hospital Mortality

For the outcome of in-hospital mortality, univariable analysis did not demonstrate a significant effect of social deprivation, material deprivation, travel time ≥1 hour, or health zone (Appendix 1). Multivariable logistic regression analysis revealed age ≥60 (OR 8.10, 95% CI 2.01-32.6), history of diabetes (OR 3.55, 95% CI 1.08-11.7), history of angina (OR 3.18 95% CI 1.14-8.82), urgent status (11.4, 95% CI 2.34-55.3), and long CPB time (3.17, 95% CI 1.01-9.93) to be risk factors for in-hospital mortality. Socioeconomic deprivation and travel time did not emerge as risk factors for this outcome following multivariable risk adjustment (Table 5.5).

Table 5.5: Multivariable Logistic Regression for In-Hospital Mortality

Variable	**OR**	**95% CI**
Age ≥60 years	8.10*	2.02-32.6
Female Sex	1.39	0.45-4.27
Diabetes	3.55*	1.08-11.7
Chronic Kidney Disease	1.88	0.28-12.6
Cerebrovascular Disease	1.70	0.34-8.50
Angina	3.18*	1.14-8.82
Urgent Status	11.4*	2.34-55.3
Combined Operation	0.42	0.13-1.38
Aortic Dissection	0.47	0.10-2.26
Prolonged CPB Time	3.18	1.01-10.1
Social Deprivation Quintile		
1	Ref	
2	1.08	0.20-6.03
3	1.63	0.36-7.41
4	0.62	0.09-4.09
5	0.96	0.17-5.46
Material Deprivation Quintile		
1	Ref	
2	1.15	0.26-5.04
3	0.63	0.14-2.91
4	0.76	0.16-3.65
5	0.70	0.09-5.58
Estimated Travel Time ≥1 Hour	1.51	0.45-5.00

Notes: Multivariable logistic regression results for outcome of in-hospital mortality. CI: Confidence Interval; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

5.6.2 Composite In-Hospital Complication

For the outcome of composite in-hospital complication, univariable analysis did not demonstrate an effect of material deprivation or travel time ≥1 hour. Compared to quintile 1 of social deprivation (least deprived), being from social deprivation quintiles 2, 3, and 5 were risk factors for composite complications (Appendix 1). Multivariable logistic regression analysis revealed age ≥60 (OR 3.37, 95% CI 2.06-5.51), long CPB time (2.19, 95% CI 1.36-3.2), and being from social deprivation quintiles 2 (OR 3.26, 95% CI 1.43-7.46) and 3 (OR 2.59, 95% CI 1.27-5.32) but not 4 (OR 0.83, 95% CI 0.42-1.63) or 5 (OR 1.73, 95% CI 0.82-3.64) to be risk factors for in-hospital composite complications. There was no effect of material deprivation, or estimated travel time (Table 5.6).

Table 5.6: Multivariable Logistic Regression for Composite In-Hospital Complication

Variable	OR	95% CI
Age ≥60 years	3.37*	2.06-5.51
Female Sex	0.93	0.54-1.62
Hypertension	1.44	0.90-2.32
Diabetes	1.82	0.70-4.73
Dyslipidemia	1.46	0.88-2.44
Chronic Kidney Disease	1.18	0.22-6.28
Peripheral Vascular Disease	1.29	0.78-2.14
COPD	1.56	0.70-3.48
Angina	1.46	0.85-2.53
Urgent Status	2.14	0.62-7.32
Aortic Dissection	1.35	0.38-3.52
Prolonged CPB time	2.19*	1.36-3.52
Social Deprivation Quintile		
1	Ref	
2	3.26*	1.43-7.46
3	2.59*	1.27-5.32
4	0.83	0.42-1.63
5	1.73	0.82-3.64
Material Deprivation Quintile		
1	Ref	
2	0.83	0.41-1.66
3	0.79	0.38-1.65
4	0.71	0.33-1.52
5	1.19	0.46-3.11
Estimated Travel Time ≥1 Hour	1.09	0.62-1.91

Notes: Multivariable logistic regression results for outcome of composite in-hospital complication. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass Time; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

5.6.3 Prolonged Length of Stay

On univariable analysis, social deprivation, material deprivation, and travel time ≥1 hour were not risk factors for this outcome, but being from zone 3 (Eastern) compared to zone 1 (Central) was (Appendix 1). Multivariable logistic regression revealed age ≥60 (OR 2.48, 95% CI 1.58-3.90), history of cerebrovascular disease (OR 2.79, 95% CI 1.01-7.71) and long cardiopulmonary bypass time (OR 2.57, 95% CI 1.67-3.95) to be risk factors for this outcome (Table 4.7). There was no independent effect of social deprivation, material deprivation, or travel time (Table 4.7).

Table 5.7: Multivariable Logistic Regression for Prolonged Length of Stay

Variable	OR	95% CI
Age ≥60 years	2.48*	1.58-3.90
Female Sex	1.23	0.74-2.04
Hypertension	0.96	0.61-1.49
Dyslipidemia	1.22	0.78-1.92
Chronic Kidney Disease	3.66	0.43-31.2
Cerebrovascular Disease	2.79*	1.01-7.71
Peripheral Vascular Disease	1.41	0.90-2.20
Urgent Status	1.95	0.65-5.83
Aortic Dissection	1.31	0.46-3.74
Prolonged CPB time	2.57*	1.67-3.95
Social Deprivation Quintile		
1	Ref	
2	1.13	0.55-2.34
3	0.90	0.46-1.76
4	0.84	0.43-1.63
5	1.14	0.56-2.31
Material Deprivation Quintile		
1	Ref	
2	1.05	0.56-1.99
3	1.14	0.58-2.26
4	1.36	0.68-2.72
5	1.21	0.52-2.81
Estimated Travel Time ≥1 Hour	1.15	0.68-1.93

Notes: Multivariable logistic regression results for outcome of prolonged length of stay. CI: Confidence Interval; CPB: Cardiopulmonary Bypass; OR: Odds Ratio: Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

5.6.4 Discharge Disposition to Other Institution or Nursing Home

On univariable analysis, social deprivation, material deprivation and travel time ≥1 hour were not risk factors for the outcome of discharge to other institution or nursing home (Appendix 1). Multivariable logistic regression analysis revealed female sex (OR 3.09, 95% CI 1.46-6.57) and chronic kidney disease (OR 10.6, 95% CI 2.37-47.0) to be risk factors for discharge to other institution or nursing home (Table 5.8). Social deprivation, material deprivation and estimated travel time did not emerge as risk factors for this outcome (Table 5.8).

Table 5.8: Multivariable Logistic Regression for Discharge Disposition Other Than Home

Variable	**OR**	**95% CI**
Age ≥60 years	1.92	0.92-4.02
Female Sex	3.09*	1.46-6.57
Hypertension	1.51	0.71-3.20
Chronic Kidney Disease	10.6*	2.37-47.0
Combined Procedure	1.07	0.49-2.34
Aortic Dissection	2.94	0.74-11.7
Prolonged CPB time	1.84	0.89-3.81
Social Deprivation Quintile		
1	Ref	
2	1.09	0.34-3.46
3	0.53	0.17-1.68
4	1.20	0.42-3.42
5	0.47	0.14-1.57
Material Deprivation Quintile		
1	Ref	
2	0.57	0.18-1.80
3	0.55	0.18-1.66
4	1.00	0.33-3.04
5	0.87	0.23-3.29
Estimated Travel Time ≥1 Hour	1.33	0.56-3.14

Notes: Multivariable logistic regression results for outcome of discharge disposition other than home. CI: Confidence Interval; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

5.6.5 Effect of Health Zone

For the complications in in-hospital mortality, composite in-hospital complications, and discharge disposition, there was no increased risk of complication based on patient's health zone. Patients from Zone 3 (Eastern) were at increased risk of prolonged hospital length of stay (OR 2.37, 95% CI 1.01-5.57) (Table 5.9).

Table 5.9: Multivariable Logistic Regression Analyses for Each Outcome Using Health Zone

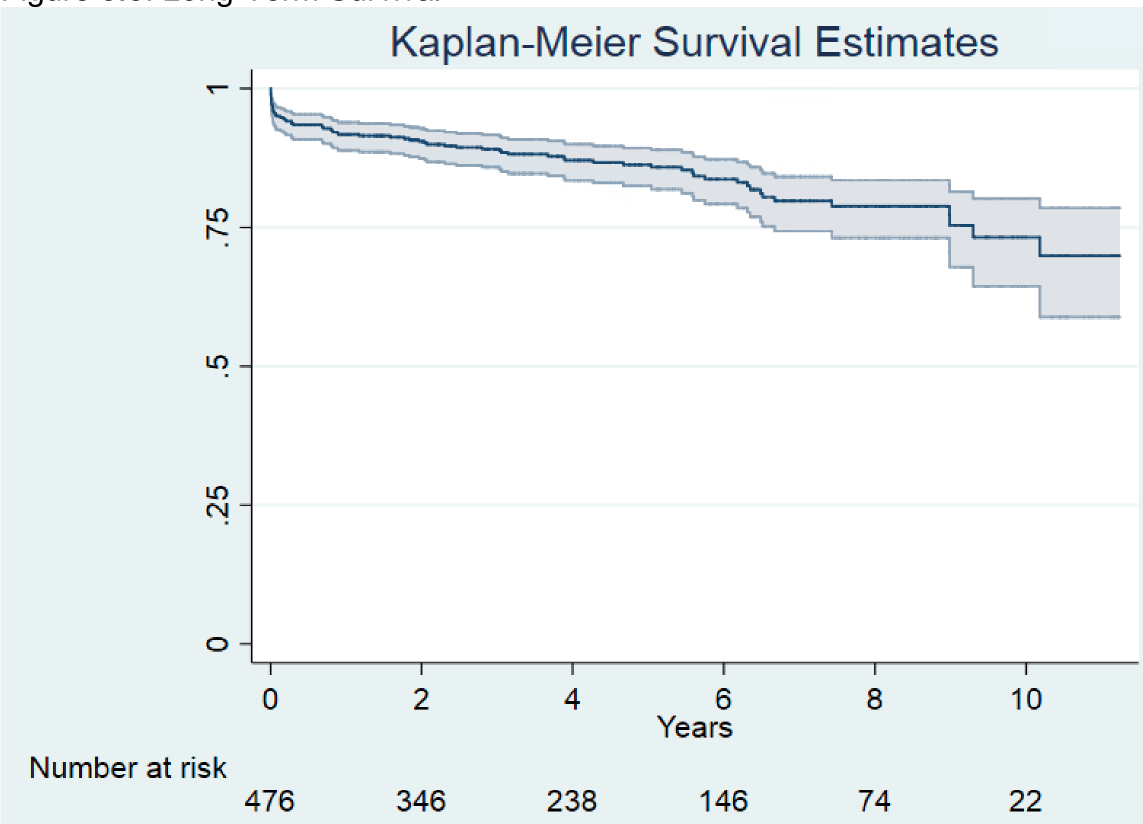
Variable	**In-Hospital Mortality**		**Composite Complication**		**Prolonged Stay**		**Discharge Disposition**	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age ≥60 years	5.62*	1.29-24.5	3.51*	2.08-5.95	2.49*	1.54-4.04	2.06	0.93-4.56
Female Sex	1.14	0.32-4.00	1.00	0.55-1.84	1.32	0.76-2.30	2.82*	1.27-6.30
Hypertension	N/A	N/A	1.42	0.86-2.35	0.77	0.48-1.25	1.21	0.55-2.67
Diabetes	5.58*	1.53-20.3	1.89	0.72-4.98	N/A	N/A	N/A	N/A
Dyslipidemia	N/A	N/A	1.69	0.97-2.93	1.58	0.97-2.57	N/A	N/A
Chronic Kidney Disease	2.51	0.33-19.1	0.73	0.14-3.84	N/A	N/A	5.90	1.13-30.7
Cerebrovascular Disease	1.96	0.35-11.0	N/A	N/A	2.64	0.93-7.51	N/A	N/A
Peripheral Vascular Disease	N/A	N/A	1.18	0.69-2.00	N/A	N/A	N/A	N/A
COPD	N/A	N/A	1.38	0.61-3.09	N/A	N/A	N/A	N/A
Angina	N/A	N/A	1.40	0.78-2.52	N/A	N/A	N/A	N/A
Urgent Status	11.0	2.11-57.1	2.23	0.65	2.83	0.90-8.91	N/A	N/A
Combined Operation	0.34	0.09-1.28	N/A	N/A	N/A	N/A	0.96	0.43-2.18
Aortic Dissection	0.52	0.10-2.68	1.17	0.35-3.90	1.31	0.43-3.96	3.15	0.74-13.4
Long CPB time	3.50	0.93-13.1	2.00*	1.21-3.31	2.47*	1.56-3.90	1.44	0.67-3.11
Social Deprivation Quintile 1	Ref		Ref					
2	4.15	0.35-48.6	3.64*	1.46-9.11	0.85	0.38-1.88	0.92	0.24-3.59
3	4.98	0.46-53.5	2.69*	1.25-5.79	0.79	0.39-1.61	0.72	0.20-2.61
4	2.21	0.16-29.8	0.73	0.35-1.52	0.63	0.31-1.29	1.49	0.46-4.87
5	3.33	0.28-40.1	1.87	0.84-4.18	0.93	0.44-1.99	0.49	0.13-1.86
Material Deprivation Quintile 1	Ref		Ref					
2	0.83	0.17-4.17	0.95	0.45-2.01	1.27	0.65-2.50	0.75	0.23-2.42
3	0.69	0.13-3.55	0.77	0.35-1.70	1.17	0.55-2.47	0.78	0.24-2.56
4	0.42	0.07-2.65	0.73	0.35-1.52	1.61	0.74-3.51	1.57	0.46-5.35
5	0.53	0.04-7.21	1.87	0.84-4.18	1.24	0.49-3.13	0.98	0.23-4.14
Zone 1 Western	0.94	0.17-5.29	0.82	0.38-1.73	1.09	0.55-2.19	0.49	0.15-1.63
Zone 2 Northern	1.81	0.39-8.32	1.74	0.34-1.59	0.70	0.34-1.43	1.13	0.38-3.41
Zone 3 Eastern	1.33	0.18-10.0	0.84	0.35-2.02	2.37*	1.01-5.57	1.96	0.62-6.12
Zone 4 Central	Ref		Ref		Ref		Ref	

