Access to Trauma Centre Care in Canada

A National Comparison

by

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Abstract

Objectives: (1) To examine the association of transfer from a non-trauma hospital to a trauma centre, compared to direct transport to a trauma centre, on patient outcomes; (2) to describe temporal trends and provincial variations in major trauma hospitalization and outcomes; (3) to describe trends in the receipt of trauma centre care for severely injured patients; and (4) to identify factors associated with the receipt of trauma centre care.

Methods: To address the first objective a systematic review and meta-analysis of published observational studies was performed. The remaining objectives were addressed as part of a population-based retrospective cohort study using the National Trauma Registry Minimum Dataset. Age-standardized hospitalization and death rates were calculated using the direct method. Multi-level logistic regression analyses were used to explore factors associated with receipt of trauma centre care.

Results: The meta-analysis revealed no difference in mortality between direct and indirect admissions to a trauma centre (pooled odds ratio (OR), 1.06; 95% confidence interval (CI): 0.90 - 1.25). The population based study identified increasing hospitalization rates for major trauma among older Canadian patients (≥ 65 years) over the eight-year period (estimated annual percent increase of 3.3%;95% CI: 2.8% - 3.8%). Case fatality rates declined modestly. Overall, 41% of major trauma patients did not receive care in a trauma centre, ranging from 28% to 76% across the provinces. A disproportionately greater proportion of older Canadians did not receive care in a trauma centre. The odds of receiving care in a trauma centre were 64% lower among older compared to young patients. Compared to men, the odds of receiving care in a trauma centre were 21% lower amongst women (adjusted OR 0.79; 95% CI: 0.76, 0.82). These findings were consistent across the provinces.

Conclusion: Major trauma hospitalization rates increased over the study interval. Moreover, decreased likelihood of trauma centre care was demonstrated for elderly patients and women. These findings highlight important opportunities for injury prevention and strategies to improve access to trauma centre care for patients. Further studies examining the underlying reasons for the gender and age disparity in access to trauma centre care are warranted.

Dedication

This thesis is dedicated to

My mother, Avrille

Whose quiet strength is the force behind all I accomplish.

My grandmother, Evelyn

“So, fall asleep love, loved by me....for I know love, I am loved by thee.”

-- Robert Browning

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To my thesis supervisor Dr. Robert Fowler, my immense gratitude for your patience and guidance. Your generosity of spirit, expertise, honesty and insightful feedback has guided me on this journey. Rob, thank you for staying focused and engaged, you continue to challenge me to go *beyond* – for this, and much more, I remain grateful.

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As ever, my family and friends remain the source of my strength. I am grateful for their encouragement and steadfast love. Their support and belief in me continue to make all things possible.

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Chapter 1 : Thesis Overview

1.1 Problem Statement

Trauma is a leading cause of death in North America and consumes a large proportion of direct and indirect health care costs.[1-3] A substantial body of evidence supports the benefits of an organized system of trauma care that integrates pre-hospital care, acute care and rehabilitation for improving patient outcomes,[4, 5] with reported reductions in patient mortality of up to 20%.[6, 7] A key feature of an organized trauma system is the designation of trauma centres, hospitals resourced and committed to treating seriously injured patients.[8] It is generally accepted that timely access to and management in these centres results in reduced mortality and morbidity for patients with severe injuries.[9-11] Despite this however, a significant proportion of severely injured patients are not managed in a trauma centre.[12-14]

In Canada, there is no national standard for organizing trauma services and there remains marked variability in the support for trauma care organization across the provinces.[15-17] Importantly, progress towards an integrated system within each province has been slow and there is no standardization of pre-hospital triage or transfer criteria.[15, 16] The impact of this variability on the receipt of trauma centre care and outcomes for Canadians with major trauma is largely unknown. Existing Canadian studies examining receipt of trauma centre care have centered on a single province[9, 18, 19] or city within a province.[20] The dearth of Canadian data on receipt of trauma centre care for Canadians with major trauma and factors related to patients not receiving care in a trauma centre is a significant barrier to the development of effective policies and programs that would facilitate improvements in the organization of trauma services in Canada. Further, a comprehensive profile of major trauma epidemiology in Canada is lacking. This information is essential to establishing priorities for injury prevention to minimize the consequences of this disease.

In this thesis, the gaps identified in the Canadian literature are addressed through a series of research questions and studies. It is anticipated that the data generated from these studies will allow for more targeted injury prevention strategies and will expand the evidence on which to base policy and resource allocation decisions regarding how best to organize trauma services to meet current and future demand.

1.2 Overview of the Thesis

Chapter 2 provides a background to the thesis and includes a discussion of major trauma epidemiology, the clinical and economic impact of major trauma and the optimal organization of trauma services. Access to trauma centre care for patients with major trauma is discussed with respect to the magnitude of the problem and potential determinants of access based on current literature. Chapter 3 describes the conceptual framework used to guide the conduct of this thesis and the research questions addressed. Chapter 4 (Paper 1) is a systematic review and meta-analyses of studies that have examined the association between transfer status (direct admission or inter-hospital transfer) and outcomes for patients admitted to a trauma centre. Descriptions of the study populations, outcomes assessed and the methodological quality of the included studies are provided. The chapter concludes with a discussion of the findings, limitations to the review and recommendations for future studies. Chapter 5 provides a detailed description of the methods used in chapters 6 through 9. Chapter 6 (Paper 2) highlights the trends in population-based major trauma hospitalization rates in Canada over the 8 year period from fiscal 2002/2003 to 2009/2010. Variations in the trends across gender, age and mechanism of injury are described. The chapter concludes with a discussion of findings and its implication for trauma prevention and service organization. Chapter 7 (Paper 3) provides a profile of the recent (2002/03 to 2009/2010) trends in major trauma hospitalization across 9 Canadian provinces and the Territories. It complements the results reported in Chapter 6 by delineating patterns in gender and age specific hospitalization rates across individual provinces and the Territories. The chapter closes with a discussion of the findings of variation in major injury hospitalization rates across the provinces and over time and offer explanations for the observed differences. Chapter 8 (Paper 4) describes trends in age, sex and cause specific population-based injury case fatality and mortality rates in Canada over the 8 year study period. It includes an examination of age and sex-specific case fatality and mortality rate by province and the Territories. The chapter also provides a description of population-based trends in the rates of hospital bed-days utilized by patients with major trauma over the study interval. Differences in provincial case-fatality, mortality and bed-day utilization rates are explored. The chapter concludes with a discussion of the major findings with respect to the patterns in national injury case fatality, mortality and bed-day utilization rates, and highlight important policy implications of the findings. Chapter 9 provides a comprehensive examination of the receipt of trauma centre care for Canadians with major injury. It includes extensive analysis of age and gender related differences in the receipt of trauma centre care following major injury. The impact of location of patient residence and other determinants on the receipt of trauma centre care is also addressed in this chapter. Chapter 10 summarizes the thesis, including a comprehensive discussion of the findings, thesis limitations, and the clinical, policy and health systems implications of the results. Recommendations for future studies are also discussed.

Chapter 2 : Introduction

2.1 Background

As a first step in understanding the challenges of injury prevention and planning of injury services, this chapter provides a review of major injury epidemiology with specific reference to the Canadian setting. The evidence for optimizing the delivery of trauma services to improve access to care (receipt of trauma centre care) and outcomes for injured patients is presented and discussed in light of the determinants of access to trauma centre care.

2.2 Profile of Major Trauma in Canada

Hoff and Schwab have described trauma in its most basic form as a, *"physical injury which, because of its severity, poses a potential threat to life or limb."*[21] In 2009, unintentional injury was the third leading cause of death in Canadian men and the sixth leading cause of death amongst women in Canada.[1] Further, injury is an important cause of disability and impairment for Canadians.[22, 23] The economic burden of injury in Canada has been estimated at $19.8 billion per year, with direct health care costs of injury of $10.7 billion.[2]

While no globally accepted standard for defining major trauma exists, an Injury Severity Score (ISS)[24, 25] > 15 is generally recognized by the trauma research community as identifying patients with major trauma.[26-28] Within Canada, a broader ISS threshold of 12 has been selected for the Canadian National Trauma Registry comprehensive dataset (NTR-CDS),[29] which collects data on all patients with ISS > 12 that are admitted to a participating trauma centre. The 2009 NTR-CDS report provides an overview of major trauma (ISS >12) in Canada.[30] The report, based on data submitted for the 2008-2009 fiscal year by 8 provinces (British Columbia, Alberta, Ontario, Manitoba, New Brunswick, Quebec, Nova Scotia and Newfoundland and Labrador), highlighted that there were 14,065 major trauma admissions seen at the 107 participating trauma centres.[30] The mean age of these patients was 48 years, reflecting a relative increase of 11.6% over the figure reported for the previous fiscal year (43 years). The report showed that in fiscal year 2008-2009 men accounted for the highest proportion (71%) of patients with severe injury. The leading cause of injury amongst severely injured patients was motor vehicle collision (41%) followed by unintentional falls (38%). The report also identified important age-related differences in the cause of injury. Specifically, while motor vehicle collision was the major cause of injury for patients under 65 years, it represented only 20% of the cause of injury for the elderly (65 years and older). For the latter group, falls was the leading cause of injury accounting for 74% of all injuries in this group.[30]

While the authors of the report caution interpretation of trend data given differences in the number of hospitals contributing data to the NTR-CDS each year, they noted that mortality rate amongst major trauma admissions was 11%, which was similar to data for fiscal 2007-08 but slightly lower than the 13% reported for the 2004-2005 fiscal year.[30, 31] The report highlighted that of the 1,605 patients who died in fiscal 2008-2009, falls (48%), motor vehicle collision (32%) and gunshot wounds (4%) were the leading cause of death. With regards to utilization of hospital resources, in fiscal 2008-09 major trauma admissions resulted in the use of a total of 212,098 hospital bed-days across the eight provinces, the mean and median hospital length of stay in fiscal 2008-

2009 was 15 days and 8 days, respectively. The report also highlighted a trend towards longer length of stays for elderly patients compared to their younger counterpart (mean length of stay of 18 days in patients 65 years and older compared to 15 days for patients 35-65 years).[30]

While not comprehensive, the provinces included in the report do account for approximately 70% of the Canadian population.[32] However, it should also be noted that reports based on NTR-CDS are somewhat limited since this database does not include severely injured patients not seen at participating trauma centres. As such, estimates of population-based rates of major injury hospitalization in Canada cannot be determined using this database. Furthermore, since trauma patients who die prior to hospitalization are not included in the NTR, the database does not capture major trauma incidence for the Canadian population. To gain further insights into the Canadian injury epidemiology, studies from individual provinces are discussed in light of the global injury epidemiology.

2.2.1 <u>Incidence of Major Trauma</u>

Using data from the Calgary Health Region, Laupland and colleagues reported an annual adult (≥ 18 years) crude incidence rate of major trauma (ISS > 12) of 69.5 per 100,000 population.[33] The majority (78%) of major trauma cases were unintentional (crude incidence of 53.9 per 100,000 population per year). Similar to the 2009 NTR-CDS report, these authors found that motor vehicle collisions and falls were the primary mechanism of injury, accounting for 39% and 33% of major trauma cases, respectively. Further, males were more than 3 times more likely to suffer major trauma than women (relative risk 3.0, 95% confidence interval (CI) 2.64 – 3.35).[33]

These authors also reported that compared to rural residents, individuals residing in urban areas were at a significantly higher risk of major trauma, with crude incidence rates of 49.0 and 70.7 per 100,000 population, respectively. Although the absolute numbers of those affected was small, the reported incidence of major trauma was highest among patients 85 years or older (crude rates 242.3 per 100,000 population per year), with older men having a greater than 16-fold increase in the risk of major trauma compared to women aged 18 - 49 years.[33] Evidence that certain groups within Canada may suffer an even greater impact of major trauma has also been provided by Karmali and colleagues, who reported an annual crude rate of 257.2 episodes of traumatic injury per 100,000 Aboriginal Canadians (compared to a crude rate of 68.8 per 100,000 population being served by the same Calgary Health Region).[34]

More recently, Minei and colleagues have reported the incidence rate of severe trauma for Ottawa, Toronto and Vancouver.[35] Using the American College of Surgeons Committee on Trauma (ASCOT) major trauma triage guidelines to define severe trauma, these authors found age-sex-adjusted incidence rate of 15.2, 30.8 and 14.3 per 100,000 populations in Ottawa, Toronto and Vancouver, respectively. The study population was restricted to patients with severe traumatic injury assessed or treated by emergency medical services personnel in the participating regions.[35] As expected, the reported rates for severe injury (variably defined in the study from Minei and colleagues and the two studies from Calgary) are much lower than the rates reported using a broader definition of traumatic injury. Specifically, Pickett and colleagues observed crude hospitalization rates of 300 per 100,000 population using all injury hospitalizations in their cohort of patients from Kingston, Ontario.[36] In this study, injury hospitalization rates for males and females were 303 per 100,000 population and 297 per 100,000 population, respectively.

While sparse, the current Canadian literature highlights substantial variability in the estimates of trauma incidence rates; reflecting, in part, variations in the definition of trauma, populations and time period examined and the injury databases used. [33, 35] Data from other jurisdictions examining major injury hospitalization have shown similar variability.[37-41] Within the European setting annual crude incidence rate of major trauma (ISS > 15) hospitalization have been reported as 23.2 per 100,000 population for all trauma[38] and 19 per 100,000 population for blunt trauma.[42] These figures are comparable to the major trauma (ISS > 15) hospitalization rates of 22 per 100,000 population reported for Victoria State, Australia[40] but lower than the 33.6 per 100,000 population reported for Auckland, New Zealand.[43] Similar variability in population based rates of trauma for selected traumatic injuries are also noted.[42, 44] Further, cause of injury varies markedly across different populations and countries, and as such data from other jurisdictions are frequently not generalizable to the Canadian context. For example, as highlighted in their study, Laupland and colleagues identified motor vehicle collisions as the primary cause of injury in the Calgary Health Region, with crude incidence rate of 27 per 100, 000 population per year,[33] while, as noted, motor vehicle related injury rate was reported as 102 per 100,000 population in Rhode Island.[45] Similarly, these authors observed that firearm injuries which are uncommon within the Canadian setting (2.0 per 100,000 population in the Calgary Health Region),[33] were a leading cause of injury in a study conducted in the United States, with an incidence of 42 per 100,000 population.[37]

2.2.2 Factors Associated with Major Trauma

Several studies have identified important risk factors for major trauma. Importantly, male gender and age has consistently been identified as population risk factors for major trauma.[33, 35, 43] Compared to women, men have up to a 3-fold greater risk of major trauma.[33, 43, 45, 46] Further, increasing age has been found to be associated with major trauma, with Laupland and colleagues reporting a significant increase in the annual age-specific population incidence of major trauma among the elderly in the Calgary Health Region.[33] As these authors noted, however, the greatest absolute number of major trauma tend to occur in the younger age groups, suggesting that the greatest impact of major trauma in terms of number of individuals affected and potential years of life lost is in the young.[33] This is consistent with a study by Creamer and colleagues that showed that while the highest age-specific injury rates were noted in patients 15 – 29 years and 75 years and older, the latter population accounted for less than 7% of the total major trauma population.[43] Unlike age and gender, evidence of an association between major trauma and urban/rural location is less consistent. Within the Canadian setting Laupland and colleagues identified urban residents as having a higher risk of major trauma.[33] While these findings are consistent with an Italian study by Friuli et al.,[39] it contrasts with data from some US jurisdictions.[47] The urban/rural differences as well as other inconsistencies across studies may be explained, in part, by such factors as differences in population demographics and differences in cause specific injury rates.[33, 47]

2.2.3 Injury Mortality

Injury death rate varies markedly across different populations.[48] Recently, Minei and colleagues reported age-sex adjusted mortality rates of 7.3 deaths due to traumatic injuries per 100,000 population for Vancouver and 5.2 per 100,000 population in both Ottawa and Toronto.[35] Applying a definition of ISS > 12, Laupland and colleagues reported an annual population mortality rate of 20 per 100, 000 adult population in the Calgary Health Region.[33] This is lower than the reported annual mortality rate of 30.9 per 100,000 population observed in Los Angeles,[37] but higher than the 14.4 per 100, 000 population reported in Auckland, New Zealand.[43] Similar figures from European range from 35 per 100, 000 population to 126 per 100, 000s.[49] In addition to the observed variability in injury mortality rates across different health systems, several studies have demonstrated disproportionately higher injury mortality rates in rural communities as compared to urban locations.[50-53] Within the Canadian context, higher injury death rates have been noted for rural areas in British Colombia and Ontario compared with more urban areas within the provinces.[53, 54] While differences in patient populations and clinical practice may explain some of the observed mortality differences across regions, it is also possible that variation in access to trauma care may account for some of the variability.[54] In rural regions with limited geographical access to trauma hospitals, longer transport times to definitive care may place severely ill patients at increased risk of death in the pre-hospital setting;[53, 54] Simons and colleagues found that 82% of traumatically injured patients from rural areas died outside of hospitals compared to 67-73% of patients in more urban areas of British Colombia.[53]

The above discussions highlight that trauma remains a significant public health problem. Despite this, however, there is a paucity of population-based studies in the peer-reviewed literature that examines the incidence, causes and outcomes of major injury. More importantly, very few studies have been conducted in a Canadian setting. While inferences regarding major trauma epidemiology may be drawn from other jurisdictions, differences in population demographics, population density and the organization of health services may limit applicability to the Canadian setting. This review highlights the need for additional studies aimed at understanding the local experience with trauma. This information is invaluable to informing targeted prevention strategies and optimizing the delivery of trauma care. The next section of the chapter discusses the optimal approaches to organize trauma care and the factors that determine access to care for trauma patients.

2.2.4 Trauma Care Organization and Access to Care

As highlighted in the previous discussions, major trauma has important societal implications in terms of years of life lost and lost productivity to the economy. In response, over the past several decades many health care systems have engaged in efforts to reduce trauma related mortality and morbidity. Among the approaches, the development of an organized system of trauma care delivery has been shown to improve the outcomes for this patient population.[4-7, 55]

This systems approach has been developed to provide a coordinated approach to care including a network of pre-hospital care (e.g. emergency medical services), predefined triage and transfer protocols to facilitate appropriate triage to definitive acute care, the designation of hospitals according to the level of available trauma resources (human and medical equipment) and rehabilitation services.[56, 57] The aim is to ensure that injured patients have timely access to resources to meet their care needs.

The designation of trauma centres, hospitals resourced and committed to treating seriously injured patients, is a core component of the system approach. This concentration of specialized services within designated centres is predicated on the principle that concentrating the care of patients with severe injuries within a small number of hospitals will result in larger volumes of patients, hence increased expertise within these hospitals. The anticipated results are improved outcomes for patients and better efficiencies in the management of this patient population.[58] An effective trauma system, therefore, necessitates triage processes that include standardized pre-hospital (field) and hospital triage guidelines and hospital transfer protocols, intended to facilitate rapid evaluation of the needs of injured patients and decisions with respect to the most appropriate resource to manage these needs.[57, 59] Several studies have demonstrated substantial reductions in trauma-related deaths associated with the adoption of these formal structures and processes in the delivery of trauma care.[11, 55, 60, 61] Despite this evidence, however, progress towards establishing trauma systems have been slow across most jurisdictions. Even within the United States (US) with its longer history of trauma systems development, the extent to which the different components of a trauma system have been developed vary across states.[8, 60, 62] In Canada, there is no national standard for organizing trauma services.[15, 16, 63] The Trauma Association of Canada (TAC) has been established to promote the development of trauma systems across the country.[15, 16, 63] Similar to the American College of Surgeons Committee on the Organization of Trauma (ACS-COT)[64] in the United States, TAC has produced guidelines for triage and the designation of acute care hospitals providing trauma care based on available resources, from a Level V hospital (rural hospitals with no immediate access to a major trauma centre that provide emergency services to stabilize trauma patients prior to transfer to the nearest appropriate trauma centre) to a Level I trauma centre (a university-affiliated, large metropolitan hospital, providing care for the most acutely injured patients).[63] This is a voluntary accreditation process, and currently 28 hospitals in Canada are accredited as trauma centres (Level I to Level V).[63]

While most provinces have established trauma centres in primarily urban areas, the support for trauma care organization varies across the provinces, with some provinces having government mandates that ensure province-wide trauma service, while in other provinces trauma system implementation is primarily facilitated by local hospital initiatives.[15] This has resulted in *"have and have-not jurisdictions."*[15] As a consequence, there is marked variation in the organization of trauma care across and within individual provinces, with variable integration to fully organized systems. Of note, within each province there are differences in the number of and type of trauma services provided by hospitals that are designated as trauma centres.[17, 65, 66] The provision of trauma care for Canada's rural population is also challenging. In particular, while major injury related mortality rates may be higher in rural areas as compared to urban settings,[53, 54] the development of rural trauma care has lagged,[15] with few designated trauma centres or clear triage and transport systems to serve these areas.[16, 17]

Potential access to trauma centre care (Level I and II) within the Canadian health system has recently been described by Hameed and colleagues.[17] As part of a national survey, these authors demonstrated that 22% of Canadians live outside 1-hour driving distance from a trauma centre. However, marked disparities exist between different regions and provinces, for example the authors found that 60% of the population of Newfoundland and Labrador resided outside of one-hour to a trauma centre.[17] Emerging evidence from Ontario has shown that despite good potential access (85% - 95% of Ontarians live within 1-2 hours of a trauma centre)[17] receipt of trauma care (realized access) is less than optimal in this province.[9, 18-20] These authors have shown that as many as 43% of severely injured patients do not receive care in a trauma centre.[19] While data from other provinces is limited, it is noted that even among jurisdictions with a longer history of efforts to adopt an organized system of trauma care, providing consistent access to care is challenging. In the United States marked regional variability in the number and distribution of trauma centres has resulted in differential access to definitive trauma care.[67, 68] Over 46 million Americans, predominantly from rural area, have no access to Level I or Level II trauma centres within one hour of ground transportation time.[67] Further, Mackenzie and colleagues showed that in Maryland, a state which supports a coordinated system of trauma care, 34% of patients who were classified as requiring trauma centre care were not treated in a trauma centre.[28] When these authors applied a more stringent criteria of ISS > 15 to define patients requiring trauma centre care, undertriage rate (severely injured patients not seen at Level I trauma centres) remained high at 22%, a finding consistent with other studies in this population.[69] In California, where there is no statewide integration of trauma care using common criteria for triage and transportation,[28] Vassar and colleagues have shown that only 56% of trauma patients requiring care in trauma centres received care in this setting.[12] More recently, Hsia et al have reported an undertriage rate of 26.5% for seriously injured patients (ISS > 15) in California.[14] The observed high but variable rates of undertriage for seriously injured patients has been noted in other jurisdictions[13, 69-73]

While there are notable differences in the definitions used to define serious injury and trauma centre designation, studies highlighting that a considerable proportion of patients with major trauma do not receive care in a trauma centre is concerning given the evidence that supports improved outcomes for patients treated in these centres.[7, 11] Evidence from the reviewed studies suggests that patients that were undertriaged have significantly higher mortality than patients appropriately triaged to a trauma centre, after adjusting for injury severity.[12, 18, 71] The lack of efficient transfer systems across many Canadian provinces, and in particular within more rural provinces, may therefore have significant consequences for both access to and the quality and timeliness of care provided to severely injured patients. Importantly, in certain instances, such as when weather conditions, long distance between the scene of injury and trauma centre, or terrain discourages direct transports, severely injured patients may be transferred to more proximal hospitals for stabilization before transfer to a trauma centre for definitive care. This unavoidably increases the time to definitive care, which may be exacerbated in the absence of formal processes and communication systems to facilitate rapid evaluation, stabilization and inter-hospital transfer of severely injured patients.[74] The consequence of which is possible compromised patient outcomes, including morbidity and mortality.[74, 75] The noted gap in the current understanding of how regional differences in organizing trauma care across Canada impacts access to care is of interest since inequities in access to trauma care may highlight opportunities for improving the delivery of trauma services in different regions of the country.

2.3 Determinants of Hospitalization in a Trauma Centre

The following section summarizes the existing literature on the determinants of access to trauma centre care for severely injured patients. The determinants identified are summarized under two broad headings: socio-demographic and clinical factors and system factors.

2.3.1 Socio-demographic and Clinical Factors

2.3.1.1 Age

The findings from several studies suggest that older patients with major trauma are less likely to be admitted to a trauma centre than their younger counterparts.[12, 20, 69-72, 76, 77 78] Chang and colleagues demonstrated that a disproportionate number of older patients with major trauma did not receive care in a trauma centre, with patients ≥ 65 years of age 52% less likely to be transported to trauma centre compared to younger patients (<65 years) after controlling for sex, study year, type of injury, mechanism of injury and geographic region, among other variables (Odds Ratio (OR) of being transported to a trauma centre 0.48 and 95% confidence interval (CI) 0.30 – 0.76).[69] This is consistent with a much earlier study that demonstrated a greater than 5-fold increase in the risk of elderly patients with severe injuries being admitted to non-trauma hospitals.[70] Using a higher age cutoff (> 70 years) Rehn and colleagues similarly found that older patients were more than 5 times more likely to be undertriaged after adjusting for important covariates.[71] In a cohort of mild to severely injured patients, Hsia and colleagues demonstrated that after controlling for injury severity, older patients (45 – 64 years old) were 34% less likely to be treated in a trauma centre compared to patients less than 45 years old. This disparity was more pronounced for the very elderly (>85 years) who were 5 times less likely to be admitted to a trauma centre than patients 25 – 44 years old.[14] More recently these authors extended these finding by demonstrating that decreased access to trauma centre for elderly patients, compared to younger patients, was consistent across mechanism of injury and injury severity.[78]

2.3.1.2 *Sex*

As noted earlier, sex is an important determinant of injury risk, with males more likely to suffer major injury than females.[33, 79] However, similarly to the conflicting evidence regarding an association between sex and outcomes for trauma patients,[80-82] reports of the association between trauma centre hospitalization for injury and sex has been inconsistent, with some studies finding no association[69, 76] and others documenting higher undertriage in women.[19, 70, 71] In multivariate analysis, female patients were 1.48 ($p < 0.001$) times more likely to be triaged to a non-trauma centre than males with similar severity of illness.[70] This result is in contrast with Rehn and colleagues who found that this gender bias was attenuated after controlling for age.[71] Within the Canadian context, Gomez and colleagues identified sex as an important determinant of receiving care in a trauma centre following major trauma, with women having a 12% (95% CI: 6% - 21%) lower odds than that of men to be cared for in a trauma centre after controlling for covariates such as age and injury severity.[19] Importantly, these authors demonstrated that the likelihood of women receiving care in a trauma centre was lower, compared to men, from the field as well as from transfer from outlying hospitals following initial stabilization.

2.3.1.3 *Insurance Status and Income*

While less relevant to the Canadian setting given our single payer model of health care delivery, several studies from the US have examined insurance status as a determinant of trauma centre care.[14, 69, 83] Compared to severely injured patients with public or private non-Health Maintenance Organization (HMO) insurance, patients with HMO were less likely (likelihood ratio 0.25) to be admitted to a trauma centre after controlling for such factors as age and injury severity.[14] This observation is supported by other evidence from the peer-reviewed literature that have shown that underinsured injured patients, regardless of injury severity, are preferentially transferred to trauma centres from non-trauma hospitals.[83, 84] Consistent with these findings there is some evidence to suggest that injured patients from low income neighbourhoods are more likely to receive care in a trauma centre compared with individuals from higher income, after controlling for important covariates such as age and severity of illness.[14] The evidence of the influence of payer status on trauma centre admission is derived primarily from the US. As noted, the observation that these patients are preferentially transferred to a trauma centre may reflect, in part, a method of placing the costs of caring for patients who are uninsured or underinsured on trauma centres,[84] since regardless of insurance status, by law, centres must accept acutely and critically injured trauma patients as long as resource capacity permits.[85]

2.3.1.4 Injury Severity and Other Clinical Factors

Consistent with theoretical expectations, injury severity has been found to be associated with trauma centre hospitalization - patients with increasing severity of illness are more likely to be admitted to a trauma centre.[14, 69, 70] Zimmer-Gemmeck and colleagues demonstrated that in severely injured patients (ISS>15) for every one point increase in ISS the likelihood of undertriage decreased by 17% (OR 0.83).[70] Similarly, Hsia and colleagues demonstrated that patients with an ISS > 15 were more than 3 times more likely to be hospitalized in a trauma centre when compared to patients with ISS ≤ 4.[14]

Few studies have examined physiological and injury characteristics as determinants of undertriage in patients with major trauma. Of note, Zimmer-Gembeck and colleagues found that severely injured patients meeting state level mandatory criteria for transport to a Level I trauma centre, were less likely to be undertriaged if they had multisystem injuries (OR 0.55).[70] The authors found no other association between undertriage in severely injured patients and other comorbid conditions examined. In contrast to these findings, Chang and colleagues found that undertriage following severe injury was not associated with patient physiology or mechanism of injury.[69]

2.3.2 System Factors

2.3.2.1 Availability and Location of Trauma Centre

The concentration of trauma services within a small number of dedicated hospitals is predicated on the principle that concentrating of these services will lead to increased expertise within these hospitals, resulting in better efficiencies in the system and improved outcomes for patients.[57] The expectations for such systems are that regardless of location, patients will be appropriated triaged to the hospital to meet their care needs. Evidence from several studies have, however, demonstrated that the distribution of trauma centres within a given jurisdiction is an important determinant of undertriage.[12, 14, 86] Of note, Wang and colleagues demonstrated that patients who resided in a county with a trauma centre were 3 times more likely of being hospitalized in a trauma centre compared to patients residing in counties without a trauma centre (OR 3.07, 95% CI 2.53 – 3.74).[86] Similarly, in unadjusted analysis, Hsia and colleagues found that only 30.8% of severely injured patients (ISS > 15) residing in counties without a trauma centre received care in these centres compared to 82.4% of those living in areas with a trauma centre.[14] In examining this association across all injury levels, these authors found that after controlling for injury severity, age, insurance type, proximity to trauma centre and neighbourhood income, patients living in counties without trauma centres were still less likely to be admitted to a trauma centre. Moreover, distance from patient residence to a trauma centre (proximity to a trauma centre) was a significant predictor of undertriage, with patients living greater than 50 miles away from a trauma centre less likely to receive care in a trauma centre compared to patients living less than 10 miles from a trauma centre.[14] In extending the literature regarding distance and trauma centre access, Douroumas and colleagues showed that even within the urban setting of Toronto, Ontario where access to a trauma centre is within 30 minutes for the majority of the population, differential distance between the closest trauma centre and the closest hospital resulted in marked undertriage of severely injured patients.[20] Notably, compared to a differential distance of < 1 mile, distances of 1 – 2 miles resulted in decreased likelihood of transport to a trauma centre (adjusted odds ratio 0.37, 95% confidence interval, 0.21 - 0.67).

Utter and colleagues examined the impact of trauma system organization on triage for severely injured patients in the US.[60] Trauma systems were categorized according to the proportion of all acute care hospitals that were designated trauma centres (level I-V). Systems with higher proportions of trauma centres were defined as more inclusive. These authors defined states as “exclusive” if 0% - 13% of acute care hospitals in the state were designated as a trauma centre; states with 14% - 37% and 38% - 100% of hospitals designated as trauma centre were defined as “more inclusive” or “most inclusive”, respectively. In states with an inclusive system, 29.8% of severely injured patients (ISS >15) were not hospitalized in a Level I or Level II trauma centre.

Further, in unadjusted analysis, compared to exclusive systems, these authors found no significant differences in triage to a trauma centre (Level I or II) for severely injured patients treated in more inclusive or most inclusive systems. After controlling for payer status, age, mechanism of injury, system maturity, and statewide median household income, there was no significant difference in triage to a trauma centre between exclusive systems relative to more inclusive or most inclusive systems, ORs 1.07 (95% CI: 0.70 – 1.63) and 1.05 (95% CI: 0.56 – 1.98), respectively.[60] Suggesting that the influence of a greater proportion of hospitals being designated as trauma centres (Level I – V) may not be the most influential aspect of trauma system development with respect to assuring that severely injured patients are triaged to higher level of care centres. Instead this may relate to other aspects of a trauma system, including, for example, the structures and processes supporting optimal patient transport systems and the number of Level I/II trauma centres available to manage severely injured patients.

2.3.2.2 Emergency Medical Personal

Studies examining the type of emergency medical providers involved in the triage decisions are conflicting. Chang and colleagues found no association between undertriage and whether paramedics or non-paramedic personnel were involved in patient transport.[69] Conversely, Rehn et al noted that compared to initial assessment by anesthetists or paramedics, paramedics were significantly associated with greater undertriage rates, with an adjusted OR of 5.84 (CI 3.73 – 9.13; $p < 0.001$).[71]

Current evidence suggests that there are important factors which determine the extent to which severely injured patients receive definitive care in a trauma centre.

Importantly, what was identified was that not only do individual patient factors matter, but the local context including geography, and trauma services infrastructure are important determinants of trauma centre care. However, while the review suggests that there may be important inequities in trauma centre access, with respect to age and geography for example, there is a notable gap in the literature as it pertains to the robustness of the statistical techniques employed to adjust for the multiple patient and contextual indicators. Importantly, none of the included studies incorporated multilevel statistical techniques to account for the patient and contextual influences on variations in trauma centre access.

2.4 Summary of the Chapter

The dearth of studies describing population-based trends in injury epidemiology within the Canadian context is concerning. This information is essential to optimizing the planning and organization of trauma services. Additionally, although accumulating evidence has established regional variability in utilization of trauma centres for severely injured patients,[12, 13, 70, 71, 86] only a few studies, centered on one province, have examined this issue within Canada. The location of trauma centres across the provinces does, however, suggest that geographical inaccessibility may place some communities at higher risk for suboptimal access to these services, a point highlighted by a recent national survey of trauma systems across the provinces.[17] This problem may be compounded by the lack of a structured and integrated approach, including standardized triage and transfer protocols, to delivering trauma care to severely injured patients. Consistent with data from other settings,[87, 88] emerging evidence from the trauma patient population suggest that socio-demographic and system factors, such as clinical characteristics, age, income level and availability of resources, may have important influences on regional differences in patient access to trauma centre care. More importantly, any variation in the utilization of trauma centre care identified at the regional level may be due to regional differences in the distribution of these putative factors. The extent to which observations from a single province,[19, 20] or jurisdictions outside of Canada[28, 78] may be applicable to the Canadian setting is unknown. This is of great practical interest since inequities in access to trauma care may highlight opportunities for improving trauma care in different regions of the country. The body of work covered by this dissertation addresses some of the current information gaps within the Canadian context and improves our understanding of severe trauma in Canada by being the first study to examine national patterns in severe injury hospitalization and access to trauma centre care.

Chapter 3 : Conceptual Model and Research Questions

3.1 Access to Health Care

Despite the importance placed on achieving equitable access to health services, the term "access" remains ill-defined.[89, 90] While several theories and frameworks have been proposed to examine access to health services[90-92] much of the empirical research on the determinants of access to health services have been based on the conceptual framework proposed by Aday and Anderson[93] and subsequent revisions.[94, 95] As argued by Andersen, a major aim of the "Behavioral Model of Health Services Use" (hereafter referred to as behavioral model) was to provide a measure of access.[94] Andersen proposes that access indicators measure "potential access" and "realized access".[94] Potential access, defined as the presence of enabling resources, indicates whether an individual has a relationship to the health system that is likely to facilitate them obtaining services.[96] Realized access is the actual use of health services. In this perspective, access to health services is evidenced not only by potential entry into the health system but also by the utilization of services and associated outcomes.[93, 94]

The behavioral model and subsequent revisions draws on a systems perspective to integrate individual, environmental and health care provider related factors to understand individual utilization of health services.[95] The model proposes that use of health services (i.e. realized access to care) is determined by predisposing characteristics of individuals and their environment, enabling factors, need factors (perceived and or evaluated need for health services) and environment (societal and health services system) factors.[94, 95] *Predisposing characteristics* refers to individual predisposition towards using health services. These include socio-demographic characteristics such age, sex, marital status and race.[94] *Enabling resources* refer to those individual/family factors that facilitate or impede access to health services, including for example, income level, household income and area of residence.[94, 95] *Environmental factors* describe the specifics about the health care system and the external environment that impact the health status of individuals within communities.[94, 95] *Need factors* include both perceived (self-assessed) and evaluated factors (e.g. measures of illness severity).[94]

Andersen suggests that enabling and need factors will have differential ability to explain use of health services, depending on what type of services are examined. He argues that hospital services received in response to serious conditions would be primarily explained by need and demographic characteristics.[94] However, in expanding on the behavioral model, Phillips and colleagues have highlighted the importance of the environmental and provider related factors that impact health care utilization.[95] Environment variables include, for example, availability of services and policies, resources and organization that affect accessibility of health services.[95]

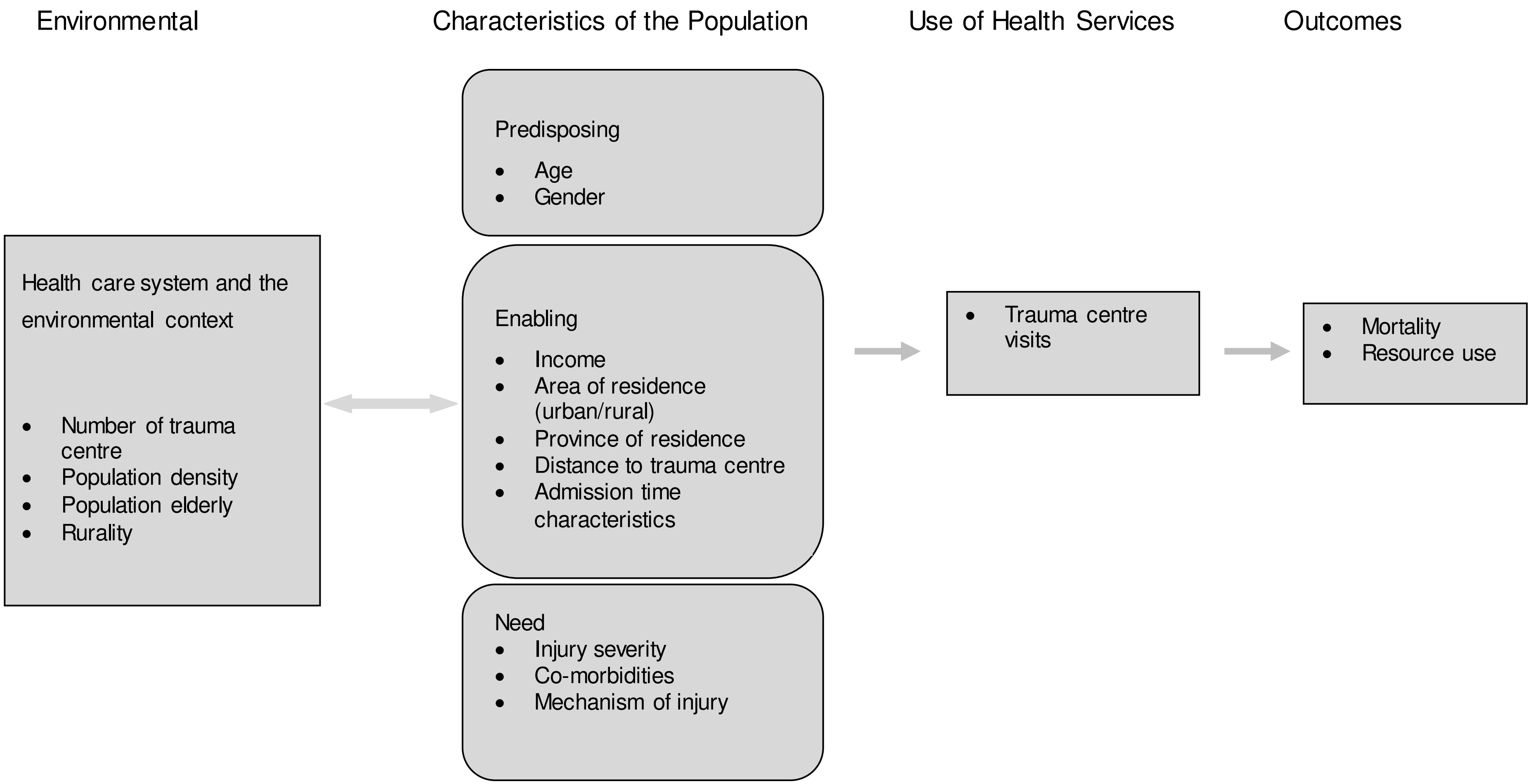
The behavior model and its subsequent revisions suggest that the concept of access can be summarized as an interaction between the characteristics of the health care system (e.g. the availability and distribution of the health care resources) and the population at risk (i.e. potential users of the service).[94-96] This study proposes that a modified version of the health behavioral model that reflects a more complex understanding of the determinants of trauma centre utilization would be most relevant. Such a framework would extend beyond the narrow focus on individual patient factors to include factors related to the context of care, including such factors as resources and organization that affect accessibility and availability of trauma services.

3.2 Conceptual Framework

Figure 3.1 summaries the conceptual model adopted for this study. Drawing on the studies that have examined determinants of utilization of trauma centres (undertriage), the conceptual framework proposes that demographic and need factors such as sex, age, injury severity, type of injury and patient co-morbidity will have the most important influence on patient access to trauma centre care. Further, the model proposes that enabling factors (income level) and environmental factors (number of trauma centres, population density, and rurality) will attenuate the relationship between age, sex, geography (province, urban/rural) and undertriage.

Additionally, although the health care system and environmental context are considered in this model, it should be noted that not all pertinent components are included in the framework. Particularly, factors associated with pre-hospital care, such as the availability of field triage protocols and the type of emergency medical transport services, are likely to impact where patients access care. However, these data were not available in this study, and as such the conceptual framework does not include these factors.