Notes: Multivariable logistic regression results for outcome of discharge disposition other than home. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; N/A: Not Applicable (p>0.1 on univariable analysis); OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interva

5.7 Survival Analysis

Vital statistics data was available until March 31, 2016 during which time 73 (15.3%) of patients died during the 2,074 patient-years of follow-up (Figure 5.8).

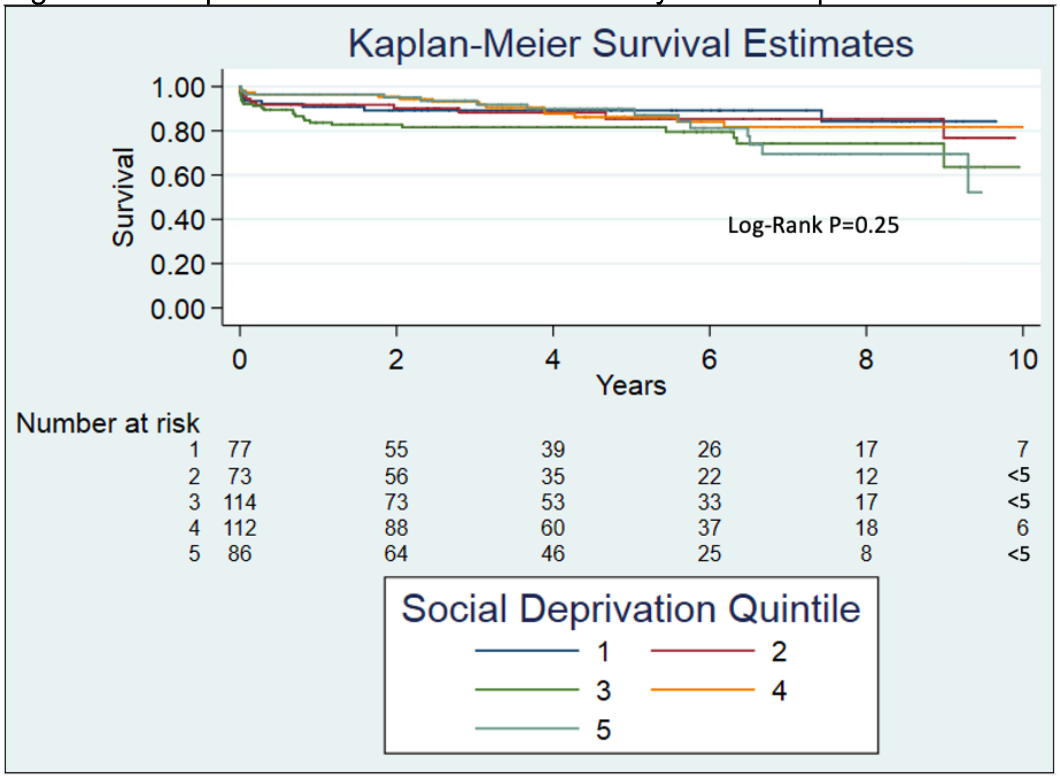
Figure 5.8: Long-Term Survival



Notes: Unadjusted Kaplan-Meier survival estimates for all patients. Shaded area represents 95% confidence interval.

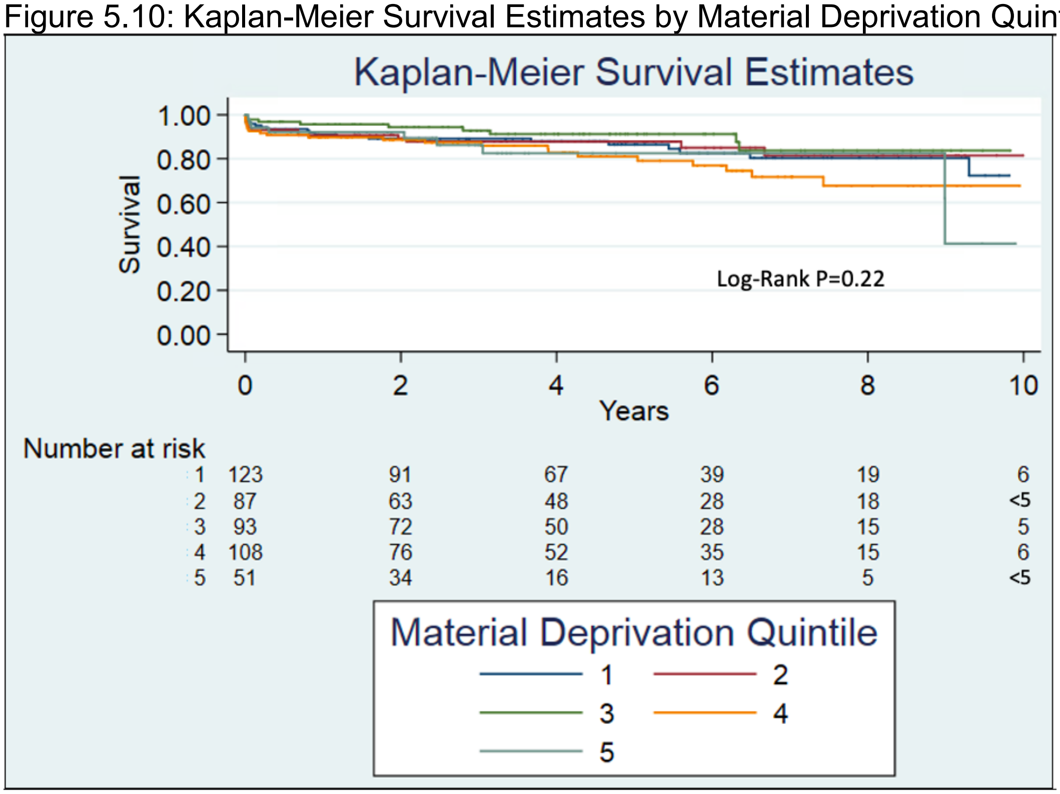
Median follow-up was 4.0 years (IQR 1.9-6.5 years). Kaplan-Meier survival estimates showed no difference in long-term survival among social deprivation quintiles (log-rank p=0.25) (Figure 5.9) and material deprivation quintiles (log-rank p=0.22) (Figure 5.10). A significant difference in long term survival among patients who resided ≥ 1 hour from the tertiary centre vs those who resided <1 hour from the tertiary center (log-rank p=0.01) (Figure 5.11) and between health zones (log-rank p=0.03) (Figure 5.12).

Figure 5.9: Kaplan-Meier Survival Estimates by Social Deprivation Quintile



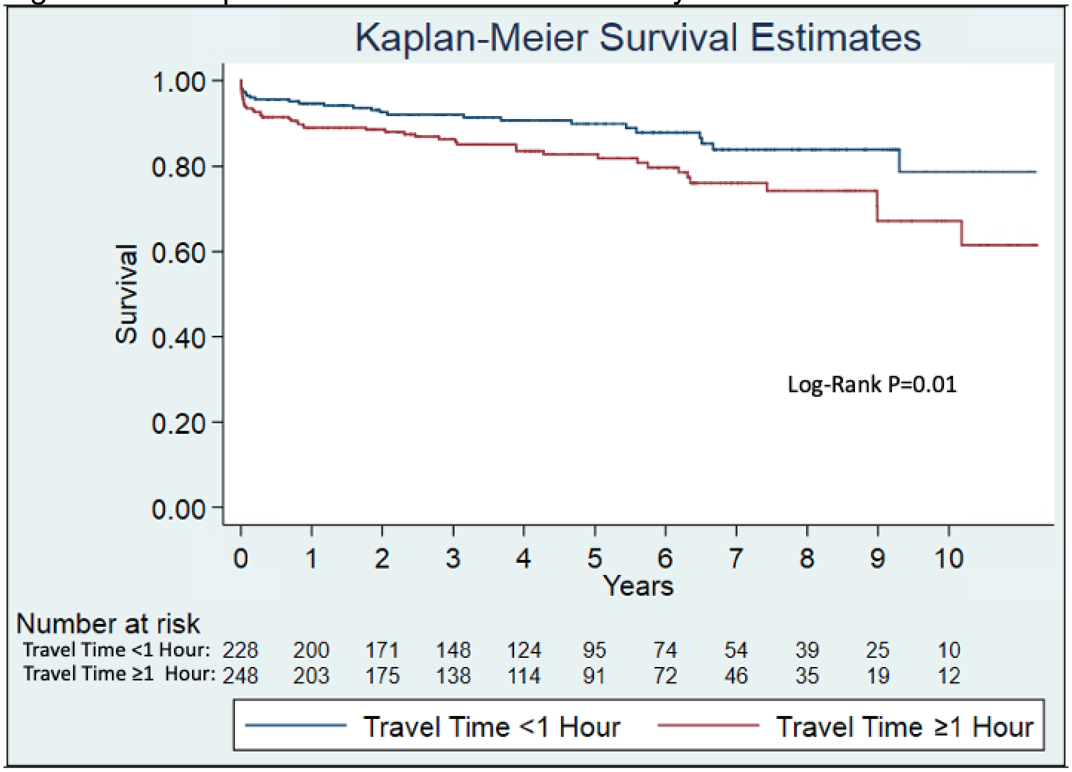
Note: Survival estimates by social deprivation quintiles.