Figure 3:1 Conceptual Framework



3.3 Research Questions

The following research questions, organized by topics, are addressed by this thesis:

3.3.1 Understanding the Impact of Inter-hospital Transfer in Trauma Care

The challenges of geography and practical resource limitations have led to a fundamental feature in the design of trauma system and management of patients with trauma: the need for interfacility transfer to a trauma centre. Understanding the impact of interfacility transfer on patient outcomes may provide an opportunity for improving trauma system design, for example the need for extending the reach of trauma transport systems to increase the probability of direct transport to a trauma centre or for expediting the process of interfacility transfer. This thesis therefore addressed the following question:

1. Are outcomes (survival, length stay, costs, complications, time to care) different in patients first stabilized in proximal hospitals prior to transfer to a higher-level of care centre for definitive management when compared to patients admitted directly to hospital of definitive care?

3.3.2 Trends in Major Trauma Hospitalization and Outcomes

Epidemiological profile of injury incidence and mortality consequences are important to developing targeted injury prevention strategies to reduce the burden of this disease and for informing policy directions regarding the optimal design of trauma services. To that end this thesis addressed the following questions:

2. What are the temporal trends in the rates of hospital admission for major trauma in Canada?
3. What are the temporal trends in cause-specific injury rates in Canada?
4. Are there are differences in rates of hospital admission for major trauma across Canadian provinces?
5. What are temporal trends in the rates of in-hospital mortality for major trauma in Canada?
6. Are there any differences in rates of in-hospital mortality for major trauma across Canadian provinces?
7. What is the utilization of acute care hospital bed-days following major trauma?

3.3.3 Undertriage Rates and Determinants of Undertriage in the Canadian Population

Numerous studies have demonstrated gaps in the access to trauma centre care for different segments of the injured patient population. Whether these findings extend to a setting designed to assure equal access to medically necessary therapies is largely unknown. To address this gap and identify opportunities for improving the delivery of trauma services to patients this thesis addressed the following questions:

8. What proportion of severely injured Canadians receives care outside of a trauma centre (undertriage)?
9. Are there regional variations in the receipt of care in a trauma centre care for Canadians hospitalized with major trauma?
10. What is the impact of age and gender on receiving care in a trauma centre within the Canadian population?

11. What are other determinants of receiving care in a trauma centre within the Canadian population?

In addressing these questions, this dissertation will provide estimates of the annual rates of severe trauma hospitalization in Canada. Further it will be the first study to apply consistent definitions and methodologies to investigate rates of undertriage across Canada. The findings will be important to policymakers in understanding trauma hospitalization rates and trauma centre utilization patterns and how these differ among population subgroups. As the delivery of trauma services evolves in Canada, this will not only be important to establishing priorities, but will also inform policy decisions regarding the most appropriate system design given current resources. Moreover, it will make a significant contribution to the trauma literature, by expanding the information available on jurisdictional differences in access to trauma centre care and outcomes for trauma patients.

A version of Chapter 4, which follows, has previously been published as:

Hill AD, Fowler RF, Nathens AB. *Impact of Interhospital Transfer on Outcomes for Trauma Patients: A Systematic Review.* J Trauma. 2011; 71: 1885–1901

Chapter 4 : Impact of Inter-hospital Transfer on Trauma Patients: A Systematic Review

4.1 Introduction

Implementation of organized trauma systems has been shown to be effective in reducing disability and patient mortality by up to 20%.[6, 61] Importantly, such systems include the integration of pre-hospital care, acute care and rehabilitation,[4, 5] with the primary aim of ensuring the timely management of patients in the most appropriate setting to meet their needs.[61] Central to these systems is the designation of trauma centres that are resourced to care for patients with more severe injuries.[61, 67] This is based on the premise that concentration of specialized staff and technologies within a small number of centres will lead to the optimal management of severely injured patients, and ultimately improved patient outcomes. Data from a number of studies have demonstrated significantly lower mortality for trauma patients treated in designated trauma centres compared to those treated in non-trauma hospitals.[11, 97-99]

The centralization of specialized trauma resources within a few dedicated hospitals has other consequences. Importantly, some critically injured patients are initially triaged to and receive preliminary care at outlying hospitals prior to transfer to a higher-level hospital for definitive care. The initial transfer of these patients to more proximal hospitals unavoidably increases the time to definitive care, in particular for patients in rural settings that are not in close proximity to centres resourced to manage their care needs. The impact of the delay in receiving definitive care may have significant implications for patient outcomes.[100] This is consistent with evidence from other critically ill patient populations that suggests that transfer patients have higher mortality and longer lengths of stay than direct admissions.[101, 102] There is little debate regarding the necessity of interfacility transfer, particularly when faced with challenges of geography, as a policy of service delivery that transports all severely injured patients directly to trauma centres would require investments in human resources and technologies that are not practicable. However, extending the reach of transporting agencies to increase the probability of direct transport to a trauma centre or expediting the process of interfacility transfer would be necessary if a delay in the transfer process is identified as harmful. An understanding of whether, and to what extent, outcomes differ for patients with secondary transfer to trauma centres is therefore an important consideration in trauma systems design. The purpose of the study was to systematically review and summarize the outcomes of patients successfully transferred to a trauma centre compared to those transported to a trauma centre directly from the field.

The primary objective of this systematic review was to evaluate the association of transfer from a non-trauma hospital to a trauma centre (higher level of care centre), compared to direct transport to a trauma centre, on in-hospital mortality for trauma patients. Secondary objectives were to evaluate the association of transfer from a non-trauma hospital to a trauma centre, compared to direct transfer to a trauma centre, on:

- Hospital length of stay
- Intensive care unit (ICU) length of stay
- In-hospital costs
- Time to definitive care (defined as the time interval from injury to arrival at a trauma centre)

4.2 Materials and Methods

4.2.1 Search Strategy and Study Eligibility

Medline and EMBASE databases were initially searched from inception to February 28th, 2009, and updated with search to June 9, 2011. The search strategy was developed by an iterative process in consultation with a medical librarian and included the following MESH and text words: "Wounds and Injuries", "trauma", "accident", "urban population", "rural population" "trauma center", "patient transportation", "mortality", "length of stay" and "treatment outcomes" (Appendix A). The references cited in included studies and reviews conducted on related topics were examined to identify additional articles. Studies were eligible to be included in the review if they were randomized controlled trials, *controlled* before and after studies, interrupted time series, case-control and cohort studies. Case series and reviews were excluded due to the strong potential for bias. Included studies had to meet the following criteria: (1) they examined outcome (mortality, hospital or ICU length of stay, complications, or time to first hospital, time to definitive care or hospital costs) by transfer status; and (2) they examined a trauma patient population. Studies where the majority (>80%) were burn patients were excluded given that these patients are primarily treated in burn centres and often have different mechanisms of transfer. Further, studies where transfer status was not the primary exposure variable but one of a set of prognostic factors were not included in this review. Transfer status was defined as either direct admission to a higher level hospital for definitive care (direct admissions) or transfer admissions from another hospital following stabilization and/or initial treatment.

4.2.2 Study Selection, Data Extraction and Quality Assessment

The search strategy generated 3639 articles. Screening of titles or abstracts identified 95 potentially relevant articles. These were further independently reviewed by two reviewers in either abstract or full text to assess eligibility for inclusion. Disagreements were resolved by discussion and consensus among the three reviewers. Thirty-six articles were selected for inclusion in the systematic review (Figure 4.1)

A standardized, piloted data abstraction form was used to extract data, in duplicate, from included studies (Appendix B). The data abstracted form, developed based on a modification of an existing tool,[103] captured data on study characteristics, characteristics of the patient population, transfer status, outcomes reported and adjustment variables. Disagreements regarding the data extracted were resolved by discussion and with input from a third reviewer. We attempted to contact authors to clarify data when there was uncertainty about the information included in the studies. Despite a lack of response to the requests for additional information the affected studies were still included in the review.

The quality of the included studies were assessed independently by two reviewers using a criteria checklist consistent with the recommendations of the Meta-analysis of Observational Studies in Epidemiology (MOOSE) group.[104] Characteristics of the studies examined included comparability of the study groups, method used to select study participants, ascertainment of transfer status (the exposure variable), ascertainment of outcome variables, follow-up and analysis and control for potential confounding factors. Each reviewer independently categorized each study as “low risk of bias” (no criterion was judged as poor); “medium risk of bias” (no more than one criterion was judged as poor or unclear); and, “high risk of bias” (if two or more criteria were judged as poor or unclear). A numeric scoring system was not used to determine the quality of the studies nor was any attempt made to incorporate a quality score into the review as the reporting and use of this information may lead to misinterpretation of study quality and conclusions.[105]

4.3 Data Synthesis and Analysis

Given the heterogeneity in study settings and outcomes assessed, the primary synthesis focused on a descriptive summary of the included studies. However, to provide an estimate of the effect of transfer status on hospital mortality data from studies reporting mortality as an outcome were quantitatively pooled. The articles selected for meta-analysis included studies conducted with trauma patients, examined hospital mortality and reported sufficient data to compare transfer status and hospital mortality. Additionally, separate analyses were performed in a subset of studies that included only rural patients. The Cochrane Collaborative Review Manager software (Copenhagen, Denmark, version 5.0) was used to pool and analyze data. For the quantitative comparisons of direct transport to trauma centre versus transfer from a hospital to a trauma centre, odds ratios (OR) and 95% confidence intervals (CI) were calculated using random effect models. This meta-analytical model assumes that the effect being estimated across the included studies is not identical, that is, the true effect may vary from study to study.[106] The model was selected given that differences in such factors as patient population and organization of trauma services may affect the magnitude of the impact of transfer status on mortality, and these factors are likely to vary across studies. As such, it is unlikely that the true effect is consistent across studies. Heterogeneity between studies was assessed using the I^2 statistics,[107] with an I^2 greater than 50% indicating high heterogeneity.

4.4 Results

4.4.1 Description of Included Studies

Table 4.1 provides the details of the included studies. All 36 were observational cohort studies, including 11 prospective[108-118] and 25 retrospective studies.[18, 74, 75, 85, 119-139] Sample size in these studies varied from 39 to 10,349 patients. Eight studies were conducted in a rural setting.[112, 125, 127-129, 131, 135, 136] The remaining studies were conducted in urban or mixed urban/non-urban settings (Table 4.1). The patient populations were restricted to blunt or penetrating trauma,[111, 115, 117, 124] orthopedic,[132] blunt pancreatic,[131] brain and head injury,[110, 113, 114, 119, 125, 133, 134, 139] respectively, in fourteen studies. The remaining studies included a heterogeneous population of trauma patients (Table 4.1). Three studies were restricted to pediatric patients.[113, 116, 124]

The reported ISS scores in the included studies indicated predominantly moderate to major trauma. In two studies injury severity was restricted to major trauma defined as ISS > 15.[129, 137] All studies reported the association of mortality with transfer status. The primary mortality end-point assessed was in-hospital mortality in the majority of studies (Table 4.1) and a combination of 2-week mortality,[110] 30-day mortality[18, 111, 118, 121, 135], 6-month mortality[119] and 1-year mortality[120] in the remaining studies.

4.4.2 Quality of Included Studies

The methodological quality of the studies was variable, with all rated as medium to high risk of bias, primarily due to a non-interventional design. Although most studies ascertained transfer status and outcomes based on registry data or medical records, in three studies the description of ascertainment of exposure and outcome was only "adequate" [21, 22,] or "unclear".[113, 114, 133] The comparability of the transfer and direct patient groups varied across studies (Appendix C) with four studies rated "unclear" because limited description of the two study groups was provided[110, 129, 130, 132]*.* Potential confounding factors were inconsistently addressed in the studies, with control for confounding factors rated as poor or unclear in 20 studies, adequate in 9 studies, and good in 7 studies *(Appendix C).*

4.4.3 Time to Definitive Care

Mean time at the referring hospital ranged from 1.57 hours to 4.2 hours in the six studies reporting this outcome.[74, 112, 120, 126, 127, 139] In the 14 studies reporting time from injury to definitive care, transfer patients had significantly longer times to definitive care than patients directly admitted to the higher level centre.[108-110, 112, 116, 119, 125, 128, 129, 131 135, 137-139] Time from injury to first hospital was reported by three studies,[75, 111, 135] with two reporting significantly shorter time from injury to arrival at the first hospital for transfer patients.[75,135] Harrington and colleagues examined time at transferring hospital in relation to injury severity and found that with the exception of patients with ISS > 40, high ISS did not result in a prompt transfer to trauma centre.[74]

4.4.4 Mortality Outcome

In the studies reporting unadjusted in-hospital mortality, 12 reported significant differences in mortality rates between patients directly admitted to a higher level of care centre and those who were transferred from other hospitals[75, 85, 108, 109, 113, 114, 116, 122, 124, 126, 133, 137] (Table 4.2). Of these, seven studies showed higher in-hospital mortality in transfer patients.[75, 85, 109, 113, 114, 116, 133] Among the five studies reporting in-hospital mortality rates after adjustment for potential confounding factors, [75, 116, 122, 127, 137] two reported significantly higher mortality in transfer patients,[75, 116] with transfer patients as much as 3 times more likely to die in-hospital than direct admissions.[75] In adjusted analyses, hospital mortality was higher in transfer patients in one study[75] but there were no significant differences in 30-day[18, 111, 121, 135] 6-month or one year mortality[120] between the two groups. In the only study where the primary outcome was 2-week mortality, mortality was higher in transfer patients in adjusted analysis (OR 1.48, 95% CI 1.03, 2.12).[110] This was consistent with the subgroup analysis performed by Garwe and colleagues, who found higher 2-week mortality in transfer patients (Hazard Ratio 2.71, 95% 1.31, 5.6).[135] Of the seven studies conducted in predominantly rural settings [112, 125, 127-129, 131, 135], only one demonstrated a mortality difference between transfer and direct patients.[116] These authors found a three-fold higher adjusted incidence rate of death in transfer patients compared to direct admissions.[116]

In addition to the conventional approach that compares mortality outcomes between direct and transfer admissions to higher level of care centres, Haas and colleagues also identified a group of patients who were triaged to a non-trauma centre from scene but died in the emergency department of the non-trauma centre prior to transfer or admission to the non-trauma centre. When these authors included these "potential transfers" as part of the transfer group they found the adjusted odds ratio for death was 1.24 (95% CI .1.1, 1.4).[18] In contrast, Fatovich and colleagues found no significant difference between transfer and direct admissions when they included deaths at the referring hospitals as part of the transfer group.[137]

4.4.5 Hospital and ICU Length of Stay (LOS)

Hospital length of stay was reported in 19 studies, seven of which reported significantly longer hospital length of stays for transfer patients in crude analyses[75, 109, 122, 127, 132, 137] (Table 3). Two studies reported adjustment for potential confounders. In one, transfer was not associated with longer hospital length of stay (relative increase 1.02, 95% CI 0.97, 1.07)[126] but was in the other (16.0 (0.59) days versus 13.2(0.44) days, respectively).[75] In a matched cohort of orthopedic trauma patients Obremskey and Henley demonstrated longer hospital length of stay in transfer patients compared to direct admissions (14.4 days versus 10.6 days, respectively; p=0.02).[132] In unadjusted analysis, ICU length of stay was significantly longer for transfer patients in four [75, 113, 127, 132] of the 14 studies reporting this outcome (Table 3). In the only study reporting adjustment for potential confounding factors in statistical analysis, ICU length of stay remained significantly longer in transfer patients (mean 0.95 [0.09] versus 2.02 [0.12] days, respectively).[75]

4.4.6 In-Hospital Costs

Six of the studies meeting the inclusion criteria reported on costs for transfer versus direct admissions. This included five studies from the United States (US)[115, 116, [122, 126, 132] and a single Canadian study.[112] In the study by London and colleagues[122], compared to direct patients, transfer patients had higher mean total costs of care (US$21,177 versus US$16,975, p<0.001). These authors also reported higher direct costs (costs associated with direct patient care) and indirect costs (costs associated with supportive services e.g. laundry and food services) for transfer patients, with mean direct and indirect costs for transfer patients versus patients directly admitted to trauma centre being US$14,617 versus US$11,502, and US$7,255 versus US$5,902, respectively (p<0.001 for each comparison). Significantly higher total hospital costs for transfer patients were also noted in three of the other studies from the US, [115, 126, 132], which demonstrated almost 10% higher costs for transfer patients after adjusting for potential confounding (relative increase 1.09, [95% CI 1.08–1.09]).[126] In the Canadian study involving rural patients, Cummings and colleagues found significantly higher transport costs but not total costs for transferred patients compared to patients admitted directly to a trauma centre.[112]

4.4.7 Complications

In studies reporting this outcome, the types of complications studied varied.[122, 128, 131, 136] Two studies found that transferred patients had significantly more complications than direct admissions, 27.8% versus 23.3% (p <0.001) [122]and 39.1 versus 57.6% (p = 0.009),[128] respectively. Only one of the studies reporting higher complication rate in transfer patients reported the type of complications assessed, these included atelectasis, pneumonia, sepsis, and ARDS.[128]

4.4.8 Meta-analysis

Thirty-four studies that examined in-hospital or 30-day mortality were included in the meta-analyses (Figure 4.1). There were no statistically significant association between transfer status (transfer versus direct) and mortality (pooled OR and 95% CI: 1.06 [0.90, 1.25]). This result was unchanged when the “potential transfers”[18, 137] were included in the analysis (see Figure 4.3; OR 1.11 [95% CI: 0.94 - 1.31]). Heterogeneity of the studies for both analyses was high (83% and 84%, respectively). No statistically significant association between transfer status and in-hospital mortality was noted in the subgroup analyses that was restricted to studies conducted in rural patients (OR, 0.94 [95% CI: 0.77 - 1.14]) (Figure 4.4). Similar results were obtained when the study by Odetola et al.,[116] predominantly rural patients, was included in the subgroup analysis (OR, 1.05 [95% CI: 0.75 - 1.47]).

4.5 Discussion

The primary focus of this paper was to review the evidence examining differences between outcomes for patients directly admitted to a trauma centre with patients transferred from another hospital to the trauma centre (indirect admission). The examined outcomes included mortality, length of stay, costs, complications and total time to definitive care. Time to definitive care was longer for transfer patients; however, there was no evidence of differences in hospital length of stay. Results regarding morality were inconsistent across studies but pooled estimate point to no additional risk for transferred patients (pooled OR 1.06 [95% CI: 0.90 - 1.25]). Transfer patients incurred more in-hospital costs than patients directly admitted to trauma centres;[115, 122, 126, 132] however, the underlying mechanisms for this increased cost (for example higher complexity in transfer patients) could not be ascertained from these studies.

Caution in interpreting these results is warranted. While the data among similar studies were quantitatively pooled, there was substantial heterogeneity among studies. Important sources of heterogeneity across studies may result from differences in the included patient populations, study setting and outcomes assessed. To mitigate the challenges associated with comparing outcomes in rural settings with those of urban settings, separate analysis were conducted for rural environments; however, as noted previously, place of initial injury was but one source of heterogeneity.

The reviewed studies were observational in nature and as such, are subject to bias through unmeasured or unadjusted confounding factors.[140] In the study by Nathens et al. transfer patients were less severely injured than those directly admitted and had a lower rate of significant co-morbidity than patients directly admitted to the trauma centre.[126] These patients may therefore represent a healthier cohort of patients with a lower risk of mortality as compared to direct admissions. Further in the majority of studies reporting significant age differences between transfer and direct admissions, directly admitted patients were significantly older than transfer patients. Such differences, or others not considered, may confound the observed mortality differences between patients directly admitted and those transferred to a higher level facility for definitive care. As evidenced by differences in the type of referring centres and prolonged stays at the referring hospital in some studies, there may be variation in the level of trauma care organization across studies.[75, 110, 112, 126] The extent to which trauma care is organized within the individual study settings, with respect to transport systems and provider transport practices for example, may have important influences on the examined outcomes and their comparability across studies. A related issue is the time period of these studies. Just under one-third of the included articles were published prior to 2005, with 11 published between 1986 and 1999. Improvements in the organization of trauma services and management of trauma patients, including for example triage guidelines and transport systems, may reduce the current relevance of the results of these earlier studies. Importantly, eight of these earlier studies (pre-2000) favored the direct group. One hypothesis that may explain this observation is that transfer patients in the earlier studies might have had excessively longer times to definitive care because of less developed transport systems and processes. Such delay to definitive care may result in poorer outcomes for these patients. Unfortunately, the data in the included studies does not allow evaluation of this as a possible explanation for this observation.

The potential for selection bias (survivor bias) introduced by missing patients because of early mortality (severely injured patients first seen at local hospitals that would have been transferred to a higher level of care centre but do not survive to transfer) was addressed by only a few of the included studies. Using a population database Haas and colleagues demonstrated that while there were no mortality differences in their adjusted conventional analysis (including only patients successfully transferred to a higher level of care), inclusion of “potential transfers” who died at the sending hospitals resulted in a significantly higher adjusted mortality for transferred patients. This finding was not changed when the authors restricted the “potential transfers” to patients surviving at least an hour in the emergency department of the non-trauma centres.[18] Similarly, while significantly higher unadjusted mortality for directly admitted patients was obtained in conventional analysis, Fatovich and colleagues found no significant differences in mortality between transfer and direct admissions after including deaths occurring at the sending hospital.[137] In the absence of data on mortality outcomes for patients remaining at the sending hospitals, Cheddie and colleagues excluded earlier deaths from their analysis to mitigate the potential impact of survivor bias. These authors found that the mortality rate was higher in transfer patients after excluding early deaths (deaths before 12 hours), compared to no significant difference between the groups when all deaths were included in the analysis.[138] In only one of the reviewed studies was outcome of major trauma patients (ISS > 15) remaining at the sending hospital compared with those transferred.[121] These authors found no significant difference in 30-day mortality between patients admitted to a non-trauma centre and those transferred or admitted directly to a trauma centre after controlling for potential sources of confounding.

Other limitations of this review should be noted. First, it is possible that, while comprehensive, the search strategy did not identify all relevant studies. However, to minimize this risk the referred reference lists and contacts with experts in the field was used to identify further published or *in press* studies. It is unlikely that the inclusion of any study not identified by the search strategy would significantly alter the conclusion. Second, the criteria used for extracting data about the quality of included study are subjective. They are, however, based on the MOOSE recommendations and were applied independently by two reviewers with consistent results. Third, unpublished studies were not included in this systematic review. While the relevance of considering unpublished studies for inclusion is recognized,[140] based on the assessment of the methodological quality of the available studies, it is unlikely that a more methodologically rigorous unpublished study exists, that if included would change the conclusions.

Regional systems of trauma care have been developed to ensure that patients are managed in the most appropriate settings to meet their needs. Some severely injured patients are initially transported to local hospitals for stabilization prior to transfer to a centre resourced to meet their required level of care. These results emphasize the need for more rigorous evaluations aimed at understanding the outcomes for transferred trauma patients. Particularly, attention should be focused on examining this issue for both rural and urban environments. Further, most of these analyses take the perspective of the trauma centre, thus those patients who do not survive to be transferred are excluded from the analyses. Future studies should include potential transfer patients by using data that prospectively follows patients from scene of injury to definitive care. This is important not only for identifying opportunities for improving patient outcomes but will also be important for informing policy decisions aimed at optimizing resource use and access to trauma services for patients.

Establishment and maintenance of trauma centres and trauma systems require significant investments. As demonstrated in two of the studies reviewed, transfer patients may have significantly higher in-hospital charges than patients directly admitted to a trauma centre. While the observed differences may be due to unmeasured and/or uncontrolled for differences in the two cohorts, it is also possible that transfer patients have more complications as a result of delays in receiving definitive care. Available evidence from other critically ill patient populations have documented inadequate stabilization of patients during transport, with increased complications including respiratory insufficiency and the need for a greater number of interventions directly after admission to the referral hospitals in unstable transfer patients.[141] Regardless of the explanation, there may be important financial implications to trauma centres that receive these patients. While differences in health system organization and funding may limit the generalizability of these findings to setting outside the United States, if this evidence is confirmed in other studies policies for funding or reimbursing trauma centres must acknowledge costs implications of referral patients. The findings also have implications for efforts to benchmark and compare trauma outcomes across hospitals. Importantly, methods comparing outcomes across hospitals that do not account for transfer status may lead to erroneous conclusions about the quality of care in these centres. This supports the need for the inclusion of admission source and patient severity of illness at the referring centre in order to adjust for differences in patient case mix and illness. While separate analyses (by directness of admission to trauma centre) may prove instructive, consideration must be given to the inherent problem of selection bias created by transfer patients. The recent study by Moore and colleagues that incorporates transfer status in their risk-adjusted method for comparing mortality across centres provide evidence of this approach.[142]

4.6 Conclusion

In light of the limitations of the current evidence it is premature to make definitive conclusions as to whether initial stabilization in lower level hospitals prior to transfer to a centre for definitive care affects mortality, length of stay or costs. Further studies evaluating this question using a variety of methodological approaches and conducted in both urban and rural settings are warranted. In the absence of interventional studies, a methodologically rigorous observational study that prospectively follows patients from scene of injury to admission to the trauma centre and collects data to control for potential confounding (e.g. pre-hospital time, pre-hospital interventions, injury severity) is needed. Such a study should include a heterogeneous population to permit *a priori* subgroup analysis to examine whether outcomes vary across different trauma patient populations and or settings (rural and urban). This information is important to inform decisions as to whether, and which, patients should appropriately be triaged directly to a higher-level trauma centre.

Tables and Figures Chapter 4

Figure 4:1 Flowchart of the study selection process

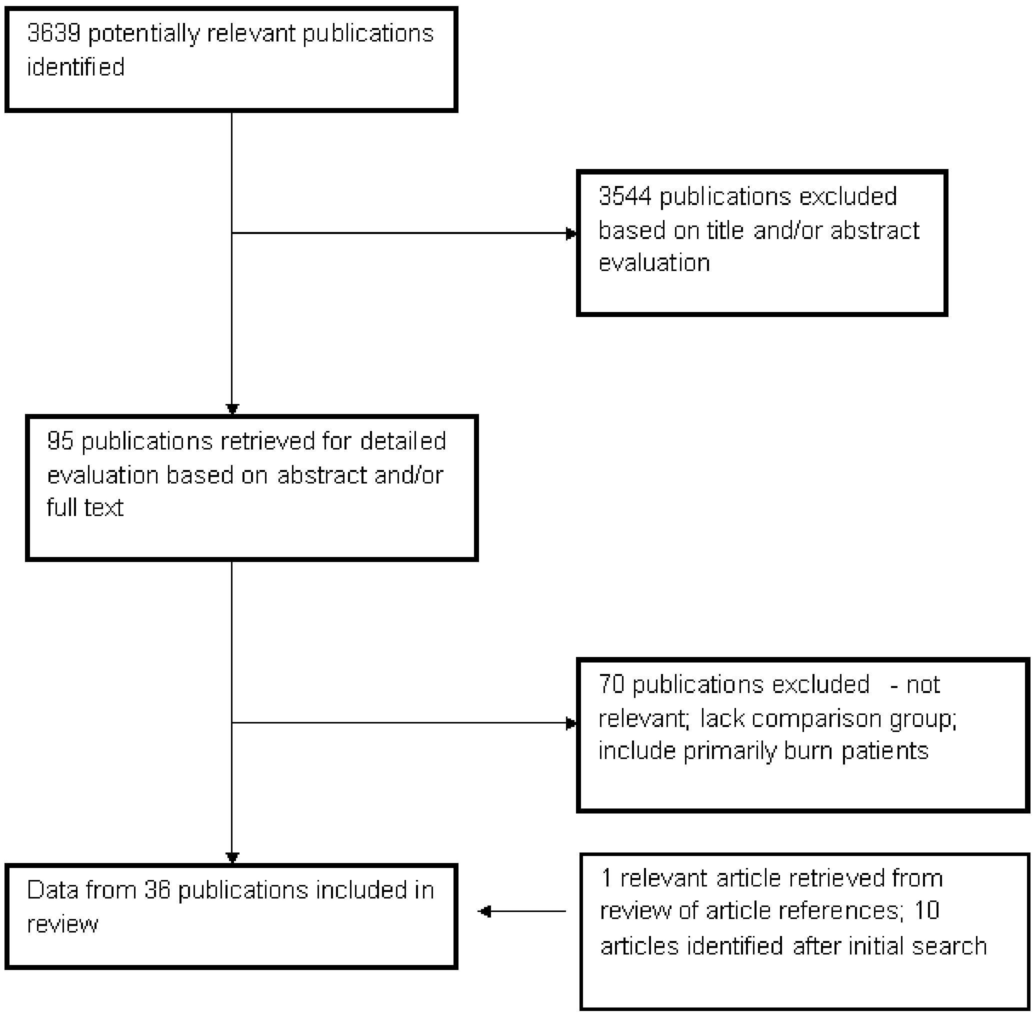


Table 4.1 Description of included studies

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Fatovich et al (2011)	RC	All major trauma (ISS > 15)	ISS > 15	None identified	2005	1078	Non trauma centres	Trauma centres	Median ISS 24 (range 17 – 29)	Hospital mortality; time to trauma centre	Age, ISS, RTS, time, number of regions injured
Cheddie et al (2010)	RC	All trauma patients	All patients admitted to the Level 1 trauma centre	None identified	119	288	Not described	Level I trauma centre	Median ISS 22 (range 14 -24)	Hospital and ICU mortality; 12hr mortality; time to ICU	None
Haas et al (2010)	RC	All severe trauma injuries; adults (age ≥ 18 years)	Presenting to any ED (trauma centre or non-trauma centre) with severe injury	Patients with non mechanical mechanisms of injury, dead on arrival in ED and late effects of injury	7481	3, 469 (3917)*	Non trauma centres	Trauma centre	46% of direct patients had an ISS < 25 vs. 39% in transfer patients	30-day mortality	Age, gender, ISS, AIS, mechanism of injury, Charlson index
Nirula et al (2010)	PC	Adult (age ≥ 16); blunt trauma	Presenting to hospital within 6 hours of injury; AIS ≥ 2 in any body region and intact cervical spine cord	Patients with isolated severe head injuries or spinal cord injuries	787	318	Non trauma centres	Trauma centre	Mean ISS(SD) 31 (13) for direct and transfer patients	Time to trauma centre; in-hospital mortality	Age, ISS, APACHE II, time from injury to trauma centre,
Meisler et al (2010)	PC	All trauma patients	Trauma team activated	Drug overdose, burns, poisoning and drowning	676	203	Non trauma centres	Level I trauma centre	19.8% of patients with ISS > 15 in direct vs 57.1% in transfer	Time; 30 day mortality	NR
Hsiao et al (2010)	RC	Severe traumatic brain injury	GCS score of 3 – 8	VSA prior to hospital arrival; multiple traumas; penetrating brain injury; , 18 years; GCs > 8 after drugs	87	167	Not described	University affiliated general hospital	NA	Hospital mortality	Age; hypotension; hypertension; GCS; surgical intervention; hyperglycemia; hyperthermia

* includes actual and "potential" transfer patients

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Helling et al (2010)	RC	All trauma patients	Patients included in a trauma registry; all deaths at the trauma centre	Transferred > 24 hours to trauma centre; HLOS < 24 hours in trauma centre; ISS < 9	2388	529	Non trauma hospitals	Level I trauma centre	Mean ISS(SD) 18.7(11) direct vs 17 (8.5) transfer patients,	Functional status; time to trauma centre; mortality; HLOS; ICU LOS; complication	NR
Odetola et al. (2010)	PC	All pediatric (≤ 17 years) trauma injuries;	Admitted directly or transferred from another hospitals	None	1175	1017	Non pediatric trauma centre	Level I pediatric trauma centre	Mean ISS(SD) 8.9(6.8) direct vs 11.8 (8.2) transfer patients,	HLOS, ICU LOS, hospital costs, mortality	ISS, GCS, age, time from injury to trauma centre
Kejriwal and Civil	RC	Adults; moderate to severe TBI	Head AIS ≥ 3;	Chronic subdural haematoma; presentation to hospital > 24 hours after injury; missing time of injury or trauma centre arrival time	97	73	Local hospitals	Primary hospital providing care for patients with TBI		Time from injury to trauma centre; mortality; ICU LOS; HLOS	Entrapment (for time from injury to arrival at trauma centre)
Moen et al, 2008 (Norway)	RC	Head injury; median age (range) - 34 years (1-88)	NR/NS	admitted > 24 hrs after injury; unknown type of injury	83	63	Local hospital	University hospital	Mean (range): 29.7 (9 - 75)	6-month mortality	GCS, age, pupillary status
Rivara et al, 2008 (US)	RC	All trauma injuries; adults (age range 18 -84 years)	one injury of AIS ≥ 3; vital signs present for ≥ 30 mins on admission to receiving hospital	transfer patients were excluded if they were admitted to sending hospital	7570	2779	NR/NS	Trauma centre	75% of patients with NISS >15	1-year mortality	Age, gender, NISS, mechanism of injury, Charlson index
de Jongh et al, 2008 (Dutch)	RC	All trauma injuries; mean age (SD) - 47.3 years (26.8)	admitted directly or transferred from another hospitals or DOA or died in ER	missing data on ISS, GCS, outcome, type of injury, age and transfer; discharged before 30 days	382	69	NR/NS	Trauma centre	Median (range): 5 (4-9)	30-day mortality	ISS, GCS, age, severe neuro-trauma

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Spain et al, 2007 (US)	RC	All trauma injuries; adults; mean age(SD) - 32(1.5) and 38.9 (0.51) in transfer and direct patients, respectively	Transfers from another hospitals ED for higher level of care (EMTALA)	NR/NS	1899	256	Non trauma centres, Level I and Level II trauma centres	Trauma centre (Level I)	Mean (SD): 13.6(0.62), 13.7(0.26), transfer and direct patients respectively	LOS, mortality	No
Sethi et al, 2007 (Malaysia)	PC	All trauma injuries; >12 years	Admitted to hospital for ≥ 72hrs, admitted to ICU or died after arrival in hospital	NR/NS	3354	1980	NR/NS	Tertiary care hospital and district hospitals	NR/NS	HLOS, mortality	No
London et al, 2006 (US)	RC	All trauma injuries; > 15 years		Burns, poisoning, suffocation, adverse effects from drugs or medical care, drowning	5308	3357	Level II to IV trauma centres	Trauma centre (Level I)	Mean (SD): 12.4 (9.0), 11.7 (10.6), transfer and direct patients respectively	HLOS, hospital costs, mortality, complications	No
Hartl et al, 2006 (US)	PC	Brain injury; mean age(range) - 36 (0.1 - 93.7) years	admitted ≤ 24 hrs after injury; GCS < 9 for at least 6hrs post injury; mechanism of injury consistent with trauma	SAH secondary to stroke or aneurysm; died in ED; brain dead; transferred after > 24hrs of injury; nonparalyzed patients with GCS 3 -4	864	254	Non trauma centres	Trauma centres (Level I and Level II)	NR/NS	2-week mortality	Age, GCS
Harrington et a, 2005 (US)	RC	All trauma injuries; adults; age mean(SD) - 43 (1.2) and 44 (0.4) years, in transfer and direct patients, respectively)	NR/NS	NR/NS	3227	280	Non-trauma centres	Trauma centre (Level I)	Mean (SD): 17.5(0.8), 11.7(0.2), transfer and direct patients respectively	Mortality	Not Clear

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Lubin et al, 2005 (US)	RC	All trauma injuries	Transported by HEMS	NR/NS	658	345	Community hospitals ED	Trauma centres	Mean: 15.7, 15.4, transfer and direct patients respectively	HLOS, ICU LOS, Mortality	No
Larson et al, 2004 (US)	RC	Blunt or penetrating injuries; pediatric < 19 years;	Transported by air ambulance	Missing data on ISS; injuries that were from burns, hanging or drowning	379	842	NR/NS	Trauma centre (Pediatric Level I)	Mean (SD): 12.9(10.4), 14.1(13.1), transfer and direct patients respectively	HLOS, ICU LOS, Mortality	No
Sollid et al, 2003 (Norway)	RC	Head injury	Undergoing surgery for acute head injury	depressed/open skull fractures without intracranial mass lesions or diagnostic burr holes; surgery > 48hrs after injury; re-operations; unknown time of trauma	47	38	NR/NS	University hospital	NR/NS	Mortality	No
Nathens et al, 2003 (US)	RC	All trauma injuries; aged ≥ 16 years	LOS > 2 days; ICD-9 diagnostic codes 800-958 and 994; transferred within 24hrs of injury	late effects of trauma and isolated hip fractures; burns	4439	281	Level III/IV trauma centres	Trauma centre (Level I)	Mean (SD): 8.9(7.4), 11.7(12.9), transfer and direct patients respectively	HLOS, Hospital costs, mortality	Age, mechanism of injury, ISS, AIS, shock, payer status
Sethi et al, 2002 (Malaysia)	PC	All trauma injuries; > 12 years	LOS ≥ 72hrs, admitted to ICU or died after arrival in hospital	NR/NS	286	198	NR/NS	Tertiary care hospital and district hospitals	NR/NS	HLOS, mortality	No
Osterwalder et al, 2002 (Switzerland)	PC	Blunt poly-trauma; age median (range) - 31 (3-91) years	treatment in shockroom; AIS ≥ 2 in 2 or more defined body regions; admit to ICU or LOS > 3 days or death after admission	Missing data to calculate ASCOT	280	190	Regional hospitals (limited trauma care capacity)	Trauma centre	Mean 23.4, 24.1, transfer and direct patients respectively	30-day mortality	No

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Cummings et al, 2000 (Canada)	PC	All trauma injuries; adults; age median(range) 38 (25-53)	admitted ≤ 24 hrs of injury; died in ER of receiving centre	burns; died before arrival to receiving centre	53	52	Rural hospitals	Trauma centre	Median(range): 14 (1-75)	Costs, mortality	No
Rogers et al, 1999 (US)	RC	All trauma injuries; age mean(SD) - 35(23.5) and 44(28) years in transfer and direct patients, respectively	ICD-9 diagnostic codes 800-959.9	NR/NS	1608	1061	Local hospitals	Trauma centre (Level I)	Mean (SD): 11.1(8.5), 7.9(5.3), transfer and direct patients respectively	HLOS, ICU LOS, Mortality	Age, ISS, RTS (mortality only)
Falcone et al, 1998 (US)	RC	All trauma injuries; mean age 39.1 and 34.5 in transfer and direct patients, respectively	Transported by air ambulance		363	231	NR/NS	Trauma centre (Level I)	NR/NS	HLOS, mortality, complications	No
Young et al, 1998 (US)	RC	All trauma injuries; age > 18	ISS > 15; deaths in trauma centre ED	NR/NS	165	151	Local hospitals	Trauma centre (Level I)	Mean (SD): 23.1(7.2), 24.8(8.2), transfer and direct patients respectively	HLOS, ICU LOS, Mortality	No
Kam et al, 1998 (China)	RC	All trauma injuries	Patients managed by the hospital trauma team of the receiving hospital	NR/NS	60	34	ED of district hospitals	General hospital (between a Level II and Level I)	75% of patients with ISS >15	Mortality	No
Sampalis et al, 1997 (Canada)	RC	All trauma injuries; mean age 45 years	injured within city limits; transported by EMS; alive on arrival at the trauma centre; LOS > 3 days or admitted to the ICU or died as a result of injury	NR/NS	2756	1608	Secondary (level II trauma centre) and primary hospitals (ER coverage; limited surgical staff availability)	Trauma centres (Level I)	Mean (SD): 14.4(10.7), 14.1 (9.6), transfer and direct patients respectively	HLOS, ICU LOS, Mortality	ISS, age, type of injury

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Timberlake, 1996 (US)	RC	Blunt pancreatic trauma; age mean(range): 29 (3-52), and 35(13-69) years for transfer and direct patients, respectively	NR/NS	NR/NS	28	11	Non-trauma centres	Trauma centre (Level I)	Mean (SD): 27.2(11.3), 29.0 (9.3), transfer and direct patients respectively	HLOS, ICU LOS, Mortality	No
Johnson et al, 1996 (US)	PC	Head injured; age mean(SD) 6.8(5.1) years	NR/NS	patients DOA at trauma centre	841	479	NR/NS	Trauma centre (Level I Pediatric)	Mean (SD): 11.6 (10.4) and 10.2 (9.9), transfer and direct patients respectively	ICU LOS, Mortality	No
Obremskey et al, 1994 (US)	RC	Orthopedic; age > 12 years	musculoskeletal injury included in ISS	NR/NS	384	129	NR/NS	Trauma centre (Level I)	Mean (SD): 13.6(8.7) and 11.8(9.3), transfer and direct patients respectively	HLOS, ICU LOS, Mortality, Costs	Matching on age, ISS
Poon et al, 1991 (China)	PC	Traumatic extradural haematoma	supratentorial and posterior fossa lesions; intradual lesions requiring decompressive surgery	NR/NS	71	33	NR/NS	Teaching hospital	NR/NS	Mortality	No

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.1 (continued)

Study	Study Design	Patient Population	Inclusion Criteria	Exclusion Criteria	Direct (n)	Transfer (n)	Sending Hospitals	Receiving Hospitals	Illness Severity (ISS)	Outcomes	Adjusted Variables
Schwartz et al, 1989 (US)	PC	Blunt trauma; age mean(SE) - 20(3) and 22(2) years in transfer and direct patients, respectively	NR/NS	single fracture of an extremity; penetrating trauma; burns; transport mode other than air or ground ambulance; missing follow-up data; died in ED of trauma centre	673	204	NR/NS	Trauma centre	Mean (range) 13.7 (1-66)	HLOS, costs, mortality	
Stone et al, 1986 (US)	RC	Acute subdural hematoma; age mean (range) 42 (3-83)	NR/NS	Hematomas complicating open injury (e.g. depressed skull fractures or gunshot wounds)	82	46	Community hospitals	Trauma centre	NR/NS	Mortality	No