Figure 5.10: Kaplan-Meier Survival Estimates by Material Deprivation Quintile



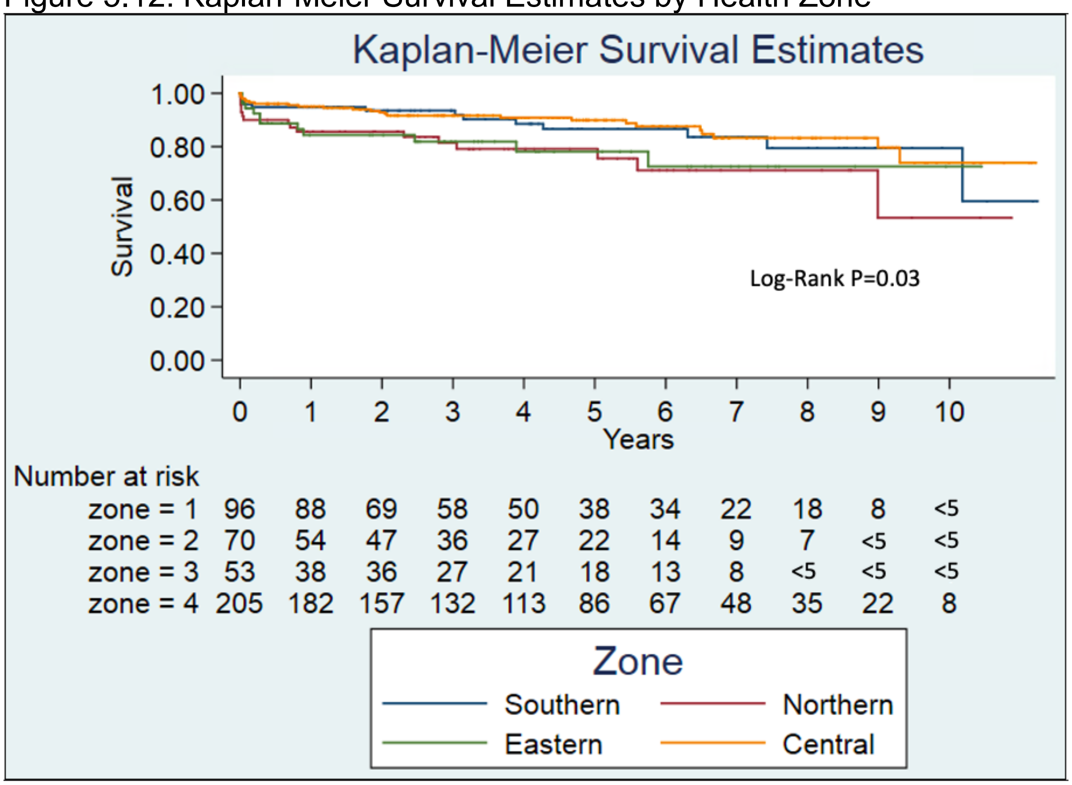
Note: Survival estimates by material deprivation quintiles.

Figure 5.11: Kaplan-Meier Survival Estimates by Travel Time <1 and ≥1 Hour



Note: Survival estimates by estimated travel time <1 and ≥ 1 hour.

Figure 5.12: Kaplan-Meier Survival Estimates by Health Zone



Note: Survival estimates by estimated travel time <1 and ≥ 1 hour.

On univariable Cox proportional hazard modeling, social and material deprivation were not risk factors for all-cause death during follow-up, but travel time ≥1 hour and health zone was (Appendix 1). When estimated travel time was used as the geographic variable of interest, multivariable Cox proportional hazard modeling revealed age ≥60 (Hazard Ratio [HR] 4.60, 95% CI 2.37-8.91), diabetes (HR 2.78, 95% CI 1.40-5.50), COPD (HR 3.15, 95% CI 1.71-5.81), urgent status (HR 4.01, 95% CI 1.59-10.1), and travel time ≥1 hour (HR 2.19, 95% CI 1.13-4.28) to be risk factors for long-term mortality. Compared to material deprivation quintile 1, material deprivation quintile 3 was actually at decreased risk for long-term mortality (HR 0.35, 95% CI 0.15-0.84) (Table 5.10). When health zone was used as the geographical variable of interest, multivariable Cox proportional hazard modeling also reveal being from health zone 2 (Northern), compared to zone 4 (Central) to be at risk for decreased long-term survival (HR 2.79, 95% CI 1.26-6.14) (Table 5.11).

Table 5.10: Multivariable Cox Proportional Hazard Modeling for Long-term Survival Using Estimated Travel Time as Geographic Variable of Interest

Variable	**HR**	**95% CI**
Age ≥60 years	4.60*	2.37-8.91
Female Sex	1.65	0.94-2.91
Hypertension	0.91	0.52-1.60
Diabetes	2.78*	1.40-5.50
Chronic Kidney Disease	1.27	0.51-3.17
Peripheral Vascular Disease	1.47	0.88-2.48
Cerebrovascular Disease	1.90	0.90-4.02
COPD	3.15*	1.71-5.81
Urgent Status	4.01*	1.59-10.1
Combined Operation	0.76	0.41-1.43
Aortic Dissection	0.82	0.32-2.10
Long CPB Time	1.45	0.83-2.51
Social Deprivation Quintile		
1	Ref	
2	0.75	0.30-1.92
3	0.91	0.41-2.01
4	0.92	0.39-2.18
5	0.87	0.37-2.03
Material Deprivation Quintile		
1	Ref	
2	0.69	0.31-1.52
3	0.35*	0.15-0.84
4	0.65	0.29-1.46
5	0.70	0.26-1.84
Estimated Travel Time ≥1 Hour	2.19*	1.12-4.28

Notes: Cox proportional hazard model for long-term all-cause mortality. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease, CPB: Cardiopulmonary Bypass Time; HR: Hazard Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table 5.11: Multivariable Cox Proportional Hazard Modeling for Long-term Survival Using Health Zone as Geographic Variable of Interest

Variable	**Long-Term All-Cause Mortality**	
	HR	**95% CI**
Age ≥60 years	4.52*	2.20-9.29
Female Sex	1.59	0.86-2.94
Chronic Kidney Disease	1.62	0.65-4.07
Peripheral Vascular Disease	1.40	0.80-2.46
Cerebrovascular Disease	2.07	0.94-4.56
COPD	3.62	0.90-6.91
Urgent Status	3.70*	1.34-10.2
Combined Operation	0.69	0.35-1.35
Aortic Dissection	0.85	0.30-2.40
Long Cross-Clamp Time	1.38	0.77-2.47
Social Deprivation Quintile		
1	Ref	
2	0.71	0.25-1.98
3	0.88	0.36-2.15
4	0.83	0.31-2.19
5	0.73	0.28-1.93
Material Deprivation Quintile		
1	Ref	
2	0.69	0.30-1.56
3	0.32	0.13-0.83
4	0.76	0.32-2.18
5	0.80	0.29-2.18
Health Zone		
1 Southern	1.09	0.44-2.66
2 Northern	2.79*	1.26-6.14
3 Eastern	2.20	0.92-5.26
4 Central	Ref	

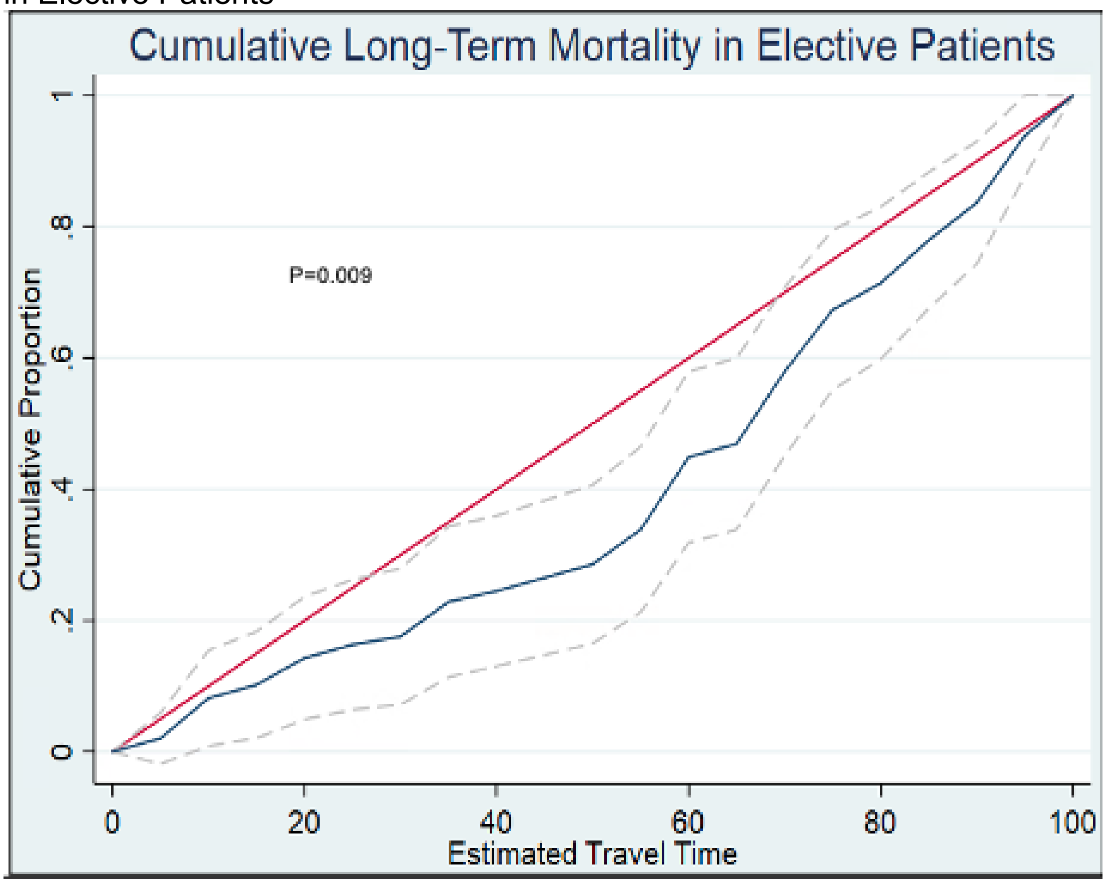
Notes: Cox proportional hazard model for long-term survival. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; HR: Hazard Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

5.8 Elective Patients

In an analysis of the 393 patients who underwent elective ascending aortic surgery, in-hospital mortality was 9 (2.3%), in-hospital composite complications occurred in 249 (63.4%), median hospital length of stay was 9 [IQR 6-15] days and 30 (7.6%) were discharge to another institution or nursing home (Table 5.3).

For the outcome of composite in-hospital complications, in addition to social deprivation quintiles 2 and 3, quintile 5 was at increased risk compared to quintile 1. For the outcome of prolonged length of stay, the C showed that prolonged length of stay is concentrated among high materially deprived patients (C: 0.1051, 95% CI -0.0094 to 0.2197, p=0.072), but this did not research statistical significance. For the outcomes of all-cause long-term mortality, there was inequality favouring patients residing close the tertiary centre (C: 0.2298, 95% CI 0.0575 to 0.4021, p=0.009) (Figure 5.13). Multivariable logistic regression for all outcomes revealed similar significant risk factors for each outcome as was found in the analysis of all patients (Appendix 2).

Figure 5.13: The Concentration Curve of Long-Term Mortality by Estimated Travel Time in Elective Patients



Notes: The Concentration curves demonstrating cumulative proportion of outcome of long-term all-cause mortality ranked by estimated travel time. Dashed lines represent 95% confidence interval.

Chapter 6: Discussion

This study describes an increase in incidence of TAA repair in males, but not females, and in TAAD repair in both males and females over the course of the study period. Outcomes in patients undergoing TAA and TAAD repair are described as well as and the effect of SES and remoteness from the tertiary care on outcomes. This study uses two types of analyses to examine the relationship between socioeconomic factors and remoteness from the tertiary centre on outcomes in patients with thoracic aortic disease. Using the C, it was determined that socioeconomic variables have little effect on in-hospital mortality, composite in-hospital complications, discharge disposition, and all-cause mortality. The adverse outcome of prolonged length of stay showed more concentration among patients with lower income and more material deprivation. The adverse outcome of long-term mortality showed inequality in distribution among patients who live at increased travel time to the tertiary centre but this did not reach statistical significance (p=0.07) when looking at all patients but it did when only looking at elective patients (p=0.009). Unlike the analysis using C, logistic regression analysis showed quintiles 2 and 3 of social deprivation are at increased risk of composite in-hospital complications. Logistic regression showed no effect of other socioeconomic variables or remoteness on the outcomes of in-hospital mortality, prolonged length of stay, or discharge disposition. Cox-proportional hazard modeling showed a significant effect of increased estimated travel time on long-term mortality. The rest of this chapter discusses the main findings of the study, some considerations about the interpretation of the results and implications for healthcare resource planning.

6.1 In-Hospital Outcomes

Using the C, no effect of median household income, social or material deprivation, or estimated travel time was found on the outcomes of in-hospital mortality, composite in-hospital complication, or discharge disposition to other institution or nursing home. Using multivariable logistic regression modeling, no effect of social or material deprivation quintiles or estimated travel time on the outcomes of in-hospital mortality, prolonged length of stay, or discharge to other institution or nursing home was found.

Studies on SES and outcomes in patients undergoing AAA repair have shown conflicting results, with no effect of SES on 30-day mortality in two studies (Agabiti et al., 2008; Durham et al., 2010) and increased 30-day mortality with lower SES in 5 studies (Al Adas et al., 2019; Boxer et al., 2003; Khashram et al., 2017; Lemaire et al., 2008). Studies in patients undergoing cardiac surgery have been much more conclusive, with lower SES being associated with worse short-term outcomes in eight studies (Butt et al., 2019; Charles et al., 2019; Coyan et al., 2020; Dalén et al., 2015; Gibson et al., 2009; Koch et al., 2010; Nielsen et al., 2019; Pagano et al., 2009). Until now, no studies have examined the effect of SES in elective TAA repair. This study fills a gap in the literature on SES and outcomes in TAA repair.

Two single-institution studies examining patients undergoing TAAD repair in the Unites States have shown no effect of lower SES on 30-day mortality (Altomare, 2015; Kabbani et al., 2016); however, a larger study of 15,641 patients using nation-wide administrative data showed patients with lower median income and those who are supported by Medicare experienced worse in-hospital mortality (Zimmerman et al., 2016). The current study included patients with TAAD, but only 85 patients presented with this diagnosis, making the cohort too small to draw statistical conclusions on the effect of SES on outcomes in this population.

The C and multivariable logistic regression drew different conclusions for the effect of SES on the outcome of prolonged length of stay. While the C suggested a higher concentration of prolonged length of stay among patients with lower median household income and greater material deprivation, those with more material deprivation were not at increased risk of prolonged length of stay on multivariable logistic regression. This could be because the unfair distribution is seen across the spectrum of quintiles 2-5, and is not evident when simply comparing each quintile to the least deprived quintile. Prolonged length of stay can have both a clinical basis (increased need for hospitalization beyond usual timeframe due to comorbidities and post-operative complications) and a socioeconomic basis due to inadequate patients supports at home which may impede discharge. It is also possible that increased concentration of prolonged length of stay among patients with lower median household income and greater material deprivation is due to clinical factors that are adjusted for in multivariable logistic regression. It is possible that socioeconomic factors and clinical variables are multiplicative rather than additive in driving prolonged length of stay, as a more complex clinical picture would require both increased time in hospital to treat comorbidities and increased supports at discharge.

An analysis of 3578 consecutive cardiac surgery patients from a single institution in the United Kingdom showed that increased socioeconomic deprivation was associated with increased hospital length of stay; however this finding was not risk-adjusted for differences in clinical variables (Taylor et al., 2003). In Canada, research has shown an association between lower socioeconomic status and prolonged length of stay in trauma patients (Moore et al., 2015) and in seniors presenting to hospital (Amegbor et al., 2020). The findings in those studies were felt to be due to inadequate resources needed to facilitate timely discharge. The finding of increased concentration of prolonged length of stay in patients with lower median household income and greater material deprivation, but not social deprivation, in the current study is interesting as it suggests financial barriers might prevail over social support barriers; however, these data (as well as data from other studies) are drawn from neighbourhood level socioeconomic deprivation and may not reflect the individual patient's social support system. Qualitative methods might be better suited to further explore barriers to discharge on an individual basis.

Patients from Zone 3 (Eastern) were at increased risk of prolonged length of stay compared to patients from Zone 4 (Central). Eastern zone includes residents of Cape Breton island and Guysborough County, and has 2 regional hospitals and 11 community hospitals. Further research is needed to identify barriers to home hospital transfer or discharge supports, should they exist, in patients from Eastern Zone, with possible consideration of expansion of hospital and/or community services. Not only would this better serve patients from this region, but it would also facilitate patient flow from the tertiary centre to increase surgical capacity.

For the outcome of composite in-hospital complication, there was no increased concentration of composite in-hospital complications among patients with more social deprivation. However, on multivariable logistic regression quintiles 2 and 3 were at higher risk of composite in-hospital complications compared to quintile 1 (least deprived). The lack of significant concentration when ranking by social deprivation could be due to quintiles 4 and 5 not being at significant risk for composite in-hospital complications. In elective patients only, patients from social deprivation quintiles 2, 3, and 5 were at increased risk for composite in-hospital complications compared to quintile 1. This is also an interesting finding as it is not clear why patients at higher social deprivation quintiles would be at higher risk of in-hospital composite complications when this variable was not significant for other in-hospital complications including mortality, prolonged length of stay, or discharge disposition. Additionally, social deprivation would be hypothesized to be more related to factors affecting patient discharge, such as prolonged length of stay or discharge disposition to other institution or nursing home. It is possible patients with poor social support networks present later, resulting in more complications from delayed presentation or delays in having elective operations. Further exploration of the effect of SES on time from presentation to surgery might help explain these findings.

6.2 Remoteness and Long-Term Mortality

Using the C, all-cause long-term mortality was found to be more concentrated among patients who resided further away from the tertiary centre. However, this finding was only statistically significant in elective patients and not when elective patients were combined with those who underwent urgent or emergent TAA surgery. Cox proportional hazard modeling found that patients whose estimated travel time was ≥1 hour from the tertiary centre were at increased risk for long-term mortality. Health inequality must be distinguished from health inequity. A health inequality can be defined as “differences in health status or in the distribution of health determinants between different population groups.” Some of these inequalities are due to biological determination or free choice and are based on the individual, and do not represent inequities. If the health inequality is due to an external environment or condition that is mainly outside the control of the individual, this uneven distribution is avoidable, unjust, and unfair, representing a health inequity (World Health Organization, 2010). The Canada Health Act promises equal access to care (Canada Health Act, 1984), and decreased survival following TAA and TAAD repair is a health inequity (unfair inequality) of healthcare utilization in Nova Scotia that should be addressed.

This is the first study to examine the effect of remoteness on elective ascending thoracic aortic operations, but comparisons can be made to patients who experience aortic dissection and AAA repair, as there is some overlap in follow-up management of these patients. In a study of patients who underwent endovascular AAA repair or TBAD repair, there was no effect of increased distance on being lost to follow-up (Kret et al., 2013). In patients undergoing elective AAA repair in Australia, being from rural or remote areas had no effect on long-term survival, but was associated with increased AAA-related events (Golledge et al., 2020). In a study conducted at the Veteran’s Affairs (VA) Medical Centre in Albuquerque, New Mexico, which serves rural populations from 3 adjacent states in the US, patients at ≥100 miles from the tertiary centre experienced equivalent follow-up and long-term survival following elective endovascular AAA repair. This can be postulated to be related to several factors. First, the VA hospitals share an integrated electronic system which can track patients in any VA facility in the country, facilitating follow-up. Second, patients in the VA system have added cost coverage, including travel vouchers, that minimize cost implications related to travel. Finally, many of these patients were enrolled in clinical trials and had dedicated nursing staff to ensure complete follow-up for patients, which would likely result in improved follow-up in all patients compared to routine care (Sarangarm et al., 2010). At the time of the current study, the province of Nova Scotia did not have properly integrated electronic records to allow for complete sharing of patient data across hospitals and there was no reimbursement for travel costs for patients seeking medical care. With regards to clinical staff facilitating follow-up, patients who undergo thoracic aortic surgery could be referred to a multidisciplinary connective tissue clinic. This clinic has some nursing staff who can provide enhanced follow-up for patients, however referral to this clinic was not standard, and wait times could exceed a year for follow-up visits. For patients who are not referred to the clinic it was up to individual surgeons to ensure follow-up. As 11% of patients do not have a family doctor in some Health Zones in Nova Scotia (Nova Scotia Health, 2021), there is an insufficient safety net for patients who are lost to follow-up.

A large component of patient follow-up after aortic surgery are specialized gated CT scans (timed to the cardiac cycle) which were only conducted at the QEII Health Sciences centre at the time of the study. The inability to perform gated CT scans at outside institutions means patients need almost yearly visits to Halifax to have follow-up imaging. In the case of acute emergencies, sometimes CT scans performed in the periphery have to be repeated to ensure accurate diagnosis of acute aortic syndrome, resulting in delays in care. The finding of this study justifies expansion of gated CT scans to all regional hospitals located outside of Central Zone.