GCS – Glasgow Coma Scale; AIS- Abbreviated Injury Scale; ISS - Injury Severity Score; NISS – New Injury Severity Score; PC - Prospective Cohort; RC – Retrospective Cohort; ED – Emergency Department; NR/NS – Not Reported/Not Specified; HLOS – Hospital Length of Stay; ICU LOS – Intensive Care Unit Length of Stay; SAH - Subarachnoid Hemorrhage Secondary; RTS – Revised Trauma Score; APACHE- Acute Physiology and Chronic Health Evaluation; VSA – Vital Signs Absence BP – Systolic Blood Pressure

Table 4.2 Mortality associations

Study	Mortality	Direct n (%)	Transfer n (%)	Point Estimate (95% CI) Unadjusted*	Point Estimate (95% CI) Adjusted*	Favors
Fatovich et al (2011)	Hospital	395 (19.7)	140 (13)	NA	NA	Transfer
Fatovich et al (2011)	Hospital	395 (19.7)	214 (18.6)	NA	0.99 (0.58, 1.68)	Transfer
Cheddie et al (2010)	Hospital	37 (31.1)	70 (24.3)	NA	NA	Transfer
Haas et al (2010)	30- day	1192 (16)	425 (12)	OR: 0.74 (0.65, 0.83)	OR: 0.91(0.80, 1.04)	Transfer
Haas et al (2010)[*]	30-day	1192 (16)	861 (22)	OR: 1.51 (1.37, 1.67)	OR: 1.24 (1.10, 1.40)	Direct
Nirula et al (2010)	Hospital	94 (12)	38 (12)	NA	OR: 2.8 (1.3, 5.7)	Direct
Meisler et al (2010)	30-day	45 (7)	12 (6.2)	NA	NA	
Garwe et al (2010)	30-day***(in hospital)	125 (8.9)	63 (10.5)	RR: 1.17 (0.87, 1.56)	HR: 2.86 (0.67, 12.2)	
Hsiao et al (2010)	Hospital	55 (63.2)	86 (51.5)	NA	OR: 0.51 (0.24, 1.09)	Transfer
Helling et al (2010)	Hospital	205 (9)	33 (6)	NA	NA	Transfer
Helling et al (2010)	Hospital[†]	189 (15.6)	29 (10.9)	NA	NA	Transfer
Odetola et al (2010)	Hospital	5 (0.4)	26 (2.6)	IRR: 7.16 (2.49 – 20.58)	IRR 3.01 (1.01 - 8.98)	Direct
Kejriwal and Civil (2009)	Hospital	17 (18)	7 (10)	NA	Na	Transfer
Moen et al.(2008)	6-month	23 (31)	9 (15)	NA	OR: 0.43 (0.16, 1.14)	Transfer
Rivara et al. (2008)	1-year**	765 (10.1)	308 (11.1)	OR: 1.22 (0.93, 1.60)	HR: 0.90 (0.70, 1.15)	Direct
de Jongh et al. (2008)	30-day	110 (28.8)	15 (21.7)	OR: 1.5 (0.8, 2.7)	OR: 1.9 (0.9 , 4.1)	Transfer
Spain et al. (2007)	Hospital	78 (4.1)	30 (11.8) [a]	NA	NA	Direct
Sethi et al. (2007)	Hospital	304 (9.1)	138 (7.0) [a]	NA	NA	Transfer
London et al. (2006)	Hospital	361 (6.8)	161 (4.8) [a]	NA	NA	Transfer
Hartl et al. (2006)	2-week	179 (20.7)	65(25.6)[a]	NA	OR: 1.48 (1.03, 2.12)	Direct
Harrington et al. (2005)	Hospital	237 (7)	28 (10)	NA	NA	Direct
Lubin et al. (2005)	Hospital	50 (7.6)	22 (6.4)	NA	NA	Transfer
Larson et al. (2004)	Hospital	33 (8.7)	46 (5.5)[a]	NA	NA	Transfer
Sollid et al. (2003)	Hospital	16 (34)	10 (26)	NA	NA	Transfer
Nathens et al. (2003)	Hospital	439 (10)	14 (5)[a]	RR: 0.5(0.30, 0.86)	RR: 1.05 (0.61, 1.80)	Transfer
Sethi et al. (2002)	Hospital	20 (7.2)	24 (12.4)[a]	NA	NA	Direct
Osterwalder et al. (2002)	30-day	33 (11.8)	27 (14.2)	NA	NA	Direct
Cummings et al. (2000)	Hospital	7 (13.2)	4 (7.7)	NA	NA	Transfer
Rogers et al. (1999)	Hospital	53 (3.2)	40 (3.7)	NA	OR: 0.84 (0.46, 1.50)	Direct
Falcone et al. (1998)	Hospital	43 (11.8)	25 (10.8)	NA	NA	Transfer
Young et al. (1998)	Hospital	38 (23)	28 (18.5)	NA	NA	Transfer
Kam et al. (1998)	Hospital	21 (35)	15 (44)	NA	NA	Direct
Sampalis et al. (1997)	Hospital	131 (4.8)	143 (8.9)[a]	OR: 1.96 (1.53, 2.50)	OR: 1.57 (1.17, 2.08)	Direct
Timberlake (1996)	Hospital	2 (7)	2 (18)	NA	NA	Direct
Johnson et al. (1996)	Hospital	16 (1.8)	22 (4.7)[a]	NA	NA	Direct
Obremskey et al. (1994)	Hospital	17 (4.4)	6 (4.3)	NA	NA	Matched group: 3% vs 3%
Schwartz et al. (1989)	Hospital	33 (4.9)	20(9.8)	NA	NA	Direct
Poon et al. (1991)	Hospital	3 (4)	8 (24)[a]	NA	NA	Direct
Stone et al. (1986)	Hospital	41 (50)	35 (76)[a]	NA	NA	Direct

a – $p < 0.05$; * reference group is direct admission; ** also reported hospital mortality; ***also reported 24 hour and 2 week mortality; # - undertriage group defined as patients transferred to a trauma centre and patients dying in ER of non- trauma centre; [†]mortality for patients with ISS > 15
OR – Odds Ratio; RR – Relative Risk; HR – Hazard Ratio; IRR – Incidence Rate Ratio; NA - Not Available

Table 4.3 Length of stay outcome

Study	LOS	Direct	Transfer	Adjusted Point Estimate (95% CI)
Fatovich et al (2011)	HLOS – median (IQR) days	9 (3 -19)	10 (5-20) [a]	
Garwe et al. (2010)	HLOS – median (range) days	6(9)	7 (9)	NA
Garwe et al. (2010)	ICU LOS – median (range) days	4(8)	4 (8)	NA
Helling et al (2010)	HLOS - mean (SD) , days	6.4 (8.5)	5.5 (6.0)	NA
Helling et al (2010)	ICU LOS (median hours)	5.3 (8.5)	3.9 (4.7)	NA
Odetola et al. (2010)	HLOS - mean (SD) , days	6.6 (9.1)	9.3 (10.6) [a]	NA
Odetola et al. (2010)	ICU LOS (median hours)	23	22	NA
Kejriwal and Civil (2009)	HLOS – median days	7	7	NA
Kejriwal and Civil (2009)	ICU LOS – median days	1	3	NA
Spain et al.(2007)	HLOS - mean (SD)	7.4 (0.25)	7.0 (0.70)	NA
Sethi et al.(2007)	HLOS - median (range); mean	7 (5-13); 12.1	6 (3-13); 11.7	NA
London et al. (2006)	HLOS (median)	3	5[a]	
London et al. (2006)	ICU LOS (median)	Value not reported	Value not reported	
Lubin et al.(2005)	HLOS (mean)	6	6.17	
Lubin et al.(2005)	ICU LOS (mean)	2.2	1.9	
Larson et al.(2004)	HLOS (mean, 95%CI)	7.7 (6.3, 9.2)	7.4 (6.5, 8.3)	
Larson et al.(2004)	ICU LOS (mean hours, 95%CI)	54.1 (41.3, 66.8)	47.0(37.7, 56.3)	
Nathens et al.(2003)	HLOS (median)	6	7	1.02 (0.97, 1.07)**
Sethi et al.(2002)	HLOS mean (SD)	10.8 (9.1)	13.0 (11.3)[a]	
Rogers et al.(1999)	ICU LOS (mean, SD)	3.8 (6.7)	5.9 (10.3)[a]	
Rogers et al.(1999)	HLOS (mean, SD)	6.0 (8.7)	9.0 (11.8)[a]	
Falcone et al.(1998)	HLOS***	6.9	7.3	NA
Young et al. (1998)	ICU LOS (mean, SD)	10.1 (15.8)	12 (5.4)	
Young et al. (1998)	HLOS (mean, SD)	15.4 (21.3)	19.1 (20.6)	
Sampalis et al.(1997)	ICU LOS (mean, SD)	4.8 (8.1)	6.5 (9.3)[a]	†0.95(0.09) vs 2.02(0.12)[a]
Sampalis et al.(1997)	HLOS (mean, SD)	13.6 (23.9)	15.5 (22.1)[a]	†13.2(0.44) vs 16.0(0.59)[a]
Timberlake (1996)	ICU LOS	15.7	10.8	
Timberlake (1996)	HLOS	25.9	20	
Johnson et al. (1996)	ICU LOS (mean, SD)	3.71 (7.85)	4.48 (9.44) [a]	NA
Obremskey et al.(1994)	ICU LOS (mean, SD)	0.06 (0.52)	0.92 (4.3)[a]	Matched group: 0.12 vs 1.04 days (p=0.06)
Obremskey et al.(1994)	HLOS (mean, SD)	11.8(9.3)	14.0(13.5)[a]	Matched group: 10.6 vs 14 .4 days (p=0.02)
Schwartz et al. 1989	HLOS (mean)	12	18	NR/NS

a – $p < 0.05$; * reference group is direct admission; †adjusted mean; ** relative increase; ***mean or median not specified.
NA – Not Available; NR – Not Reported; NS – Not Significant

Figure 4:2 Impact of transfer status on hospital mortality

Study or Subgroup	Transfer Events	Transfer Total	Direct Events	Direct Total	Weight	Odds Ratio M-H, Random, 95% CI
Cheddie	70	288	37	119	3.3%	0.71 [0.44, 1.14]
Cummings	4	52	7	53	1.2%	0.55 [0.15, 2.00]
de Jongh	15	69	110	382	2.8%	0.69 [0.37, 1.27]
Falcone	25	231	43	363	3.1%	0.90 [0.54, 1.52]
Fatovich	140	1078	395	2005	4.2%	0.61 [0.49, 0.75]
Garwe	63	600	125	1398	3.9%	1.19 [0.87, 1.64]
Haas	425	3469	1192	7481	4.4%	0.74 [0.65, 0.83]
Harrington	28	280	237	3227	3.5%	1.40 [0.93, 2.12]
Helling	33	529	205	2388	3.6%	0.71 [0.48, 1.04]
Hsiao	86	167	55	87	3.1%	0.62 [0.36, 1.05]
Johnson	22	479	16	841	2.6%	2.48 [1.29, 4.77]
Karn	15	34	21	60	2.0%	1.47 [0.62, 3.46]
Kejriwal	7	73	17	97	1.8%	0.50 [0.20, 1.28]
Larson	46	842	33	379	3.3%	0.61 [0.38, 0.96]
London	161	3357	361	5308	4.3%	0.69 [0.57, 0.84]
Lubin	22	345	50	658	3.1%	0.83 [0.49, 1.39]
Meisler	12	203	45	676	2.6%	0.88 [0.46, 1.70]
Nathens	14	281	439	4439	3.0%	0.48 [0.28, 0.83]
Nirula	38	318	94	787	3.6%	1.00 [0.67, 1.49]
Obremskey	6	129	17	384	1.8%	1.05 [0.41, 2.73]
Odetola	26	1017	5	1175	1.8%	6.14 [2.35, 16.05]
Osterwalder	27	190	33	280	3.0%	1.24 [0.72, 2.14]
Poon	8	33	3	71	1.1%	7.25 [1.78, 29.53]
Rivara	236	2779	620	7570	4.3%	1.05 [0.90, 1.23]
Rogers	40	1061	53	1608	3.5%	1.15 [0.76, 1.75]
Sampalis	143	1608	131	2756	4.1%	1.96 [1.53, 2.50]
Schwartz	20	204	33	673	2.9%	2.11 [1.18, 3.76]
Sethi	138	1980	304	3354	4.2%	0.75 [0.61, 0.93]
Sethi (2002)	24	198	20	286	2.7%	1.83 [0.98, 3.42]
Sollid	10	38	16	47	1.8%	0.69 [0.27, 1.77]
Spain	30	256	78	1899	3.4%	3.10 [1.99, 4.83]
Stone	35	46	41	82	2.2%	3.18 [1.42, 7.11]
Timberlake	2	11	2	28	0.5%	2.89 [0.35, 23.63]
Young	28	151	38	165	3.0%	0.76 [0.44, 1.32]
Total (95% CI)		**22396**		**51126**	**100.0%**	**1.06 [0.90, 1.25]**
Total events	2001		4876			

Heterogeneity: Tau² = 0.16; Chi² = 191.50, df = 33 (P < 0.00001); I² = 83%

Test for overall effect: Z = 0.67 (P = 0.50)

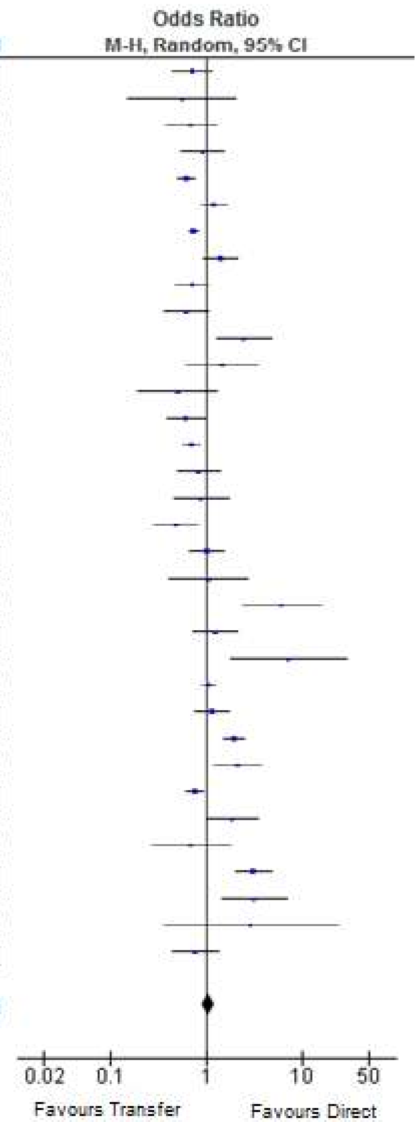
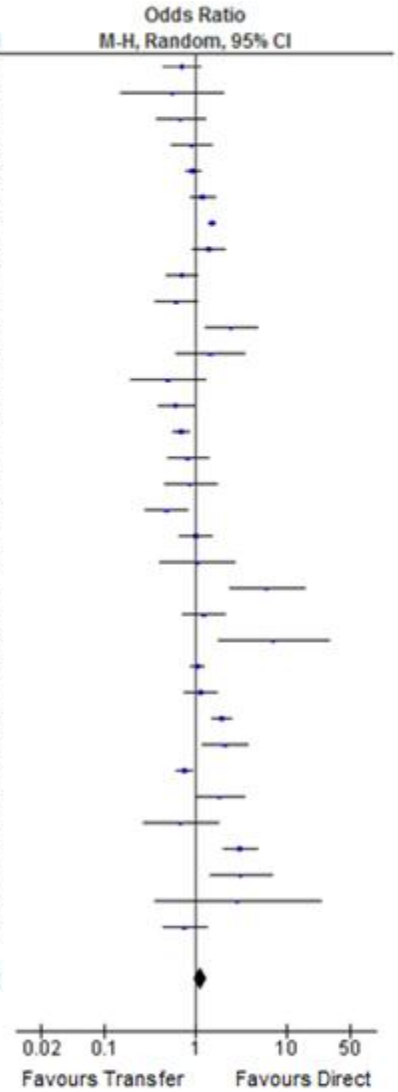


Figure 4:3 Impact of transfer status on hospital mortality (inclusion of potential transfers)*

Study or Subgroup	Transfer Events	Transfer Total	Direct Events	Direct Total	Weight	Odds Ratio M-H, Random, 95% CI
Cheddie	70	288	37	119	3.3%	0.71 [0.44, 1.14]
Cummings	4	52	7	53	1.2%	0.55 [0.15, 2.00]
de Jongh	15	69	110	382	2.8%	0.69 [0.37, 1.27]
Falcone	25	231	43	363	3.1%	0.90 [0.54, 1.52]
Fatovich	214	1152	395	2005	4.3%	0.93 [0.77, 1.12]
Garwe	63	600	125	1398	3.9%	1.19 [0.87, 1.64]
Haas	873	3917	1192	7481	4.5%	1.51 [1.37, 1.67]
Harrington	28	280	237	3227	3.5%	1.40 [0.93, 2.12]
Helling	33	529	205	2388	3.6%	0.71 [0.48, 1.04]
Hsiao	86	167	55	87	3.1%	0.62 [0.36, 1.05]
Johnson	22	479	16	841	2.6%	2.48 [1.29, 4.77]
Kam	15	34	21	60	2.0%	1.47 [0.62, 3.46]
Kejriwal	7	73	17	97	1.8%	0.50 [0.20, 1.28]
Larson	46	842	33	379	3.3%	0.61 [0.38, 0.96]
London	161	3357	361	5308	4.3%	0.69 [0.57, 0.84]
Lubin	22	345	50	658	3.1%	0.83 [0.49, 1.39]
Meisler	12	203	45	676	2.6%	0.88 [0.46, 1.70]
Nathens	14	281	439	4439	3.0%	0.48 [0.28, 0.83]
Nirula	38	318	94	787	3.6%	1.00 [0.67, 1.49]
Obremskey	6	129	17	384	1.8%	1.05 [0.41, 2.73]
Odetola	26	1017	5	1175	1.8%	6.14 [2.35, 16.05]
Osterwalder	27	190	33	280	3.0%	1.24 [0.72, 2.14]
Poon	8	33	3	71	1.0%	7.25 [1.78, 29.53]
Rivara	238	2779	620	7570	4.4%	1.05 [0.90, 1.23]
Rogers	40	1061	53	1608	3.5%	1.15 [0.76, 1.75]
Sampalis	143	1608	131	2756	4.1%	1.96 [1.53, 2.50]
Schwartz	20	204	33	673	2.9%	2.11 [1.18, 3.76]
Sethi	138	1980	304	3354	4.2%	0.75 [0.61, 0.93]
Sethi (2002)	24	198	20	286	2.7%	1.83 [0.98, 3.42]
Sollid	10	38	16	47	1.8%	0.69 [0.27, 1.77]
Spain	30	256	78	1899	3.4%	3.10 [1.99, 4.83]
Stone	35	46	41	82	2.2%	3.18 [1.42, 7.11]
Timberlake	2	11	2	28	0.5%	2.89 [0.35, 23.63]
Young	28	151	38	165	3.0%	0.76 [0.44, 1.32]
Total (95% CI)		**22918**		**51126**	**100.0%**	**1.11 [0.94, 1.31]**
Total events	2523		4876			

Heterogeneity: Tau² = 0.15; Chi² = 202.19, df = 33 (P < 0.00001); I² = 84%
Test for overall effect: Z = 1.26 (P = 0.21)

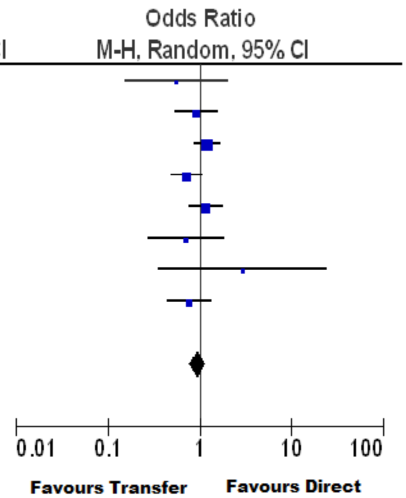


*Studies by Haas and colleagues and Fatovich and colleagues include patients dying in non-trauma centres in the transfer group.

Figure 4:4 Pooled estimate of transfer on hospital mortality for rural patients

Study or Subgroup	Transfer Events	Transfer Total	Direct Events	Direct Total	Weight	Odds Ratio M-H, Random, 95% CI
Cummings	4	52	7	53	2.3%	0.55 [0.15, 2.00]
Falcone	25	231	43	363	12.6%	0.90 [0.54, 1.52]
Garwe	63	600	125	1398	28.1%	1.19 [0.87, 1.64]
Helling	33	529	205	2388	21.6%	0.71 [0.48, 1.04]
Rogers	40	1061	53	1608	18.5%	1.15 [0.76, 1.75]
Sollid	10	38	16	47	4.3%	0.69 [0.27, 1.77]
Timberlake	2	11	2	28	0.9%	2.89 [0.35, 23.63]
Young	28	151	38	165	11.7%	0.76 [0.44, 1.32]
Total (95% CI)		2673		6050	100.0%	0.94 [0.77, 1.14]
Total events	205		489			

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 7.95$, df = 7 (P = 0.34); $I^2 = 12\%$
Test for overall effect: Z = 0.63 (P = 0.53)



Chapter 5 : Methods for National Population-based Study

5.1 Study Approach

5.1.1 Overview and Study Design

This chapter details the methods used in the population-based retrospective cohort studies described in Chapter 6 through Chapter 9. The primary objectives of these studies were to: (1) describe temporal trends and provincial variations in major trauma hospitalization and outcomes; (2) describe trends in access to trauma centre care for severely injured patients; and (3) identify factors associated with access to trauma centre care.