Significantly increased mortality was observed in Health Zone 2 (Northern) and near significant increased mortality was observed in Health Zone 3 (Eastern). The cause of increased mortality in patients from Health Zone 2 is of concern. In Health Zone 2, 10.3% of the population does not have a family physician, compared to only 2.3% in Zone 4 (Central Zone) (Nova Scotia Health, 2021), possibly contributing to loss to follow-up. Further analysis of the Health Zone 2 population could help identify drivers for increased mortality in this population. This study also spans a period from 2005-2015 which included restructuring of Nova Scotia Health Zones, so the patients from Zone 2 actually would have been spread across the Cumberland Health Authority, Colchester East Hants Health Authority, and Pictou County Health Authority (Nova Scotia Health Authority, 2015). Restructuring may lead to better healthcare delivery to this population going forward from 2015 on, and this analysis should be re-evaluated with the new model of care.

Finally, this analysis attempts to study the independent effects of socioeconomic deprivation and remoteness from the tertiary centre by including both in multivariable logistic regression models. This analysis showed that increased travel time, but not socioeconomic deprivation, is associated with decreased long-term survival. In Canada, increasing remoteness is associated with increased all-cause mortality (Subedi et al., 2019), possibly highlighting drivers for mortality among patients at increased travel time that would exist beyond their diagnosis of thoracic aortic disease. It is possible that patients at increased distance from the tertiary care centre are experiencing decreased long-term survival not just due to geographic barriers to access care to care for thoracic aortic disease, but also due to unmeasured causes of adverse health outcomes that are found in rural populations, and the solution may not be as simple as increasing resources for thoracic aortic disease clinical follow-up. Increased overall cardiovascular health promotion for patients who live in rural Nova Scotia, which would help all aging populations not just those with aortic disease, may be a more important health initiative.

6.3 Sex and Outcomes in Thoracic Aortic Aneurysm

While sex effects of outcomes in TAA and TAAD repair was not the main objective of this study, females are often under-represented in cardiovascular research and female-specific findings should be reported (Chung et al., 2020). Current guidelines are unclear on distinct cut-offs for surgical intervention in females (Boodhwani et al., 2014) despite females having lower body surface area than men, and a higher risk of rupture and dissection at lower aneurysm sizes (Trimarchi et al., 2012). The finding of an increase in incidence of TAA repair in men but not women, with parallel increase in incidence of TAAD repair in both men and women suggest there may be a screening gap, or a delay in referral for women for elective TAA repair in Nova Scotia. Education surrounding appropriate diameters for referral should be conducted.

The current study included 107 women, who represented 22.5% of the cohort. This sample was too small to conduct subgroup analysis in women. Multivariable regression found female sex was not a risk factor for in-hospital mortality, composite in-hospital complications, prolonged length of stay, or long-term mortality, but females were more likely to be discharged to a nursing home or other institution compared to males. This finding of no effect of sex on in-hospital morbidity and mortality is consistent with another study on proximal aortic root operations (McMullen et al., 2020). Other research has shown that among patients with thoracic aortic aneurysms, women experience more rapid growth (Boczar et al., 2019), are more likely to dissect at smaller aneurysm sizes (Trimarchi et al., 2012), experience aortic dissection (Davies et al., 2002; McMullen et al., 2020), and experience delay in diagnosis (Harris et al., 2011). In a Canada-wide analysis of 1653 complex thoracic aortic operations including 498 women, after adjusting for comorbidities and complexity of operation, women were at increased risk of death, stroke and morbidity (Chung et al., 2019). The current study's results likely diverge from this larger analysis as the result of a smaller sample size.

While there are biologic bases for sex differences in cardiovascular disease in women, there are less-studied gender-based differences in the experiences of health in women based on societal gender roles. While females being at increased risk for discharged to another hospital or nursing home could be due to more clinically advanced disease, it is also possible that this finding is driven by gender role factors. Women are more likely to be care providers in older age, have functional limitations in older age, or may be widowed already, making them more vulnerable to decreased supports in the case of significant health issues (Carmel, 2019).

6.4 Implications for Health Resource Planning

Nova Scotia has a single tertiary care centre, the Maritime Heart Centre, that provides all cardiac and thoracic aortic operations for the province of Nova Scotia. Patients at increased travel time from the Maritime Heart Centre experience decreased long-term survival. While a second heart center may reduce travel time, lower surgical volume is associated with increased 30-day mortality in patients undergoing elective thoracic aortic aneurysm repair and emergent TAAD repair (Brescia et al., 2019; Gazoni et al., 2010). In a nation-wide analysis of Medicare beneficiaries in the United States, it was shown the inter-institution transfer was not associated with increased risk of mortality, and that transfers to high-volume hospitals was associated with a 7.2% absolute risk reduction in operative mortality (Goldstone et al., 2019). This evidence of the need to maintain hospital volume suggests improving care for patients at increased travel time should not include the addition of another tertiary centre. Rather, barriers to follow-up care can be addressed from lessons learned from the VA Medical Centre for care following endovascular AAA repair, which includes comprehensive electronic records to help track patients throughout Nova Scotia, and financial renumeration for travel costs. Increased clinical staff to facilitate follow-up can be achieved through improving Nova Scotia's general practitioner coverage, which currently leaves over 10% of Nova Scotians without a general practitioner in some Health Zones (Nova Scotia Health, 2021). Other options include expanding resources for the multidisciplinary connective tissue clinic. While travel clinics to other Health Zones is a consideration, the multidisciplinary connective tissue clinic has multiple healthcare providers (surgeon, cardiologist, psychologist and nurse practitioner), making travel clinics impractical. Telehealth integration into this clinic could be a consideration. Telehealth services, something that has been used during the current COVID-19 pandemic, has opened healthcare to a new model of care that could improve delivery to vulnerable populations post-pandemic (Nouri et al., 2020). Finally, as aforementioned, specialized gated CT scans are required for both the diagnosis and follow-up of patients with ascending aortic disease. This imaging modality should be made available in all regional hospitals outside of the Central Zone (Table 6.1).

Table 6.1 Implications for Health Resource Planning

Problem	Solution
No electronic records for patients at outside institutions	One Patient One Record for the Province
No reimbursement for travel costs	Reimbursement
Minimal staff to track patients lost to follow-up	Improved GP coverage Dedicated staff to monitor loss to follow-up

Long waitlist for multidisciplinary connective tissue clinic	Increased personnel Expansion of telehealth services
Limited access to specialized imaging	Gated CT scan availability in regional hospitals

6.5 Limitations

There are several limitations to this study. Data for thoracic aortic disease was obtained from a single centre, and while this does provide some measure of consistency, it may be preferable to obtain data from multiple centres to demonstrate the same association between distance and SES across different regions and to increase the study's power with a larger sample size. It is possible that no effect of SES was demonstrated due to inadequate sample size, representing a type II error. Also, this study only included Nova Scotians; therefore, findings of increased long-term mortality for patients at increased travel time to the tertiary centre may not be true for other jurisdictions.

This is a procedure-based cohort rather than a disease-based cohort. It is possible that SES and remoteness play a role in outcomes among patients with TAA and TAAD who do not have surgery, such as delays in referral. Disease-based cohorts can be challenging they rely purely on administrative data, and are prone to errors in coding, and do not distinguish between varying severities of TAA.

This study only used area-based socioeconomic estimates rather than individual patient data. However, findings using individual versus area-based socioeconomic measures have been shown to be consistent (Buajitti et al., 2020), including estimates of premature mortality using the Pampalon Index of Deprivation (Pampalon, Hamel, & Gamache, 2009). Individual socioeconomic variables were not available in this study.

This study did not capture race of patients presenting with TAA and TAAD. In Canada, race is associated with poor self-reported health (Veenstra, 2009), increasing burden of cardiovascular risk factors (Chiu et al., 2015) and Indigenous populations are facing a rapidly growing burden of cardiovascular morbidity and mortality (Reading, 2015; Tjepkema et al., 2012). No studies have examined the effect of race on outcomes in aortic aneurysmal disease in Canada. Increased mortality following AAA repair is experienced by Indigenous populations in New Zealand (Khashram et al., 2017), as well as African American and Hispanic populations in the United States (Vogel et al., 2009; T. K. Williams et al., 2013). African Americans present younger than white patients with TBAD and are more likely to require reintervention (Yammine et al., 2018). It is possible there are additional racial inequalities that are playing a role in patients with thoracic aortic disease in Nova Scotia.

6.6 Areas for Further Research

Further research is needed to fill unanswered questions from this study. First, what are the main barriers to discharge causing prolonged length of stay among patients with lower income and higher material deprivation? Timing of presentation should be studied to examine if patients from social deprivation quintiles 2 and 3 are presenting later causing increased in-hospital complications. The consequences of late presentation to cardiac surgery could potentially become increasingly apparent due to decreased elective operations observed during the COVID-19 pandemic (Ad et al., 2020). Barriers to presentation outside the COVID-19 pandemic will be of interest in addressing delays in presentation, should they exist. It should be determined if under-referral of women with TAA is driving increasing TAAD in women without concomitant increase in elective repair. The most important finding is increased all-cause mortality among patients who live at increased travel time to the tertiary care centre. Determining if gaps in follow-up are driving increased long-term mortality among patients who live at increased travel time from the tertiary centre should be a priority.

Chapter 7: Conclusions

This study examined trends in thoracic aortic surgery in Nova Scotia and is the first to examine the relationship between SES, geographical variables, and outcomes in patients with TAA repair and TAAD. The incidence of elective TAA repair increased in males, but not females, while the incidence of TAAD repair increased in both males and females. No effect of SES or travel time from the tertiary care centre on in-hospital mortality was found. Prolonged hospital length of stay was found to be more concentrated among patients with lower incomes and more material deprivation, and patients from social deprivation quintiles 2 and 3 were found to be at higher risk for composite in-hospital complications compared to quintile 1. Patients who resided ≥1 hour from the tertiary care centre were found to be at increased risk for long-term mortality. Additionally, women were found to be at increased risk of being discharged to another institution or nursing home.

Further research is needed to identify any delayed presentation and barriers to discharge in socioeconomically deprived patients. The finding of increased long-term mortality among patients who live at increased travel time to the tertiary centre calls for an evaluation and reform of post-operative delivery for this patient population. Gaps in care must be identified and remedied. Immediate increased access to surveillance CT scans and increased access to primary care is called for. Adoption of novel technology to improve patient tracking and access to consultation and follow-up should be expanded on. A specific evaluation and increased awareness of screening and/or referral delay in female patients is required. Finally, other health promotion strategies which expand beyond the thoracic aortic disease population to improved cardiovascular health in general among rural Nova Scotians is needed.

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Appendix 1: Univariable Analysis

Variables with p value <0.1 were included in multivariable analysis. Age, sex, social and material deprivation quintiles, remoteness variables were included a priori.

Table A.1.1: Univariable analysis for Outcome of In-hospital Mortality

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60 years	7.23	2.13-24.5	0.001*
Female Sex	1.37	0.55-3.36	0.498
Hypertension	2.01	0.82-4.91	0.125
Diabetes	3.89	1.53-9.86	0.004*
Dyslipidemia	1.21	0.54-2.71	0.653
Smoking history	1.53	0.66-3.55	0.316
Chronic Kidney Disease	3.83	0.79-18.5	0.094*
Cerebrovascular Disease	2.99	0.96-9.33	0.059*
Peripheral Vascular Disease	1.59	0.71-3.59	0.262
COPD	0.70	0.16-3.05	0.632
Ejection Fraction <60%	1.64	0.71-3.82	0.248
Angina	3.06	1.36-6.89	0.007*
Operative Characteristics			
Urgent Status	10.2	4.33-24.0	<0.0001*
Combined Operation	0.45	0.20-1.01	0.052*
Aortic Dissection	5.70	2.51-13.00	<0.0001*
Long CPB Time	3.27	1.28-8.33	0.013*
Long Cross-Clamp Time	1.08	0.48-2.41	0.854
Non-Clinical Characteristics			
Income Quintile			
1	0.81	0.22-2.96	0.748
2	0.60	0.15-2.47	0.478
3	1.20	0.39-3.71	0.747
4	0.85	0.25-2.88	0.795
5	Ref		
Social Deprivation Quintile			
1	Ref		
2	1.81	0.42-7.88	0.427
3	2.37	0.63-8.91	0.201
4	0.68	0.13-3.46	0.641
5	1.20	0.26-5.55	0.813
Material Deprivation Quintile			
1	Ref		
2	1.19	0.35-4.03	0.781
3	0.88	0.24-3.20	0.842
4	1.56	0.52-4.64	0.425
5	0.80	0.16-4.08	0.784
Travel Time ≥1 Hour	1.40	0.62-3.19	0.419
Health Zone			
1 Western	1.07	0.31-3.65	0.913
2 Northern	2.31	0.77-6.90	0.134
3 Eastern	1.48	0.38-5.77	0.575
4 Central	Ref		

Notes: COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.1.2: Univariable Analysis for Outcome of Complication

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60 years	3.80	2.53-5.72	<0.0001*
Female Sex	1.00	0.63-1.59	0.987
Hypertension	2.25	1.52-3.31	<0.0001*
Diabetes	2.64	1.21-5.79	0.015
Dyslipidemia	2.21	1.46-3.34	<0.0001*
Smoking history	1.68	1.14-2.48	0.008*
Chronic Kidney Disease	2.48	0.79-18.5	0.094*
Cerebrovascular Disease	2.12	0.85-5.28	0.107
Peripheral Vascular Disease	1.82	1.19-2.80	0.006*
COPD	2.21	1.08-4.52	0.031*
Ejection Fraction <60%	1.20	0.777-1.87	0.419
Angina	1.74	1.10-2.74	0.018*
Operative Characteristics			
Urgent Status	3.42	1.79-6.52	<0.0001*
Combined Operation	1.13	0.75-1.71	0.551
Aortic Dissection	3.19	1.71-5.97	<0.0001*
Long CPB Time	1.92	1.30-2.84	0.001*
Long Cross-Clamp Time	1.23	0.84-1.80	0.298
Non-Clinical Characteristics			
Income Quintile			
1	1.61	0.85-3.05	0.143
2	0.92	0.50-1.67	0.782
3	1.11	0.62-1.98	0.731
4	1.09	0.61-1.95	0.769
5	Ref		
Social Deprivation Quintile			
1	Ref		
2	3.51	1.68-7.33	0.001*
3	2.82	1.51-5.28	0.001*
4	0.93	0.52-1.66	0.800
5	2.15	1.12-4.13	0.021*
Material Deprivation Quintile			
1	Ref		
2	0.95	0.53-1.70	0.862
3	0.95	0.54-1.68	0.869
4	0.96	0.56-1.66	0.882
5	1.63	0.77-3.43	0.203
Travel Time ≥1 Hour	1.05	0.72-1.54	0.803
Health Zone			
1 Western	0.87	0.52-1.44	0.580
2 Northern	1.04	0.58-1.86	0.906
3 Eastern	1.10	0.57-2.12	0.780
4 Central	Ref		

Notes: COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.1.3: Univariable analysis for Outcome of Prolonged Length of Stay ≥10 days

Clinical Characteristics	OR	95% CI	p
Age ≥60	2.35	1.61-3.43	<0.0001*
Female Sex	1.12	0.72-1.76	0.489
Hypertension	1.45	1.00-2.11	0.051*
Diabetes	1.52	0.79-2.93	0.213
Dyslipidemia	1.51	1.03-2.21	0.034*
Smoking history	1.24	0.85-1.79	0.259
Chronic Kidney Disease	8.72	1.10-69.40	0.041
Cerebrovascular Disease	3.50	1.39-8.84	0.008
Peripheral Vascular Disease	1.50	1.01-2.23	0.045
COPD	1.46	0.80-2.66	0.213
Ejection Fraction <60%	1.03	0.67-1.57	0.899
Angina	1.32	0.87-2.02	0.196
Operative Characteristics			
Urgent Status	3.23	1.80-5.80	<0.0001*
Combined Operation	0.97	0.64-1.45	0.868
Aortic Dissection	3.08	1.76-5.41	<0.0001*
Long CPB Time	2.32	1.59-3.38	<0.0001*
Long Cross-Clamp Time	1.72	1.19-2.50	0.004*
Non-Clinical Characteristics			
Income Quintile			
1	1.20	0.67-2.14	0.532
2	1.32	0.74-2.36	0.343
3	1.12	0.65-1.95	0.678
4	1.40	0.81-2.43	0.232
5	Ref		
Social Deprivation Quintile			
1	Ref		
2	1.38	0.73-2.62	0.325
3	0.14	0.64-2.03	0.660
4	1.02	0.57-1.83	0.939
5	1.74	0.93-3.24	0.080*
Material Deprivation Quintile			
1	Ref		
2	1.06	0.60-1.86	0.845
3	1.37	0.79-2.37	0.269
4	1.61	0.94-2.76	0.082*
5	1.56	0.79-3.05	0.198
Travel Time ≥1 Hour	1.31	0.91-1.90	0.151
Health Zone			
1 Western	1.40	0.85-2.30	0.189
2 Northern	0.84	0.47-1.47	0.534
3 Eastern	2.76	1.40-4.44	0.003*
4 Central	Ref		

Notes: COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.1.4: Univariable analysis for Outcome of Discharge Disposition

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60	2.15	1.16-3.97	0.015*
Female Sex	2.32	1.25-4.31	0.007*
Hypertension	2.00	1.06-3.77	0.032*
Diabetes	1.38	0.55-3.47	0.490
Dyslipidemia	1.07	0.59-1.94	0.812
Smoking history	1.14	0.64-2.06	0.652
Chronic Kidney Disease	13.1	3.57-48.3	<0.0001*
Cerebrovascular Disease	0.97	0.28-3.36	0.967
Peripheral Vascular Disease	1.48	0.81-2.68	0.200
COPD	1.58	0.69-3.58	0.276
Ejection Fraction <60%	1.53	0.82-2.86	0.182
Angina	0.85	0.43-1.68	0.636
Operative Characteristics			
Urgent Status	5.63	2.97-10.7	<0.0001*
Combined Operation	0.59	0.32-1.08	0.089*
Aortic Dissection	5.85	3.12-11.0	<0.0001*
Long CPB Time	1.70	0.94-3.08	0.082*
Long Cross-Clamp Time	0.87	0.49-1.56	0.643
Non-Clinical Characteristics			
Income Quintile			
1	2.03	0.75-5.50	0.165
2	1.41	0.49-4.08	0.523
3	2.23	0.86-5.79	0.101
4	1.50	0.54-4.11	0.435
5	Ref		
Social Deprivation Quintile			
1	Ref		
2	1.45	0.54-3.91	0.466
3	0.78	0.29-2.13	0.630
4	1.23	0.49-3.10	0.662
5	0.89	0.32-2.51	0.828
Material Deprivation Quintile			
1	Ref		
2	0.69	0.25-1.92	0.479
3	1.14	0.47-2.77	0.778
4	1.42	0.63-3.24	0.399
5	1.46	0.54-3.96	0.459
Travel Time ≥1 Hour	1.27	0.70-2.28	0.431
Health Zone			
1 Western	0.72	0.29-1.78	0.483
2 Northern	1.26	0.52-3.01	0.608
3 Eastern	1.98	0.84-4.67	0.119
4 Central	Ref		

Notes: COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.1.5: Univariable Cox Proportional Hazard for Outcome of Long-Term Survival

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60	5.33	2.91-9.74	<0.0001*
Female Sex	1.60	0.98-2.61	0.060*
Hypertension	1.93	1.17-3.16	0.009*
Diabetes	2.95	1.67-5.21	<0.0001*
Dyslipidemia	1.42	0.90-2.25	0.134
Smoking history	1.64	1.01-2.68	0.047*
Chronic Kidney Disease	3.35	1.45-7.75	0.005*
Cerebrovascular Disease	2.54	1.30-4.96	0.006*
Peripheral Vascular Disease	2.03	1.27-3.25	0.003*
COPD	2.50	1.45-4.30	0.001*
Ejection Fraction <60%	1.25	0.75-2.08	0.385
Angina	1.46	0.89-2.40	0.132
Operative Characteristics			
Urgent Status	2.93	1.79-4.78	<0.0001*
Combined Operation	0.58	0.36-0.92	0.02*
Aortic Dissection	2.60	1.58-4.26	<0.0001*
Long CPB Time	1.51	0.95-2.41	0.082*
Long Cross-Clamp Time	1.05	0.66-1.66	0.833
Non-Clinical Characteristics			
Income Quintile			
1	1.04	0.51-2.10	0.924
2	0.59	0.26-1.33	0.204
3	1.02	0.53-1.98	0.953
4	0.87	0.43-1.77	0.701
5	Ref		
Social Deprivation Quintile			
1	Ref		
2	1.07	0.44-2.56	0.886
3	1.83	0.87-3.83	0.111
4	0.94	0.42-2.13	0.889
5	1.31	0.58-2.95	0.517
Material Deprivation Quintile			
1	Ref		
2	0.92	0.44-1.86	0.779
3	0.64	0.29-1.41	0.265
4	1.46	0.79-2.68	0.223
5	1.34	0.60-2.97	0.471
Travel Time ≥1 Hour	1.81	1.12-2.92	0.015*
Health Zone			
1 Western	1.15	0.59-2.25	0.682
2 Northern	2.30	1.23-4.32	0.010*
3 Eastern	2.04	1.00-4.16	0.049*
4 Central	Ref		

Notes: COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Appendix 2: Outcomes in Elective Patients

Table A.2.4: Concentration Indices for Outcomes Ranked by Socioeconomic Factors in Elective Patients

Outcome	**Median Household Income**	**Social Deprivation Quintile**	**Material Deprivation Quintile**	**Estimated Travel Time**
In-Hospital Mortality	-0.2397 (-0.6227 to 0.1434)	-0.0819 (-0.4568 to 0.2929)	0.2043 (-0.1697 to 0.5783)	0.1628 (-0.2207 to 0.5462)
Composite In-Hospital Complication	-0.0264 (-0.1459 to 0.0931)	-0.0137 (-0.1316 to 0.1041)	0.0125 (-0.1052 to 0.1302)	-0.0075 (-0.1269 to 0.1119)
Prolonged Length of Stay	-0.1031 (-0.2193 to 0.0131)	0.0477 (-0.0674 to 0.1628)	0.1051 (-0.0094 to 0.2197)	0.1111 (-0.000 to 0.2317
Discharge Disposition	-0.0095 (-0.2293 to 0.2104)	0.0466 (-0.1682 to 0.2615)	0.0463 (-0.1683 to 0.2609)	0.1170 (-0.0991 to 0.3331)
All-Cause Mortality During Follow-up	-0.0943 (-0.2695 to 0.0808	0.0273 (-0.1443 to 0.1988)	0.1265 (-0.0444 to 0.2974)	0.2298* (0.0575 to 0.4021)