5.1.2 Study Setting and Trauma System Organization

The population for these studies included residents of all provinces and Territories within Canada, excluding the province of Quebec. Data from Quebec was not included given data access restrictions imposed by the province.

Canadians are eligible for universal health coverage within Canada's single-payer publicly funded health care system. However, the provision of health services falls under provincial jurisdiction and how these services are organized is dependent on each province. To that end, there are no national standards for organizing trauma services, including for example standards for pre-hospital triage or inter-hospital transfer criteria. Moreover, the support for trauma care organization varies across the provinces,[15, 143] resulting in marked differences in the extent to which trauma system components have been adopted across the provinces.[17] For example, Nova Scotia has been described as having an *“extremely organized and evidence based trauma system”* with an integrated transport system to facilitate timely management of trauma patients.[17] In contrast, the trauma patient transport systems in Newfoundland and New Brunswick has been characterized as lacking uniformity and central dispatch capability.[17] The implication is that varying availability and organization of trauma services may have important influences on trauma care for injured Canadians, despite idealized universal access to care.

5.2 Data Sources

The primary source of data for this study is the National Trauma Registry (NTR). The NTR is a national database, maintained by the Canadian Institute for Health Information (CIHI).[29] It includes three datasets: (1) *the minimum data set* (MDS) is an administrative database that contains demographic, diagnostic (International Classification of Diseases and Related Health Problems, 10th revision, [ICD-10]), and procedural data on all admissions to acute care hospitals in Canada that are due to injuries.[144] Hospitalization data for the NTR-MDS are obtained from the Hospital Morbidity Database which is derived from the Discharge Abstract Database (DAD) for all provinces except Quebec. For this province, data are submitted to CIHI by the provincial Ministry of Health. Selection of trauma cases is based on specific external cause of injury codes within the ICD-9th revision (ICD-9) and the ICD-10. To be included in the NTR-MDS, records must include at least one of the E-codes meeting the NTR definition for trauma and be classified as an acute care hospitalization;[144] (2) the *comprehensive data set*, which contains demographic, pre-hospital care, Abbreviated Injury Scale (AIS) codes for each injury, patient outcomes and 6-month follow-up for patients hospitalized in trauma centres in Canada;[30] and (3) the *death data set* which is a joint initiative of all provincial/territorial Coroners and Medical Examiners, Health Canada, Statistics Canada, and CIHI who collect information on all deaths due to injury in Canada, whether or not the patient was hospitalized.[29] Currently, the death dataset is not yet available for research purposes from CIHI. The NTR and the databases from which it is derived have been used extensively in Canadian health administrative data research,[145, 146] and in reports on the Canadian heath system.[30, 31, 144] In addition, CIHI conducts ongoing comprehensive data quality assessment of the databases.[147, 148]

For the purposes of this study, we elected to use the NTR-minimum dataset (NTR-MDS) since it represents the most comprehensive trauma database, in terms of patient capture, in Canada. It is, however, limited in the extent to which injury severity is captured. The AIS is a system of scoring injuries to six major body regions on a scale of 1 (minor injury) to 6 (maximal injury).[24, 25] It is used to derive the Injury Severity Score (ISS), which provides an estimate of global injury severity.[25] Within the NTR, assignment of AIS scores is only performed in trauma centres and thus is only available in the NTR comprehensive dataset. The comprehensive dataset does not, however, include all trauma patients in Canada but only those with an ISS $\geq$12 admitted to trauma centres. Patients with major trauma managed in non-trauma centres can only be identified through the NTR-MDS. To facilitate classification of injury severity, a validated ICD-10 to AIS crosswalk[149] was used to assign an ISS score to each patient in the NTR-MDS. The ICD-10/AIS crosswalk is a mapping system that converts injury related ICD-10 codes into AIS scores. The crosswalk maps each ICD-10 diagnosis code (in the S00 to T79.0 range) to specific AIS body regions and severity. This mapping allows for the derivation of injury severity by body region using a standardized metric.[149]

The AIS scores generated were used to derive the ISS for all patients in the database. The AIS and its resultant ISS remains the most widely used severity scoring system for trauma. Further, increasing AIS and ISS scores are associated with an increasing probability of death following injury.

In addition to the NTR-MDS we also used demographic data available from Statistics Canada's Canadian Socio Economic Information Management System (CANSIM).[150] In the absence of national census data for each year of our study (within Canada a national census is completed every 5 years), we elected to use intercensal population estimates for each of the provinces for each year of the study. These are estimates of the population for reference dates between two censuses and are derived by Statistics Canada using population counts from two successive censuses adjusted for net census undercoverage and postcensal estimates.[151]

As well, to categorize hospitals as a trauma centre (Level I and Level II) or non-trauma centre, data from a national survey conducted in 2010 was used.[17] Based on the survey, facilities within the NTR-MDS were categorized as Level I or Level II or left blank to indicate a non-trauma centre (Appendix D). Categorization (Level I or Level II trauma centre) derived from the survey was applied to all 8 years of the study. It is recognized that there is the potential for a centre to change status. However, given the short timeframe it is unlike that a hospital identified as a trauma centre did not have such a role in the trauma system. Moreover, this would result in more conservative estimates of undertriage.

5.3 Imputation of Illness Severity Score for the 2009 Data

In 2008 ICD-10 diagnostic codes were revised by the World Health Organization (WHO), including changes to the injury specific codes (in the S range). The Canadian Institute of Health Information adopted these changes for the NTR beginning April 1, 2009, and as a result a number of injury codes were disabled and replaced with more succinct codes (Appendix E)[152]. As a consequence of these changes, the ICD-10 to AIS crosswalk, used in this project to generate injury severity score, was unable to map an AIS value to these new collapsed codes. Given that removing the data for 2009 would result in the loss of one data point in the trend analyses, we elected to impute the AIS values (and resultant ISS) for the new codes using single data imputation as described below.

Twenty-one new codes were introduced with the changes to ICD-10 in fiscal 2009. On review of these codes with clinical expertise, it was determined that 8 of these new codes represented actual new coding while the remaining 13 codes could be attributed to collapsing codes already existing in the ICD-10 lexicon. In the former case, the new codes did not appear in the crosswalk and therefore had no impact on the generation of an ISS for patients. As such, a bias was not introduced by their presence in the 2009 data. All disabled codes could be clinically linked to the other 13 codes, creating 13 categories. For these, the changes ranged from a low of 3 codes being collapsed into one code, to a high of 14 codes being collapsed into one code.

As part of the process for imputing an AIS value for these 13 codes, it was theorized that, clinically, the AIS value would be influenced by several factors, including patient age, gender and mechanism of injury. In this regard, a single AIS value for each of the new code would be less robust than assigning values based on stratification by variables associated with injury severity. A probability distribution was, therefore, generated for the disabled codes using data prior to 2009 for strata defined by age, gender and mechanism of injury. Based on review of the distribution of AIS scores within each strata it was determined that the median AIS value for each stratum would provide similar results as approximating the AIS score using imputed values based on probabilities. To that end, for each of the disabled codes a median value was generated for 36 stratum defined by gender (male, female), age (0-16 years, 17-44 years; 45 – 64 years, 65-74 years, 75-84 years and ≥ 85 years) and mechanism of injury (fall, motor vehicle collision, and other). The 36 median AIS values generated in this manner were mapped to each specific new code for the 2009 data, by groups defined by age, gender and mechanism of injury (as above). The AIS values so produced were used to derive the ISS values for patients in the 2009 cohort.

The extent to which the ISS values generated via the imputed AIS gave similar results to that obtained from the crosswalk was examined for data from fiscal year 2002 - 2008. To examine the ability of the imputed AIS (and derived ISS) to identify patients meeting the criteria for major injury (ISS > 15) the number of patients that were identified as having an ISS > 15 using scores generated by the crosswalk and the imputed values were compared. The extent to which the imputed score over or underestimated the number of patients that would be eligible for the study based on an ISS > 15 was also assessed by examining the number of records that were assigned differently by each method of determining the AIS (original crosswalk versus imputed values). In addition, the difference between the ISS derived using the imputed AIS and that obtained using the original crosswalk were compared. Specifically, we compared the absolute difference in scores as well as generated scatter plots of the “imputed” versus crosswalk ISS scores to visual examine the distribution. Finally, using the proportion of patients that were undertriage as the outcome, the robustness of our findings to the change in how the ISS was derived for the 2009 fiscal year was examined by comparing the proportion of patients identified as being undertriaged using both methods. The findings, detailed in Appendices F and G, confirmed that it was reasonable to include the data from 2009 using imputed values. Specifically, over 99% of the records that included one or more of the disabled score had the same ISS by both methods (Appendix F). Moreover, in examining whether or not an individual patient was classified as “eligible” for the study (ISS > 15) only 887 (0.15%) were classified differently by the two methods. Similarly, both methods of generating ISS score identified a comparable proportion of patients as not receiving care in a trauma centre. For example, stratifying by age, the highest absolute difference in the proportion between the two methods was 0.34% (Appendix G).

5.4 Variable Specification

Table 5.1 provides a summary of the included variables. In addition to the standard variables such as patient age, sex, diagnoses and discharge disposition, which are readily available in the NTR-MDS, the CIHI analytical team also generated the following project specific variables for each patient record in the database: (1) admission number; (2) admission time of day; (3) admission day of week; (4) death within 24 hours of hospitalization; (5) patient’s neighbourhood income quintile grouping; (6) urban-rural location based on patient’s residence; (7) Statistical Area Classification (SAC) location based on patient's residence; (8) aerial distance from patient's residence to hospital of treatment; and (9) aerial distance from patient's residence to each trauma centre. As well, the following project specific hospital level variables were created: (1) urban/rural location of each hospital; (2) Statistical Area Classification (SAC) location of each hospital; (3) designation of each hospital as a Level I or Level II trauma centre or non-trauma centre. For these purposes, Level I and Level II trauma centres were identified as previously described. A detailed description of all study variables follows and is summarized in Table 5.1.

Table 5.1 Explanatory and outcome variables used in this project

Variable	Values	Source
Patient Data		
Age in Years	Continuous	NTR
Age Group	Young = 17 - 64 years; Elderly = ≥ 65 years	NTR
Age Categories	17- 29 years, 30-49 years, 50-64 years, 65-75 years, ≥ 80 years	
Sex	M = Male; F = Female	NTR
Fiscal Year	2002; 2003; 2004; 2005 2006; 2007; 2008; 2009	NTR
Province of Patient Residence	AB; BC; MB; NB; NL; NS ON; PE; SK; TER	NTR
Patient Area Income Quintile	1 = Poorest 2 = Poorer 3 = Poor 4 = Rich 5 = Richest	NTR
Urban / Rural Location of Patient Residence	0 = Rural; 1 = Urban	NTR
Patient - Statistical Area Classification	1 = Census metropolitan area 2 = Tracted census agglomeration 3 = Non-tracted census agglomeration 4 = Strongly influenced zone 5 = Moderately influenced zone 6 = Weakly influenced zone 7 = No influenced zone	NTR
Admission Season	0 = Non Winter (April - November); 1 = Winter (December - March)	NTR
Admission Time of Week	0 = Weekday (Monday - Friday 18:00); 1 = Weekend (Saturday, Sunday and Friday after 18:00)	NTR
Admission Time of Day	0 = Day (08:00 am to 17:59 pm) 1 = Night (18:00 pm to 07:59 am)	NTR

Table 5.1 (continued)

Variable	Values	Source
Injury/Illness Data		
Number of Comorbidities	Continuous	NTR
Length of Stay (Minutes)	Continuous	NTR
ISS	Continuous	NTR
ISS Category	1 = ISS 16 -24 2 = ISS 25 - 47 3 = ISS 48 - 75	NTR
Mechanism of Injury	1 = Blunt; 2 = Fall; 3 = MVC; 4 = Other	NTR
Comorbidity Categories	0 = No Comorbidity 1 = 1 Comorbidity; 2 = 2 Comorbidities 3 = 3 Comorbidities 4 = > 3 Comorbidities	NTR
Home to Nearest Trauma Centre (km)	Continuous	NTR
Distance to Nearest Trauma Centre Category	1 = 0 - 10 Km; 2 = 11 - 25 Km 3 = 26 - 50 Km; 4 = 51 -100 Km 5 = > 100 Km	NTR
Hospital Data		
Encrypted Facility ID		NTR
Hospital Peer Group	0 = 1 - 49 beds 1 = 50 - 99 beds 2 = 100 - 199 beds 3 = 200 - 399 beds 4 = ≥ 400 beds 5 = Teaching hospital	NTR
Trauma Centre	0 = Non trauma centre 1 = Level I and Level II trauma	Survey

Table 5.1 (continued)

Variable	Values	Source
Hospital Data		
Encrypted Facility ID		NTR
Hospital Peer Group	0 = Community 1 = Teaching hospital	NTR
Trauma Centre	0 = Non trauma centre 1 = Level I and Level II trauma	Survey
Provincial Data		
Population Data	Count	CANSIM
Percent Population Elderly Category	0 = Low 1 = High	CANSIM
Population Density Category	0 = Low 1 = High	CANSIM
Trauma Centre Density Category	0 = Low 1 = High	CANSIM
Outcomes		
Receiving Care in a Trauma Centre	0 = No 1 = Yes	NTR
Died	0 = No (Discharged Alive) 1 = Yes (Died)	NTR
Bed-days	Total number of hospital days	NTR

5.4.1 Dependent (outcome) Variables

The four dependent variables examined in this study include: having been hospitalized for major trauma, hospital mortality after major trauma, hospital bed-days used for major trauma and having received care in trauma centre.

1. Major injury hospitalization

For the purposes of this project, patients were considered to have had a major injury hospitalization if they were admitted to an acute care hospital within Canadian with: (1) an external cause of injury code that met the definition of trauma used in the NTR; and (2) had an ISS > 15 or death within 24 hours of admission. An ISS > 15 is generally accepted as requiring admission to a trauma centre and has been used previously to define patients with severe injuries.[28] We also elected to include all injured patients dying within 24 hours of hospitalization to allow for the inclusion of patients with severe injury but for whom an accurate ISS was not determined due to incomplete clinical assessment. For all analyses, a hospitalization was treated as count data. Specifically, when describing temporal trends in hospital admissions, the outcome was the annual rate of hospitalization, determined by dividing the total hospitalizations in one year by the population count for that year. Similarly, when examining provincial trends in major injury hospitalization, the outcome was a provincial level variable, determined by dividing the number of hospitalizations within the specified province by the total population within that province. A full description of the calculations of the rates is provided in the Statistical Analysis section of this chapter.

2. Hospital mortality:

To assess in-hospital mortality, the seven response categories for the variable “discharge disposition” in the NTR-MDS were dichotomized into “died” and “discharged alive” (by collapsing all other non-missing response categories). For the binary in-hospital mortality variable, ‘died’ indicates that the patient did not survive his/her stay at the hospital providing definitive care. In separate analyses, this variable was also treated as count data. In these analyses, the number of deaths was counted to determine death rates, as described previously for hospitalization rates.

3. Hospital bed-days:

Hospital bed-days was calculated as the total number of bed-days utilized by major trauma patients at the hospital providing definitive care. This was derived from the variable “los” in the NTR and was treated as a continuous variable.

4. Undertriage:

The final and main dependent variable for this study was being cared for in a non-trauma centre (undertriaged). For the purposes of this study undertriage was defined as a binary (yes/no) variable, where “yes” indicates patients with major trauma not treated in a Level I or Level II trauma centre (see Appendix D).

5.4.2 Explanatory Variables

While inter-related, the explanatory variables examined in this study were selected to reflect the main outcome variable – undertriage. Given the focus of the study, the three primary independent variables identified for this project were age, gender and province of residence.

5.4.2.1 Age

Patient age was *a priori* believed to be an important predictor variable for all three outcomes examined in this project and was represented as follows in separate analyses: (1) as a continuous variable; (2) as a binary variable with values defined by ages 17 - 65 years old (young) and age 65 years and older (elderly). These values were chosen to facilitate comparison with previous studies (for all outcomes); (3) as a categorical variable indicated by five age groups reflecting the age distribution of the dataset, specifically: 17 – 29 years; 30 – 49 years; 50 - 64 years; 65 -75 years and ≥ 80 years; and (4) as a categorical variable reflecting approximately 10 year age bins to facilitate the calculation of age-standardized rates: These were: 17 – 24 years, 25 – 34 years, 35 – 44 years, 45 - 54 years, 55 – 64 years, 65 – 74 years, 75 – 84 years, and ≥ 85 years.

5.4.2.2 Gender

This was a dichotomous variable with values of 1 for male and 0 for female.

5.4.2.3 Province of residence

Province of residence was defined as a categorical variable, with 9 response categories. Given, the low frequencies of major injury hospitalizations in the three territories and the potential for zero counts in categories in subsequent analyses, the data for the Territories were collapsed together into one "province" data.

5.4.3 Other Explanatory Variables/Covariates

As discussed previously, the conceptual model highlights a number of factors that may impact access to trauma centre care. While not all factors identified in the conceptual model were available in the administrative dataset (NTR-MDS), for example patient preference for location of care, variables that were included are described below.

5.4.3.1 Injury Severity: AIS and ISS

Perceived and evaluated clinical needs are important determinants of health services use.[93] In this study the variables used to capture patients' clinical need for trauma centre care were the AIS and ISS. The AIS is a consensus-derived system of scoring injuries to six major body regions on a scale of 1 (minor injury) to 6 (maximal injury), where a non-survivable injury to a particular body region is, by convention, assigned an AIS of 6.[24] The six body regions capture by AIS are: head or neck, face, abdomen and visceral pelvis, chest, external structures and bony pelvis and extremities. For each body region this "severity" variable was coded as 1 for AIS ≥ 3 in the specify body region and 0 for all other AIS values in that body region.

Severity of injury was also assessed using ISS. The ISS is an AIS-based scoring system that uses the three highest AIS scores obtained in different body regions to obtain an overall score for trauma patients with multiple injuries.[24] ISS is calculated by summing the squares of the highest AIS scores in the three most severely injured body regions, and as such, does not include all serious injuries in all body regions. ISS ranges from 1 – 75 and by design injuries with AIS score of 6 are given an ISS score of 75. This measure was treated as a continuous variable and, consistent with previous studies,[19] as a categorical variable (ISS 16 – 24, ISS 25 – 47, ISS 48 – 75) in separate analyses.

5.4.3.2 Mechanism of Injury

For each patient, mechanism of injury was determined by the external cause of injury mortality matrix (Center for Disease Control)[153] which is based on ICD-10. Based on this matrix, cause of injury codes were coded into the following six categories: (1) falls; (2) motor vehicle collision (MVC); (3) other blunt; (4) firearm; (5) stabbing; and (6) other, in order to derive the mechanism of injury variable.

5.4.3.3 Comorbidity

This variable was included as a categorical variable indicating the presence or absence of co-morbidities and was derived from the variable “number of co-morbidities” in the NTR-MDS. Specifically, each patient was categorized as 0 (no co-morbidity); 1 (single co-morbidity); 2 (2 co-morbid conditions); 3 (3 co-morbid conditions); and 4 (4 or more co-morbid conditions).