Notes: 95% Confidence Intervals are in brackets. Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.5: Univariable analysis for Outcome of In-Hospital Mortality in Elective Patients

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60 years	8.08	1.00-65.3	0.050*
Female Sex	4.33	1.14-16.5	0.032*
Hypertension	2.84	0.58-13.8	0.582
Diabetes	7.28	1.88-28.3	0.004*
Dyslipidemia	2.77	0.68-11.24	0.154
Smoking history	1.71	0.42-6.94	0.453
Chronic Kidney Disease	9.48	0.99-90.6	0.051*
Cerebrovascular Disease	Omitted		
Peripheral Vascular Disease	1.72	0.45-6.51	0.426
COPD	0.92	0.11-7.51	0.937
Ejection Fraction <60%	2.33	0.61-8.87	0.213
Angina	1.54	0.38-6.29	0.545
Operative Characteristics			
Combined Operation	0.65	0.16-2.64	0.545
Aortic Dissection	Omitted		
Long CPB Time	2.36	0.58-9.59	0.229
Long Cross-Clamp Time	1.90	0.47-7.70	0.370
Non-Clinical Characteristics			
Social Deprivation Quintile			
1	Ref		
2	2.59	0.23-29.3	0.443
3	2.97	0.32-27.2	0.336
4	Omitted		
5	1.97	0.17-22.3	0.584
Material Deprivation Quintile			
1	Ref		
2	2.99	0.27-33.6	0.376
3	2.86	0.25-32.2	0.394
4	2.37	0.21-26.6	0.485
5	4.90	0.43-55.6	0.199
Travel Time ≥1 Hour	3.09	0.63-15.1	0.163
Health Zone			
1 Western	2.09	0.29-15.1	0.466
2 Northern	2.84	0.39-20.7	0.301
3 Eastern	1.88	0.17-21.2	0.611
4 Central	Ref		

Notes: Univariable regression analysis for outcome of in-hospital mortality. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.6: Multivariable Analysis for Outcome of In-Hospital Mortality

Variable	**OR**	**95% CI**
Age ≥60 years	5.61*	0.61-51.7
Female Sex	5.52*	1.10-27.8
Diabetes	6.70*	1.36-33.0
Chronic Kidney Disease	5.29	0.27-104.4
Social Deprivation Quintile		
1	Ref	
2	2.64	0.20-35.2
3	1.84	0.16-20.8
4	1	(empty)
5	1.08	0.08-20.8
Material Deprivation Quintile		
1	Ref	
2	4.88	0.22-109.1
3	2.34	0.12-47.3
4	3.77	0.15-93.8
5	6.89	0.27-177.1
Estimated Travel Time ≥1 Hour	1.72	0.27-14.6

Notes: Multivariable logistic regression results for outcome of in-hospital mortality. CI: Confidence Interval; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.7: Univariable Analysis for Outcome of Composite In-Hospital Complication

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60 years	4.14	2.66-6.45	<0.0001*
Female Sex	1.09	0.67-1.77	0.739
Hypertension	2.16	1.42-3.27	<0.0001*
Diabetes	2.69	1.21-5.98	0.015*
Dyslipidemia	2.33	1.51-3.60	<0.0001*
Smoking history	1.63	1.08-2.46	0.021*
Chronic Kidney Disease	1.16	0.21-6.41	0.866
Cerebrovascular Disease	1.91	0.68-5.33	0.217
Peripheral Vascular Disease	1.70	1.07-2.68	0.023*
COPD	2.70	1.27-5.76	0.010*
Ejection Fraction <60%	1.22	0.76-1.95	0.421
Angina	1.40	0.86-2.28	0.179
Operative Characteristics			
Combined Operation	1.45	0.91-2.32	0.118
Chronic Aortic Dissection	1.31	0.40-4.34	0.656
Long CPB Time	1.85	1.21-2.81	0.004*
Long Cross-Clamp Time	1.45	0.96-2.18	0.080*
Non-Clinical Characteristics			
Social Deprivation Quintile			
1	Ref		
2	5.35	2.26-12.67	<0.001*
3	3.33	1.70-6.42	<0.001*
4	1.01	0.54-1.88	0.976
5	2.34	1.16-4.69	0.017*
Material Deprivation Quintile			
1	Ref		
2	1.00	0.53-1.86	0.991
3	0.95	0.51-1.75	0.860
4	0.81	0.45-1.45	0.475
5	1.54	0.71-3.33	0.278
Travel Time ≥1 Hour	1.11	0.73-1.67	0.627
Health Zone			
1 Western	0.78	0.45-1.33	0.358
2 Northern	1.12	0.60-2.09	0.718
3 Eastern	1.24	0.61-2.52	0.548
4 Central	Ref		

Notes: Univariable regression analysis for outcome of composite in-hospital complication. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.8: Multivariable Logistic Regression for Composite In-Hospital Complication

Variable	**OR**	**95% CI**
Age ≥60 years	4.48*	2.57-7.80
Female Sex	1.06	0.58-1.92
Hypertension	1.30	0.78-2.17
Diabetes	1.76	0.65-4.76
Dyslipidemia	1.35	0.78-2.33
Peripheral Vascular Disease	1.24	0.72-2.13
COPD	1.90	0.81-4.49
Long CPB time	2.54*	1.51-4.26
Social Deprivation Quintile		
1	Ref	
2	5.67*	2.18-14.7
3	3.41*	1.56-7.42
4	0.88	0.43-1.80
5	1.79	0.81-3.96
Material Deprivation Quintile		
1	Ref	
2	0.89	0.41-1.90
3	0.75	0.33-1.71
4	0.53	0.23-1.22
5	0.92	0.33-2.57
Estimated Travel Time ≥1 Hour	1.17	0.63-2.16

Notes: Multivariable logistic regression results for outcome of composite in-hospital complication. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass Time; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.9: Univariable analysis for Outcome of Prolonged Length of Stay ≥10 days

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60	2.66	1.76-4.02	<0.001*
Female Sex	1.06	0.66-1.72	0.803
Hypertension	1.53	1.02-2.29	0.041*
Diabetes	1.78	0.90-3.53	0.098*
Dyslipidemia	1.70	1.13-2.55	0.011
Smoking history	1.36	0.91-2.04	0.132
Cerebrovascular Disease	2.90	1.10-7.65	0.031*
Peripheral Vascular Disease	1.61	1.04-2.48	0.031*
COPD	1.84	0.98-3.45	0.058*
Ejection Fraction <60%	1.07	0.68-1.70	0.761
Angina	1.34	0.84-2.14	0217
Operative Characteristics			
Combined Operation	1.24	0.78-1.98	0.367
Chronic Aortic Dissection	2.55	0.77-8.42	0.125
Long CPB Time	2.36	1.56-3.56	<0.001*
Long Cross-Clamp Time	1.97	1.31-2.97	0.001*
Non-Clinical Characteristics			
Social Deprivation Quintile			
1	Ref		
2	1.07	0.51-2.22	0.863
3	1.12	0.59-2.12	0.724
4	0.98	0.53-1.83	0.954
5	1.48	0.75-2.93	0.261
Material Deprivation Quintile			
1	Ref		
2	1.09	0.59-2.02	0.775
3	1.20	0.65-2.20	0.555
4	1.58	0.89-2.80	0.121
5	1.62	0.79-3.34	0.189
Travel Time ≥1 Hour	1.39	0.93-2.08	0.112
Health Zone			
1 Western	1.26	0.74-2.16	0.401
2 Northern	0.91	0.50-1.67	0.765
3 Eastern	3.08	1.50-6.31	0.002*
4 Central	Ref		

Notes: Univariable regression analysis for outcome of prolonged length of stay >10 days. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.10: Multivariable Logistic Regression for Prolonged Length of Stay

Variable	**OR**	**95% CI**
Age ≥60 years	3.15*	1.93-5.13
Female Sex	1.18	0.69-2.04
Hypertension	0.98	0.61-1.57
Diabetes	0.99	0.45-2.19
Cerebrovascular Disease	2.66	0.91-7.76
Peripheral Vascular Disease	1.44	0.88-2.35
COPD	1.52	0.75-3.09
Long CPB time	3.21*	2.00-5.17
Social Deprivation Quintile		
1	Ref	
2	0.94	0.42-2.08
3	0.79	0.39-1.62
4	0.73	0.36-1.47
5	0.93	0.43-1.98
Material Deprivation Quintile		
1	Ref	
2	1.18	0.59-2.35
3	1.11	0.53-2.37
4	1.40	0.66-2.96
5	1.32	0.53-3.25
Estimated Travel Time ≥1 Hour	1.09	0.62-1.91

Notes: Multivariable logistic regression results for outcome of prolonged length of stay. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.11: Univariable analysis for Outcome of Discharge Disposition Other Than Home

Clinical Characteristics	**OR**	**95% CI**	**p**
Age ≥60	2.53	1.13-5.67	0.025*
Female Sex	2.52	1.16-5.47	0.019*
Hypertension	1.99	0.89-4.47	0.095*
Diabetes	1.45	0.48-4.40	0.514
Dyslipidemia	1.91	0.90-4.05	0.093*
Smoking history	1.31	0.61-2.80	0.487
Chronic Kidney Disease	8.36	1.34-52.1	0.023*
Cerebrovascular Disease	1.26	0.28-5.68	0.764
Peripheral Vascular Disease	1.48	0.69-3.18	0.316
COPD	1.96	0.76-5.09	0.166
Ejection Fraction <60%	1.51	0.68-3.35	0.309
Angina	1.36	0.60-3.07	0.465
Operative Characteristics			
Combined Operation	1.32	0.52-3.34	0.553
Chronic Aortic Dissection	3.82	0.99-14.72	0.051*
Long CPB Time	1.60	0.76-3.40	0.218
Non-Clinical Characteristics			
Social Deprivation Quintile			
1	Ref		
2	1.32	0.31-5.55	0.706
3	1.12	0.30-4.14	0.865
4	1.92	0.58-6.29	0.284
5	0.98	0.24-4.11	0.982
Material Deprivation Quintile			
1	Ref		
2	0.93	0.29-2.96	0.899
3	0.70	0.20-2.41	0.571
4	1.20	0.43-3.35	0.724
5	1.25	0.36-4.40	0.728
Travel Time ≥1 Hour	1.58	0.73-3.41	0.246
Health Zone			
1 Western	0.72	0.29-1.78	0.483
2 Northern	1.26	0.52-3.01	0.608
3 Eastern	1.98	0.84-4.67	0.119
4 Central	Ref		