5.4.3.4 Socioeconomic Status and Urban-Rural Location of Residence

Socio-demographic factors such as income adequacy and rurality of residence have been shown to have important influences on utilization of health services in particular, and more specifically access to trauma centre care.[14]

<u>Socioeconomic status:</u> For this project, area-level income was used to quantify individual income-level. Specifically, patients’ postal codes were assigned to neighbourhood income quintile using the 2006 Canadian Census postal-code conversion file (PCCF).[154] This linkage was conducted by the analytical team at CIHI. For this variable, quintile 1 and quintile 5 represents the lowest and highest income

quintile, respectively (see Table 5.1). While the potential ecological fallacies are recognized,[155] this income measure, which includes adjustment for household size, is a validated approach and has been used to examine differential access to health care services across several Canadian patient populations.[88, 156, 157]

Urban/rural location: Within the urban/rural continuum, the Canadian population is classified into one of six codes that define geographical location.[158] The codes are as follows: (1) urban core, (2) urban fringe, (3) rural fringe inside Census Metropolitan Areas (CMA) and Census Agglomeration (CA), (4) urban areas outside CMA and CA, (5) rural fringe outside CMA and CA and (6) secondary urban core. Postal code of each patient's residence was used to assign patients to one of these codes using the 2006 Statistics Canada Census PCCF. This mapping exercise was undertaken by CIHI. Consistent with previous reports[159] a binary urban/rural location of residence variable was created by collapsing codes 1, 2, 4, and 6 to characterize urban areas, and codes 3 and 5 to characterize rural areas. In addition to the dichotomous urban/rural variable, a second variable was used to indicate patients' residence as related to the urban-rural continuum, namely the Statistical Area Classification (SAC).[160, 161] This second approach to defining urban/rural was chosen to further delineate more rural areas within provinces. Within this classification census subdivision, legislatively determined municipalities, with populations less than 10,000 and lying outside of Census Metropolitan Area (CMA) and Census Area (CA) are classified as Rural and Small Town (RST).[160, 161] RST are further classified according to the degree of influence of neighbouring CMA and CA, as measured by commuting flows. This additional delineation is referred to as Census Metropolitan Area and Census Agglomeration

Influenced Zone (MIZ).[160, 161] The MIZ classifications are based on the percentage of the employed labour force of the population within a RST that commutes to an urban core of a CMA or CA for work.[161] The full complement of categories used in the SAC system include: (1) Urban – CMA; (2) Urban; RST – Strong MIZ; (3) RST- Moderate MIZ; (4) RST - Weak MIZ; (5) RST - No MIZ; and (6) RST – territories, where strong to weak indicates decreasing influence of larger urban areas on rural and small towns.

5.4.3.5 Distance to Nearest Trauma Centre

Proximity to a trauma centre was determined as the distance between a patient's resident postal code and the postal code of all trauma centres. This variable was prepared by CIHI's Geography Information System team and was calculated using Euclidean methods as the distance in kilometers between the centroid latitude of a patient's postal code and that of all trauma centres. The distance to the nearest trauma centre was determined by shortest distance between a patient's postal code and a trauma centre. This variable was treated as both continuous and categorical, in separate analyses. Five categories were defined (1-10 km, 11-25 km, 26 - 50 km, 51-100km, > 100 km) based on the approximate distribution of the data.

5.4.3.6 Environmental Variables

Environmental variables describe the context of the area in which individuals reside and include characteristics of the healthcare system and the external environment which may influence health services utilization.[95] The aggregate level data (at the province) environmental factors included in this project were:

Trauma centre availability: The indicator of availability of trauma centre within a province was measured as a binary variable indicated by 0 (low trauma centre density) and 1 (high trauma centre density). The cutoff for trauma centre density was the median value of the number of Level I and Level II trauma centres per 1,000,000 population within the province, for all provinces.

Proportion elderly: This variable was defined as the proportion of the population that is elderly (≥ 65 years) within a province and was measured as a binary variable indicated by 0 (low percentage of population that is elderly) and 1 (high percentage of population that is elderly). The cutoff for low/high was determined by the median value for the percentage of elderly individuals for all provinces.

Population density: This variable was defined as the population number of a province divided by the size in square kilometers of the province and was measured as a binary variable indicated by 0 (low population density) and 1 (high population density). The cutoff for low/high was determined by the median value for the population density for all provinces. For all three measures the 2006 census data, representing the closest census to the mid-point of the period examined, was used to determine population numbers and percentages.

Year: Examining temporal changes in the major injury epidemiology is important for informing strategies aimed at injury prevention and trauma system development. Further, time is an important proxy for environmental changes (such as trauma care polices) that may impact undertriage rates. To that end, fiscal years from 2002 – 2009 were used in this study.

Admission time of day: For the purposes of the observational studies, admission time of day was defined as a binary variable, indicated by day (08:00 – 17:59) and night (18:00 – 07:59).

Admission season: This variable was a binary measure indicated by winter (December-March) and non-winter (April-November). It is recognized that seasonal pattern is highly variable across the geographical areas of the country, however, this dichotomy was chosen to approximate the seasonal peak in winter weather.

Admission day of week: This was a binary variable indicated by weekend (Saturday, Sunday and Friday after 18:00 hrs.) and weekday (all other days of the week).

5.5 Patient population

To be eligible for the study, patients had to meet the following inclusion and exclusion criteria:

5.5.1 Inclusion Criterion:

To facilitate comparisons with the literature on trauma centre access for severely injured patients, this study focused on the adult Canadian population. To that end, the study included all adult (> 16 years) patients discharged (alive or dead) from an acute care hospital in Canada (except Quebec) between April 1, 2002 and March 31, 2010 with a diagnosis of acute trauma defined by a principal or secondary ICD-10 diagnostic codes for injury (in the S00 to T79.0 range). This period was selected to obviate potential biases that might have been introduced due to changes in the injury related diagnostics codes (i.e. from ICD-9 to ICD-10 coding systems) adopted by CIHI in fiscal year 2002. Manitoba and New Brunswick did not adopt the ICD-10 coding until fiscal 2004 and 2003, respectively. As such, data from these provinces are restricted to fiscal 2004 – 2009 (Manitoba) and fiscal 2003 – 2009 (New Brunswick).

5.5.2 Exclusion Criteria:

The following lists the type of patients that were excluded from the study and the reasons for their exclusion:

1. Less than 16 years old. These patients were excluded to reflect the interest in comparing the results of this study with comparable data from the literature on adult major trauma[78];
2. Admitted with a primary diagnosis of burns, poisonings, toxic effects, suffocation or drowning. Compared to patients with mechanical mechanisms of injury, these patients have different injury etiology and outcome patterns[54] and represent a distinct population of trauma patients. Further, burn patients are primarily managed in a burn centre and not a general trauma centre. As such, inclusion of these patients in the analysis of differential access to care may lead to biased estimates of access to trauma centre care;
3. Admitted with minor or moderate injuries given the focus on major trauma. These patients do not typically require management in a Level I or Level II trauma centre. As well, they, generally, have better outcomes, for example in terms of mortality and hospital length stay compared to patients with more severe injuries;[162]
4. Missing information on province of residence. These patients represent primarily non-residents of Canada for whom information on their final hospital outcome

may not be available in the NTR-MDS. As well, patients with missing information on province of residence could not be appropriately assigned in the analyses related to provincial counts of major injury, or undertriage;

5. Missing information on encrypted health card number. These patients were excluded to avoid double counting patients since a determination of the number of unique hospitalizations could not be made without the ability to identify patients.

Appendix H details the results of the application of these inclusion and exclusion criteria on the NTR-MDS.

5.6 Creating Episode of Care

To facilitate the exclusion of redundant information for the same patient, "episode of care" information was created using patients' encrypted health card number, sex, province of residence and the admission number assigned by CIHI based on the individual patient's admission and discharge dates. For patients with multiple hospital admissions within a 90-day period, we retained the first record if the length of stay in the first hospital was more than one day. If hospital length of stay in the first hospital was less than one day the second record was included in the study. In cases of multiple admissions during the same episode of care the ISS value assigned was based on the highest value during the episode. Admissions after 90 days of initial discharge were considered a new trauma (episode of care) and were retained as part of the study cohort. This approach represents a more conservative estimate of major injury hospitalization (i.e. than using all records) by minimizing the impact of double counting patients with multiple hospital admissions within a single episode of care.

5.7 Statistical Analyses

The statistical approaches used in this project included: (1) descriptive statistics and bivariate comparisons to characterize the study population; (2) estimation of rates of major trauma hospitalization, mortality and undertriage; (3) examination of trends in these rates over time; (4) assessment of the predictors of hospitalization and mortality; and (5) assessment of the impact of age, gender and province of residence on triage to trauma centre following major trauma. The details of these analyses for chapters 6 through 9 are described below.

5.7.1 Major Trauma Hospitalization in Canada: A Population Based Study (Chapter 6)

To characterize the study population, summary statistics for categorical data including frequencies and percentages were reported. For continuous data, descriptions of central tendency and variability were reported as means and standard deviation or median and interquartile range based on the distribution of these variables. The proportion of missing data for each variable was also examined. Comparisons of the differences in patient characteristics over the eight-year period were analyzed using Chi-square test or Fisher's exact test for categorical variables. For continuous data, analysis of variance (ANOVA) for differences in means or the Kruskal-Wallis test for differences in distributions were used to compare differences across years.

5.7.1.1 Derivation of National Hospitalization Rates

For each year of the study, crude annual rates of injury hospitalization were calculated for the entire cohort, and by gender, age (17 – 64 years and ≥ 65 years) and mechanism of injury. In addition to the overall annual rates for each age group, rates were also derived for young and older individuals by gender and mechanism of injury. The numerators for the rates were the number of major injury hospitalization for the specific category (e.g. entire cohort, women etc.). The rate denominator were the year specific population counts derived from Statistics Canada intercensal midyear population estimates for Canada (excluding Quebec), and groups defined by age, and sex, as appropriate. To facilitate comparison over time and between groups, age-standardized rates per 100,000 population age 16 years and over were also determined. The direct standardization method was used for the calculation of age-standardized rates[163] using the 1991 Canada census population as reference, the recommended standard reference population for disease surveillance in Canada.[164] To calculate the age-standardized rates, age specific rates of major injury hospitalization for the following age groups, 17- 24 years, 25 - 29 years, 30 - 34 years, 35 – 39 years, 40 - 44 years, 45 – 49 years, 50 - 54 years, 55 – 59 years, 60 - 64 years, 65 – 69 years, 70 - 74 years, 75 - 79 years, 80 – 84 years, and ≥ 85 years were calculated as the total number of patients hospitalized with major trauma in the specific age group divided by the total population in each age group. Using the same age-bins, the age-specific rates were applied to the 1991 census population (standard) to derive the expected number of hospitalizations given the age distribution of the standard population. The age-standardized rate (per 100,000 population) was determined as the sum of all expected events (major injury hospitalizations) divided by the total standard population.[165] These calculations were repeated for each of the previously specified strata (i.e. age, gender and mechanisms) using age and sex specific population counts as appropriate. For calculations involving younger patients (< 65 years) rate calculations were restricted to the age categories below 65 years. Similarly, for older patients (≥ 65 years), the calculations of rates were restricted to age categories 65 years and above.

To provide a more informative comparison of major trauma hospitalization over time, age-specific rates for the overall cohort and by gender were calculated for the following age groups:17- 24 years, 25 - 34 years, 35 - 44 years, 45 - 54 years, 55 - 64 years, 65 - 74 years, 75 - 84 years, and ≥ 85. These rates were calculated as: the count of all admissions in the specific age stratum divided by the intercensal midyear population estimates for the specific age-stratum, and by gender as appropriate. These calculations were repeated with stratification by mechanism of injury. All hospitalization rates were reported per 100,000 population.

5.7.1.2 Trends in National Hospitalization Rates

To examine temporal trends in the age-standardized rates, Poisson regression models were fitted with terms for age group and fiscal year. A member of the family of generalized linear models, Poisson regression is used for modeling non-negative count data, and more specific to the current study it has been used extensively to model trends in disease rates over time.[166-168] Compared to the Ordinary Least Squares approach, where either the calculated rates or the log of the calculated rates are modeled as a function of time, Poisson regression models the counts in both the numerator and denominator for each time point and therefore accounts for both the variability at each point in time and the fluctuation across time.[168] For this study Poisson regression was used to fit the following model:

$\text{Log(admits)} = \beta_0 + \beta_{(year)}X_{(year)} + \beta_{(age)}X_{(age)} + \log(\text{pop})$............(equation 1)

Where "admits" is the number of admissions in the appropriate group (age/year), "β" is the regression coefficients for the specified variable, "pop" is the population at risk of hospitalization, such that log(pop) is an adjustment term for the log link of the mean rate and is referred to as an offset.[169] A linear trend was assumed given that no other plausible trend was displayed by the data. To that end, in the regression model fiscal year was entered as a continuous variable and age was categorical as previous defined (see Table 5.1). Consistent with other investigators,[168, 170] the estimated annual percent change in age-adjusted major injury hospitalization was calculated using the regression coefficient for fiscal year as follows:

$[\text{exponential}(\beta_{(year)}) - 1]*100$ (i.e. average relative annual percent change in rates). The p-value for the coefficient for fiscal year was used to examine whether changes in hospitalization rates over time were significant (i.e. if the coefficient was significantly different from zero). In addition, the relative change in rates was calculated for the entire cohort and by strata defined by age and gender using 2002 as reference as follows:

$[100 \text{ X } (\text{Rate}_{2009} - \text{Rate}_{2002})/\text{Rate}_{2002}]$.

Temporal changes in age-specific hospitalizations rates were similarly calculated.

Mechanism-specific age-adjusted Poisson regression models were also fitted to examine temporal trends in hospitalization for each mechanism of injury. Separate analyses were conducted for younger and older patients. The models fitted the generic form:

$$\text{Log}(\text{admits}_{\text{mechanism}}) = \beta_0 + \beta_{(\text{year})}X_{(\text{year})} + \beta_{(\text{age})}X_{(\text{age})} + \log(\text{pop}) \quad \text{....(equation 2).}$$

For all age-standardized rates, 95% confidence intervals were calculated using the Poisson approximation method.[171]

5.7.2 Provincial Trends in Major Trauma Hospitalization (Chapter 7)

5.7.2.1 Descriptive Statistics and Bivariate Comparisons

To describe the characteristics of the patient population in each province absolute numbers and proportions were reported for categorical variables. For continuous data mean and standard deviation as well as median and interquartile ranges were reported. Differences across provinces were examined for statistical significance using the Chi-squared or Fisher's exact test and ANOVA or Kruskal-Walis test for continuous data, as appropriate.

5.7.2.2 Trends in Provincial Hospitalization Rates

Annual crude and age-standardized rates of major trauma hospitalization and associated 95% confidence intervals were calculated for each province for the overall cohort and separately for individuals between the ages of 17 – 64 years and for those 65 years and older, stratified by gender. Annual mechanism-specific rates of hospitalization for severe injury were also calculated for each province. Due to small numbers, the latter analysis was restricted to injuries where the external cause of injury was falls or motor vehicle collision, the two leading cause of injuries. The approach employed for the calculation of annual provincial age-standardized rates and 95% confidence intervals was similar to that taken for the entire cohort, including using direct standardization to the 1991 Canadian population. However, given the extent of zero cases for several of the annual age-specific stratum for the Territories and Prince Edward Island these areas were excluded from the analysis of temporal trends. It should also be noted that two separate analyses were performed for all provincial rate calculations. In the first analysis all records were included in the provincial rate calculation such that the numerator counts for the rates included cases managed out of province, that is, the provincial rates of hospitalization were calculated based on each patient's province of residence and not where trauma care was received. In the second analysis, provincial rates of hospitalization were also calculated based on each patient's province of residence but cases where patients were management outside of their province of residence were excluded. Review of the rates generated by both approaches revealed marginal differences and the provincial hospitalization rates (and death rates described below) reported herein reflects the rates were all records for patients were retained regardless of treatment location. This approach was selected since the focus of this thesis is on the injury experience of individuals in each province.

Similar to the national data, a Poisson regression model was initially fitted for each province to explore temporal trends in hospitalizations for major trauma. Examination of the resulting models revealed that the data was over-dispersed, that is, the variance of the observed number of hospitalizations was larger than that expected under the Poisson assumption (variance = μ (mean)). An important consequence of over-dispersion is that the standard errors of the parameters estimated by the model would be small and therefore inflate type I error (rejecting the null hypothesis when it is true).[169] Therefore, given the violation of the assumption of the Poisson model, the approach was to use negative binomial regression, since the assumption concerning the relationship between the variance and mean is less stringent (variance= $\mu(1 + k\mu)$) where k accounts for the over-dispersion.[169] The final analyses for temporal trends within each province were fitted using a negative binomial regression where age was entered as a categorical variable and year as continuous:

$$\text{Log}(\text{admits}_{\text{province}}) = \beta_0 + \beta_{(\text{year})}X_{(\text{year})} + \beta_{(\text{age})}X_{(\text{age})} + \log(\text{pop}_{\text{province}}) \quad \text{.......(equation 3).}$$

The estimated annual percent change was calculated as described above for each province. A similar model was used to determine temporal trend by age (young and elderly) stratified by gender.

To examine regional differences in hospitalization rates multivariable Poisson or negative binomial regression models were fitted that included age, gender, province of residence and year (see equation below). Separate analyses were conducted for the overall cohort and by age group (17 – 64 years and those 65 years and older).

$$\text{Log}(\text{admits}) = \beta_0 + \beta_{(\text{year})}X_{(\text{year})} + \beta_{(\text{age})}X_{(\text{age})} + \beta_{(\text{province})}X_{(\text{province})} + \beta_{(\text{gender})}X_{(\text{gender})} + \log(\text{pop}) \quad \text{..........(equation 4)}$$

5.7.3 Major Trauma in Canada: Case Fatality, Mortality and Bed-day Utilization (Chapter 8)

5.7.3.1 Fatality Rates

Crude in-hospital case fatality rate per 1000 hospital discharges was calculated as follows:

> 1000 x [(Number of major trauma hospitalization resulting in death)/(number of major trauma hospitalization as defined for this study)]

Direct age-standardization of the case fatality rates were performed using the entire cohort of major trauma patients as the standard reference population. Methods of age-standardization was similar to the approach described for hospitalization and was calculated separately for the entire cohort and groups defined by age, gender, province and mechanism of injury. However, there was one notable difference. For the case fatality data, rates were age-standardized by applying 8, instead of 14, age intervals (17- 24 years, 25 - 34 years, 35 - 44 years, 45 - 54 years, 55 - 64 years, 65 - 74 years, 75 - 84 years, and ≥ 85) to the 1991 census population to generate expected counts. This was done to facilitate more robust rate estimates given the extent of zero cases in several age categories when 14 groups were used.[163] Annual age-specific case fatality rates were also generated to further explore differences in trends by age that may be obscured by age-standardization. These rates were generated for the entire cohort and by gender by applying the case fatality rate formula (above) to the following groups: 17-24 years, 25 - 34 years, 35 - 44 years, 45 - 54 years, 55 - 64 years, 65 - 74 years, 75 -

84 years, and ≥ 85. Age-specific case fatality rates were similarly calculated for injuries resulting from the two leading causes of hospitalizations - falls and motor vehicle related injuries. To facilitate more robust estimates, age categories of 17-29 years, 30-49 years, 50-64 years, 65-79 years and ≥ 80 years were used in these analyses.

The relatively few annual in-hospital major trauma fatalities experienced by the smaller provinces, hindered meaningful comparisons of temporal trends. Further, owing to no deaths in several age-categories used in the calculation of standardized rates and the potential impact on the robustness of these rates,[163] death data for the Territories and Prince Edward Island were not reported. For the remaining provinces, deaths following injury were summarized for the 8-year period. Specifically, for each province crude case-fatality rate was calculated as the total counts of deaths over the 8-year period divided by the total hospital discharges over the 8-year period and expressed per 1000 discharges. For each province, these rates were calculated for the overall cohort, by gender and by gender stratified by age (individuals 17 - 64 years and those 65 years and older, respectively).

5.7.3.2 Mortality Rate

Annual age and sex-specific in-hospital mortality rates were calculated using counts of in-hospital deaths as the numerator and the respective Canadian population estimates as denominator. Annual mortality rates for the entire cohort were calculated separately for groups defined by age, sex and mechanism of injury. Further, these rates were directly age-standardized using the 1991 Canadian census population as previously described.

Similar to the case fatality data, crude and age-standardized mortality rates for the 8-year period was calculated for each province. Age-standardized mortality rates were calculated consistent with the approach previously described for age-standardized hospitalization rates, with the exception of using the number of deaths rather than hospitalizations in each province as the numerator. Rates were calculated separately for groups defined by gender and age, using age and sex-specific population counts, as appropriate. All rates were directly standardized to the 1991 Canadian population and are reported as rate per 100,000 population. For all age-standardized fatality and mortality rates, 95% confidence intervals were calculated using the Poisson approximation method.[171]

To provide a more detailed assessment of age and mortality in each province, age-specific in-hospital mortality rates were calculated by gender for the following age groups: 17-29 years, 30-49 years, 50-64 years, 65-79 years and ≥ 80. For these calculations the number of in-hospital deaths for each age category was used as the numerator and the appropriate age-sex specific provincial population estimates as denominator.

5.7.3.3 Trends in Case Fatality and Mortality

To assess temporal trends in age-standardized rates, Poisson or negative binomial regression models, as appropriate, were fitted to the data for the entire cohort and by groups defined by age (17 – 64 years and ≥ 65 years), gender, gender stratified by age group (17 – 64 years and ≥ 65 years) and mechanism of injury. Separate analyses were conducted for in-hospital case fatality and mortality rates. The generic form of the model was as follows:

$$\text{Log(deaths)} = \beta_0 + \beta_{(year)}X_{(year)} + \beta_{(age)}X_{(age)} + \log(\text{pop}) \text{..........(equation 5)}$$

Similar to above, the exponent of the regression coefficient for year in each model was used to estimate the annual change in the rate of death.