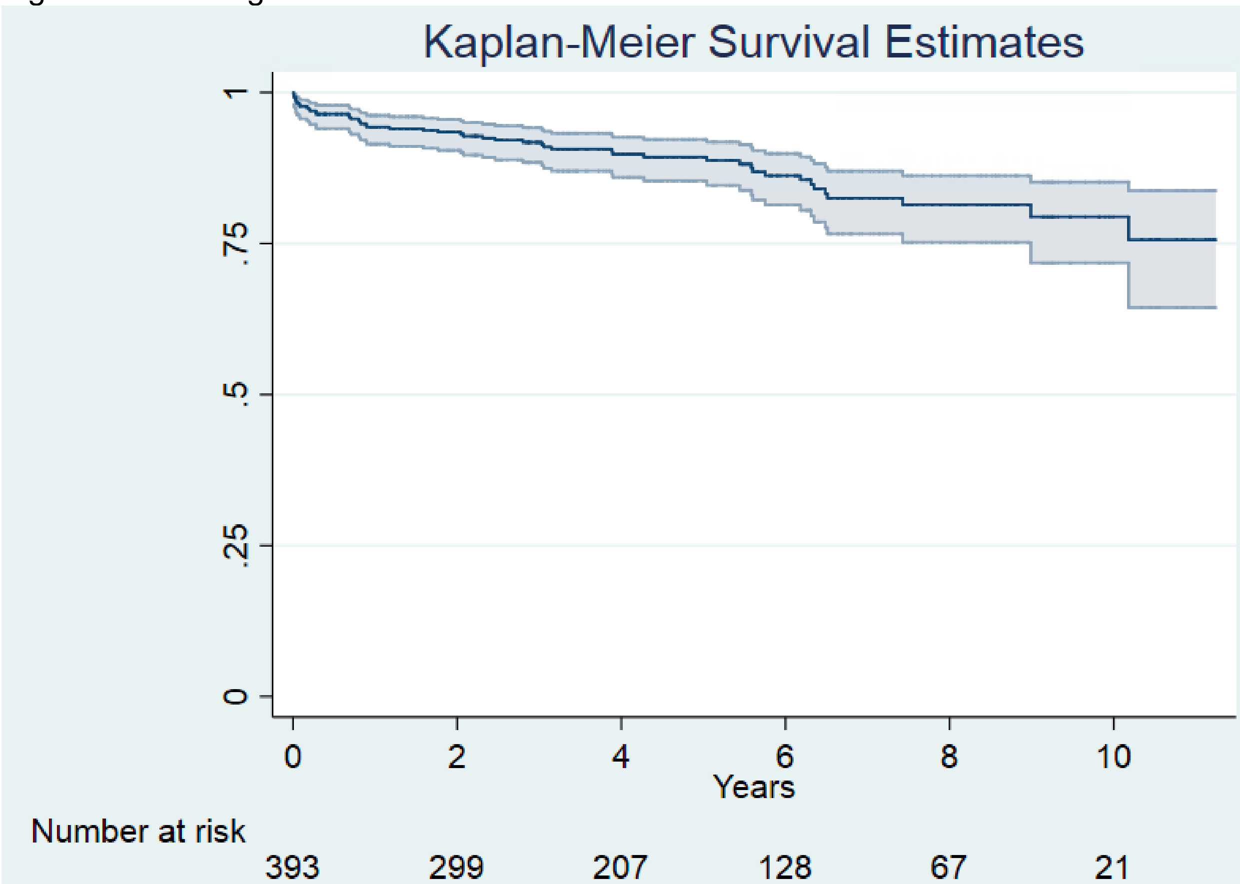
Notes: Univariable regression analysis for outcome of discharge disposition other than home. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.12: Multivariable Logistic Regression for Discharge Disposition Other Than Home

Variable	OR	95% CI
Age ≥60 years	2.03	0.79-5.22
Female Sex	2.92*	1.26-6.78
Hypertension	1.38	0.55-3.42
Chronic Kidney Disease	9.03*	1.14-71.4
Aortic Dissection	2.90	0.55-15.4
Social Deprivation Quintile		
1	Ref	
2	1.28	0.29-5.78
3	0.97	0.25-3.81
4	1.64	0.46-5.90
5	0.56	0.12-2.61
Material Deprivation Quintile		
1	Ref	
2	0.67	0.19-2.32
3	0.28	0.06-1.24
4	0.60	0.16-2.28
5	0.51	0.10-2.48
Estimated Travel Time ≥1 Hour	1.75	0.62-4.93

Notes: Multivariable logistic regression results for outcome of discharge disposition other than home. CI: Confidence Interval; OR: Odds Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Figure A.2.1: Long-Term Survival of Elective Patients



Notes: Kaplan-Meier survival estimates of patients who underwent elective ascending aortic operations. Shaded area represents 95% confidence interval.

Table A.2.13: Univariable Cox Proportional Hazard for Long-Term Mortality in Elective Patients

Clinical Characteristics	**HR**	**95% CI**	**p**
Age ≥60	5.40	2.61-11.2	<0.0001*
Female Sex	2.62	1.49-4.60	0.001*
Hypertension	2.13	1.16-3.92	0.015*
Diabetes	3.40	1.77-6.54	<0.0001*
Dyslipidemia	1.91	1.08-3.37	0.025*
Smoking History	1.50	0.83-2.70	0.176
Chronic Kidney Disease	6.14	2.20-17.2	0.001*
Cerebrovascular Disease	1.95	0.77-4.94	0.158
Peripheral Vascular Disease	2.40	1.35-4.26	0.003*
COPD	2.84	1.51-5.36	0.001*
Ejection Fraction <60%	1.14	0.60-2.15	0.687
Angina	1.01	0.52-1.99	0.967
Operative Characteristics			
Combined Operation	0.56	0.31-1.01	0.053*
Chronic Aortic Dissection	2.11	0.65-6.79	0.211
Long CPB Time	1.23	0.70-2.15	0.475
Long Cross-Clamp Time	0.92	0.53-1.62	0.779
Non-Clinical Characteristics			
Social Deprivation Quintile			
1	Ref		
2	0.90	0.28-2.83	0.851
3	1.86	0.76-4.55	0.171
4	1.03	0.40-2.67	0.943
5	1.32	0.49-3.56	0.582
Material Deprivation Quintile			
1	Ref		
2	0.92	0.36-2.37	0.863
3	0.95	0.37-2.44	0.907
4	1.85	0.86-3.94	0.113
5	1.66	0.61-4.49	0.322
Travel Time ≥1 Hour	2.63	1.39-4.96	0.003*
Health Zone			
1 Western	1.58	0.69-3.61	0.276
2 Northern	3.02	1.37-6.62	0.006*
3 Eastern	3.18	1.36-7.46	0.008*
4 Central	Ref		

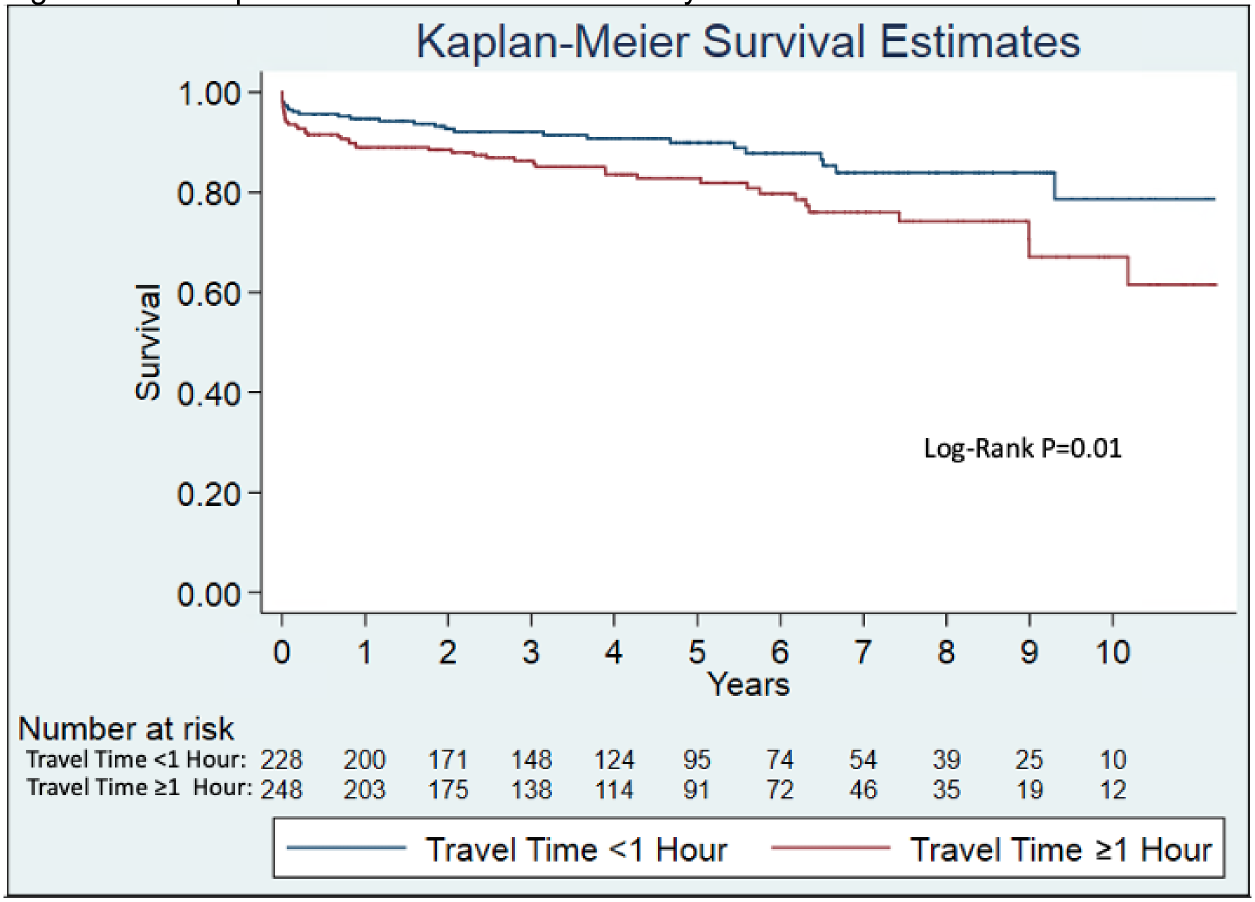
Notes: Univariable Cox proportional hazard ratios for long-term all-cause mortality. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease; CPB: Cardiopulmonary Bypass; HR: Hazard Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Table A.2.14: Multivariable Cox Proportional Hazard Modeling for Long-term Survival

Variable	**HR**	**95% CI**
Age ≥60 years	4.58*	1.94-10.8
Female Sex	3.14	1.64-5.98
Hypertension	0.86	0.43-1.71
Diabetes	3.44*	1.51-7.84
Chronic Kidney Disease	3.90	1.23-12.4
Peripheral Vascular Disease	1.85	0.98-3.49
COPD	2.09*	1.03-4.23
Social Deprivation Quintile		
1	Ref	
2	1.08	0.31-3.72
3	1.34	0.50-3.54
4	0.99	0.35-2.79
5	0.77	0.27-2.19
Material Deprivation Quintile		
1	Ref	
2	0.53	0.19-1.48
3	0.35	0.12-1.05
4	0.83	0.32-2.11
5	0.68	0.21-2.17
Estimated Travel Time ≥1 Hour	**2.60***	**1.18-5.73**

Notes: Cox proportional hazard model for long-term all-cause mortality. CI: Confidence Interval; COPD: Chronic Obstructive Pulmonary Disease, HR: Hazard Ratio; Ref: Reference Category; Asterisks indicate statistical significance at 95% confidence interval.

Figure A.2.2: Kaplan Meier Survival Estimates by Travel Time < and ≥1 Hour



Notes: Risk-adjusted Kaplan Meier Survival Estimates in elective patients with estimated travel time < and ≥ 1 hour

Appendix 3: Disclaimer

Portions of the data used in this report were made available by Health Data Nova Scotia of Dalhousie University. Although this research is based on data obtained from the Nova Scotia Department of Health and Wellness, the observations and opinions expressed are those of the authors and do not represent those of either Health Data Nova Scotia or the Department of Health and Wellness.