To examine regional variation in case fatality and age-standardized mortality rates, the extremal quotient was reported. The extremal quotient is the ratio of the highest to the lowest rate and is used as a measure of area variation.[172] Increasing values of extremal quotient above one indicates increasing variability across the provinces.[172] For the purposes of this project, the extremal quotient was calculated as the ratio of the highest provincial injury death rate to the lowest death rate. The extremal quotient was calculated separately for case fatality and mortality, for the following groups: men, women, women under 65 years; men under 65 years, women 65 years and older and men 65 years and older.

5.7.3.4 National Hospital Bed-day Utilization Rates

Crude annual rates of hospital bed-day utilization were calculated separately for the entire cohort, and by groups defined by province, age (17 – 64 years and ≥ 65 years) and gender. The rate numerator was the total number of hospital days used by major trauma patients and was determined by summing the hospital length of stay variable in the NTR for the defined group, as appropriate. The rate denominator was the year specific population counts derived from Statistics Canada intercensal midyear population estimates for Canada (excluding Quebec) and the provinces, and groups defined by age, and sex, as appropriate. Rates were age-standardized to the 1991 Canada census population using the direct method as previously described and are reported per 100,000 population age 16 years and over.

5.7.4 Undertriage in Patients with Major Trauma (Chapter 9)

5.7.4.1 Descriptive Statistics and Bivariate Comparisons

Summary statistics for categorical and continuous data were generated as previously described. Notably, the annual proportion of patients undertriaged was calculated for each gender stratified by age groups defined as a binary variable (using age younger than 65 as a cut off) and categorically using 5 – age group intervals (17-29 years, 30-49 years, 50-64 years, 65-79 years and ≥ 80 years). Given to low frequencies of events amongst several of the smaller provinces, the presentation of provincial data on the number (and proportion) of patients who were undertriaged was restricted to the overall 8 year period. To that end, the proportion of patients undertriaged for each province was reported by gender and age group (17 – 64 years and ≥ 65 years).

Comparisons of the differences in patient characteristics between groups were analyzed using Chi-square test for categorical variables and Student's t-test for differences in means. For skewed continuous data, the Wilcoxon Rank Sum Test was used to compare differences in median between groups. These comparisons were made for the following groups: (1) year periods defined as fiscal 2002-2005 and fiscal 2006-2009. These time frames represented the first and last four years of the study, respectively and were used to summarize the temporal changes in patient characteristics over time; (2) young (17 – 64 years) and elderly patients (65 years and older); and (3) men and women.

5.7.4.2 Multivariable Analyses

A series of logistic regression models were generated to examine the influence of age, gender and province of residence on receiving care in a trauma centre following major trauma. To visually examine temporal trends in the association between age and receiving care in a trauma centre, while controlling for demographic and clinical characteristics, a logistic regression of the following form was fitted for each year:

$$\text{Log}(\pi/(1-\pi)) = \beta_0 + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism\ of\ injury\ )}X_{(mechanism\ of\ injury)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} \quad \text{....(equation 6)}$$

where π is the probability of receiving care in trauma centre, β represent the regression coefficients for the terms included in the models. As previous discussed, the independent patient level variables included in the models were guided by the conceptual framework for this study. Moreover, all included variables demonstrated significant associations ($p<0.05$) in the univariate analyses comparing patients receiving trauma centre care with those who did not.

Similarly, to assess temporal trends in the association between gender and receiving care in a trauma centre while controlling for patient's demographic and clinical characteristics, age-stratified (17-64 years and ≥ 65 years) logistic regression models were fitted for each year as follows:

$$\text{Log}(\pi/(1-\pi)) = \beta_0 + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism)}X_{(mechanism)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} \quad \text{....(equation 7)}$$

For these models age was entered as a continuous variable while the remaining variables were entered as categorical (as defined previously).

For the overall cohort (all years) a logistic regression model of the following form was fitted to examine the influence of age and gender on receipt of trauma care:

$$\text{Log}(\pi/(1-\pi)) = \beta_0 + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism\ of\ injury)}X_{(mechanism\ of\ injury)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(sevhead)}X_{(sevhead)} + \beta_{(sevchest)}X_{(sevchest)} + \beta_{(sevabdomen)}X_{(sevabdomen)} + \beta_{(sevupperextremities)}X_{(sevupperextremities)} + \beta_{(sevlowerextremities)}X_{(sevlowerextremities)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(fiscal\ year)}X_{(fiscal\ year)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} + \beta_{(province)}X_{(province)} \quad \text{....(equation 8).}$$

To facilitate clinical interpretation age was entered as a categorical variable in the model. Two-way interactions between important explanatory variables of interest (age, gender, ISS, mechanism of injury and urban-rural location of residence) were examined. For example, to examine whether the effect of age varied according to gender the following interaction term was included in the model: $\beta_{(age\_gender)}X_{(age)^*}\ X_{(gender)}$

For all significant interaction terms, separate logistic regression models of the form in equation 8 above were performed stratified by the variable of interest.

Finally, to examine the influence of age and gender on receiving care in a trauma centre within each province, separate logistic regression models were fitted for each province. Owing to issues with quasi-separation of the data due to low event rate, results for Prince Edward Island and the Territories were not reported separately. This quasi-separation was largely driven by the variable representing closet distance to a trauma centre. Notably, when distance was treated as a continuous variable, patients from these provinces had extremely large values due to the longer distance to a trauma centre. Moreover, when distance was treated as a categorical variable patients from Prince Edward Island and the Territories could only be assigned to one category (i.e. > 100 km) when this variable was entered in the model as a categorical variable (in separate models). The models for the remaining provinces were as follows:

$$\text{Log}(\pi/(1-\pi)) = \beta_0 + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism)}X_{(mechanism)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} \quad \text{.....(equation 9).}$$

All variables except ISS were entered as categorical in these models.

For all logistic regression models above, separate analyses were generated with distance entered as a categorical (defined earlier) or a continuous variable. Review of the odds ratios for age revealed marginal differences between the models and the data for the model with distance as categorical are reported. Only records where ISS was > 15 were included in the models. Patients with ISS ≤ 15 (as would be the case for patients included in the study who died within 24-hours of admission) constituted less than 1% of the cohort and were excluded to mitigate the impact of lower ISS values on the regression estimates.

5.7.4.3 Multilevel Logistic Regression Model

Modeling data with hierarchical structure, for example patients nested within provinces, using multivariable modeling approaches that ignores the intra-cluster dependency of the data is problematic given the potential impact on estimates of effect and standard errors.[173] Specifically, such analyses may result in underestimation of the standard errors and biased estimates of effects.[173, 174] Within the context of this study for example, patients residing in a province with a more formal and organized system of trauma care may be more alike in terms of receiving care in a trauma centre compared to patients in another province. Therefore, in addition to the logistic regression models described above (equations 6 through 8), a multilevel logistic regression model was fitted to the data as part of our approach to examine the influence of age and gender on receiving care in a trauma centre. Multilevel models address the intra-cluster dependency of clustered data and therefore allows for more robust estimates of effects and standard errors.[173, 174] Further, prior research has established the robustness of this approach with relatively few clusters.[175] As a secondary aim, this analysis sought to determine the provincial factors that may influence trauma centre care. The measured provincial factors are detailed above. The multilevel logistic regression model with random intercept and fixed slopes was fitted using SAS Proc Glimmix.[176] The model equation was as follows:

$\text{Log}(\pi/(1-\pi)) = \beta_0 + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism)}X_{(mechanism)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(sevhead)}X_{(sevhead)} + \beta_{(sevchest)}X_{(sevchest)} + \beta_{(sevabdomen)}X_{(sevabdomen)} + \beta_{(sevupperextremities)}X_{(sevupperextremities)} + \beta_{(sevlowerextremities)}X_{(sevlowerextremities)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} + \varepsilon$ …..(equation 10) where $\beta_0 = \gamma_0 + \beta_{(TCdensity)}\ X_{(TCdensity)} + \beta_{(popdensity)}X_{(popdensity)} + \beta_{(popelderly)}X_{(popelderly)} + \mu$. Therefore:

$$Log(\pi/(1-\pi)) = \gamma_0 + \beta_{(TCdensity)}X_{(TCdensity)} + \beta_{(popdensity)}X_{(popdensity)} + \beta_{(popelderly)}X_{(popelderly)} + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism)}X_{(mechanism)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(sevhead)}X_{(sevhead)} + \beta_{(sevchest)}X_{(sevchest)} + \beta_{(sevabdomen)}X_{(sevabdomen)} + \beta_{(sevupperextremities)}X_{(sevupperextremities)} + \beta_{(sevlowerextremities)}X_{(sevlowerextremities)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} + \mu \quad \text{(equation 11).}$$

Similarly, to examine the association of trauma centre care with mortality, multilevel logistic regression models with random intercepts and fixed slopes were fitted for the overall cohort and by age groups (defined by < 65 years and 65 years and older). The generic model was as follows:

$$Log(\pi/(1-\pi)) = \gamma_0 + \beta_{(TCdensity)}\ X_{(TCdensity)} + \beta_{popdensity}X_{(popdensity)} + \beta_{(popelderly)}X_{(popelderly)} + \beta_{(hospital\ type)}X_{(hospital\ type)} + \beta_{(age)}X_{(age)} + \beta_{(gender)}X_{(gender)} + \beta_{(ISS)}X_{(ISS)} + \beta_{(mechanism)}X_{(mechanism)} + \beta_{(comorbidity)}X_{(comorbidity)} + \beta_{(proximity)}X_{(proximity)} + \beta_{(week)}X_{(week)} + \beta_{(rurality)}X_{(rurality)} + \beta_{(SES)}X_{(SES)} + \beta_{(day)}X_{(day)} + \beta_{(season)}X_{(season)} + \beta_{(year)}X_{(year)} + \beta_{(trauma\ centre)}X_{(trauma\ centre)} + \mu \quad \text{(equation 12).}$$

Where π is the probability of dying in the hospital providing definitive care, β represent the regression coefficients for the terms included in the model, and μ is normally distributed with constant variance.

All analyses were performed using SAS statistical package version 9.2 (Statistical Analysis System, SAS Institute, Cary, North Carolina, USA). For logistic and Poisson/negative binomial regression Proc Logistic and Proc Genmod were used, respectively.

Chapter 6 Major Injury Hospitalization in Canada: A Population-based Study (Paper 2)

6.1 Introduction

Injury is a serious public health burden, accounting for 5.8 million deaths per year worldwide.[177] It is the fourth leading cause of death in Canada and the leading contributor to years of life lost for Canadians under the age of 70 years.[1, 2] Despite its importance there are few population-based studies examining trends in hospitalizations and outcomes for major injury. Moreover, the comparability of the results of previous research examining rates of hospitalization for major injury are limited by such factors as varying definitions of *major* injury, geographical location studied, and methodological differences.[33, 35, 43, 48] In particular, most Canadian studies to date have focused on single regions and or specific injuries.[33, 34, 36, 44, 178]

An understanding of the trends in major injury hospitalization is essential not only for developing prevention programs but for optimizing the planning and organization of trauma services. To inform these activities we provide comparable data on population-based trends in major injury hospitalization and mortality in Canada. Given recent evidence demonstrating increasing injury hospitalization among older patients,[166, 179-181] we also explored whether, and to what extent, these trends differed by gender and age. This information is useful to inform provincial and national health policy and we provide insights into the policy implications of our findings.

6.2 Methods

The detailed methodology of this retrospective cohort study is described in chapter 5 of this thesis. Briefly, data for the study were derived from the National Trauma Registry Minimum Dataset (NTR-MDS) maintained by the Canadian Institute for Health Information (CIHI).[29] The NTR-MDS was used to define a cohort of patients hospitalized with severe trauma in all provinces (except Quebec) between April 1, 2002 and March 31, 2010. Severe trauma was defined as an ISS greater than 15 or death within 24 hours of hospitalization with an ICD-10 diagnosis code within the S00 to T79.0 range. Patients hospitalized with non-mechanical mechanisms of injury (i.e. burns, intoxication, drowning, suffocation and electrocution) were excluded from the study.

Crude and age-standardized hospitalization rates were calculated for groups defined by fiscal year province, age, and gender. Age-standardized rates were calculated using direct standardization with the 1991 Canadian population as the reference. The relative percentage changes in hospitalization rates were calculated by comparing the rates in fiscal 2009 relative to fiscal 2002. The estimated annual percent change in age-adjusted major injury hospitalization rates were calculated using the regression coefficient for fiscal year obtained from Poisson or negative binomial regression models. All analyses were performed using SAS™ statistical software. All statistical tests were two-sided and a p-value < 0.05 was considered statistically significant.

6.3 Results

6.3.1 Characteristics of Patients Hospitalized with Major Trauma

As detailed in Table 6.1, between fiscal 2002 and 2009 there were 98, 937 adult (> 16 years) hospital separations for major trauma meeting the study inclusion criteria. Of these, 33.4% were women with patients older than 65 years accounting for 38.5% of the total cohort. Amongst men, individuals under the age of 45 years accounted for 43.7% of the majority of trauma admissions. In contrast, amongst women, those 75 years and older accounted for almost half (46%) of the severe trauma admissions. The median ISS for the cohort was 21 (interquartile range (IQR) 9), with 41.7% of patients with an ISS in the range of 25 - 47. Falls (46.4%) and motor vehicle collision (35.6%) were the main mechanisms of injury.

Temporal trends in patient characteristics are detailed in Table 6.1 and Figure 6.1. The median (IQR) age increased from 53 (42) years to 58 (40) years over the period, with an increase in the proportion of patients aged 65 years and older (38.5% versus 42.1% in 2002 and 2009, respectively; $p < 0.0001$). Across all years hospital admissions for severe injury were highest amongst individuals between the ages of 75 – 84 years: representing 16% of the admissions across all age groups. There were significant differences in the number of admissions by age group for the 8 year period ($p<0.0001$ in χ^2 analysis). Notably, patients aged 85 years and older experienced the largest change in the absolute number of severe injury hospitalizations: a 2-fold increase from 991(10.0%) in 2002 to 1977(13.8%) in 2009. In contrast, while adults aged between 35 – 44 years accounted for 13.2% of severe injury hospitalizations in

2002, this number fell to 9.9% in 2009, reflecting a 25% relative decrease. There were small but statistically significant changes in the proportion of female over the same period (χ^2 p=0.0.002).

6.3.2 Trends in Age-Standardized Hospitalization Rates

The overall age-standardized annual hospitalization rate for major trauma was 59.8 per 100,000 population (95% confidence interval (CI): 59.4 – 60.2 per 100,000 population). Hospitalization rate for major trauma was higher amongst men compared to women: 85.7 (95% CI: 85.0 - 86.4) per 100,000 populations and 34.5 (95% CI: 34.1 – 34.9) per 100,000 population, respectively. For younger patients (< 65 years) the overall age-standardized rate was 46.3 (95% CI: 45.9 – 46.6) per 100,000 population. This figure was 135.1 (95% CI: 133.7 – 136.5) per 100,000 population amongst older patients (≥ 65 years).

Figure 6.2 highlights trends in age-standardized rates of hospitalization for major trauma for the overall population and by gender. Over the study period, a 13.4% relative increase in overall age-standardized hospitalization rates was observed: from 55.3 (95% CI: 54.2 – 56.4) per 100,000 in 2002 to 62.7 (95% CI: 61.6 – 63.7) per 100,000 population in 2009. The corresponding negative binomial regression analysis indicated a significant increase in the overall hospitalization rate per 100,000 population over the 8 year period: the estimated average annual percent change (EAPC) was 2.2% (95% CI: 1.8% - 2.6%; p< 0.0001). Among men, there was a relative increase of 13.5% in the major trauma hospitalization rates: from 78.0 (95%CI: 76.1 – 80.0) per 100, 000 population in 2002 to 88.6 (95% CI: 86.7 – 90.4) per 100, 000 population in 2009; and among women a 13.3% relative increase was observed: from 33.0 (95% CI: 31.9 – 34.2) per 100, 000 population in 2002 to 37.4 (95% 36.3 – 38.5) per 100, 000 population in 2009. The rising trend was significant for both men and women with an EAPC from regression analyses of 2.3% (95% CI: 1.8% – 2.8%) and 2.1% (95% CI: 1.6% – 2.7%) for men and women, respectively. However, there was no significant difference in temporal trends in hospitalization rate by gender (p=0.76 for gender*fiscal year interaction in the regression analyses).

Time trends in major injury hospitalization rates reflected significant increases for both younger and older segments of the population (Figure 6.3). For younger individuals (< 65 years) major injury hospitalization rates were 42.7 (95% CI: 41.6 – 43.8) and 46.6 (95% CI: 45.6 – 47.6) per 100,000 population in 2002 and 2009, respectively. This reflected an 8% relative increase over the period. For older patients (≥ 65 years) the relative increase was 21%: 125.3 (95% CI: 121.2 – 129.3) per 100,000 population and 152.2 (95% CI: 148.2 – 156.1) per 100,000 population in 2002 and 2009, respectively. For younger and older individuals the EAPC from 2002 to 2009 were 1.6% (95% CI: 1.1% - 2.1%, p< 0.0001) and 3.3 % (95% CI: 2.8% - 3.8%, p< 0.0001) per year, respectively. To describe these trends further, the average annual percent change in hospitalization rates were examined separately by gender. The results indicated that for younger men there was a modest but significant increase in hospitalization rate as reflected in the EAPC of 1.7% (95% CI: 1.2% – 2.3%, p<0.0001) per year. On average, older men experienced a 3.6% (95% CI: 2.9% – 4.3%, p<0.0001) increase in hospitalization rate per year. For younger and older women these figures were 1.2% (95% CI: 0.5% – 2.0%, p=0.001) and 2.9% (95% CI: 2.2% – 3.6%, p< 0.0001), respectively.

6.3.3 Trends in Age-specific Hospitalization Rates

While the overall adjusted rates suggest differences across age and gender, these differences were even more pronounced on examination of the age-specific rates (Figure 6.4 and Table 6.2). Age-specific hospitalization rates increased with increasing age, with the pattern consistent across gender (Figure 6.4). Notably, across all age groups men had the highest age-specific hospitalization rate, with the rate being highest in the youngest ages (17 – 24 years), decreasing in early to mid-adulthood and increasing again in later adulthood. A somewhat similar pattern was observed for women.

The overall (both genders) age-specific rate for major trauma hospitalization increased significantly across all age groups ≥ 45 years and older (Table 6.2). The largest average annual increased was experienced by individuals ≥ 85 years of age: EAPC 3.7% (95% CI: 2.9% - 4.6%; p < 0.0001) per year. Men and women, however, showed distinct age-specific trends in injury hospitalization over the interval. Among women, age-specific rates increased for all age groups 65 years and older but remained stable in all younger age groups except for women 45 – 54 years old (Table 6.2). For older women, the largest average annual increase of 3.0% (95% CI: 1.8% - 4.3%; p <0.0001) per year occurred amongst individual > 85 years. In contrast, among men the age-specific hospitalization rates for severe injury increased for all age groups except for men between ages 17 – 24 years. The most modest, but statistically significant, average annual increase was observed for men 35 – 44 years while the largest average annual increase was seen amongst men ≥ 85 years:1.6% (95% CI: 0.2% - 2.9%; p=0.02,) and 4.8% (95% CI: 3.4% - 6.3%; p<0.0001) per year, respectively. .

6.3.4 Rates of Hospitalization by Mechanism of Injury

Falls were the most common mechanisms of injury, with an annual age-standardized rate of 25.3 (95% CI: 25.1 - 25.6) per 100,000 population. The age-specific hospitalization rates by cause of injury appear in Table 6.3. Similar to the observation for overall hospitalization rates, cause-specific rates of hospitalization for major trauma were highest among men across all age groups. Importantly, men 75 years and older had amongst the highest age-specific motor vehicle-related hospitalization rates; 31.9 per 100,000 population and 39.3 per 100,000 population in those aged 75 – 84 years and 85 years and older, respectively. For both men and women, fall-related injury hospitalizations remained relatively low between the ages of 17 to 64, but increased steeply among the elderly, peaking in those 85 years and older.

6.3.5 Trends in Hospitalization Rates by Mechanism of Injury

Over the eight year period hospitalization rates for falls increased significantly (Figure 6.5); the age-standardized rate of fall-related hospitalizations ranging from 23.3 per 100,000 population in 2002 to 28.0 per 100,000 population in 2009. As indicated by regression analysis, this reflected an estimated average annual percent increase of 3.0% (95% CI: 2.5% - 3.5%; p<0.0001) per year. As appears in Figure 6.5C, this increase was largely attributed to the increase in fall-related hospitalization for elderly patients who experience a 25% relative increase in major injury hospitalization (95.5 per

100,000 population in 2002 to 119.5 per 100,000 population in 2009). The EAPC for elderly patients over the study period was 3.8% (95% CI: 3.2% - 4.4%; p<0.0001) per year. The pattern for younger patients was more modest over the same interval, with an average annual increase of 2.0% (95% CI: 1.3% – 2.7%; p<0.0001). In contrast to falls, rates for motor vehicle-related hospitalization were stable, with non-significant temporal trends across both age groups and the overall cohort (Figure 6.5). Interestingly, motor vehicle-related severe injury hospitalization for younger patients was generally stable from 2002 to 2005, but increased sharply in 2006 and declined in 2008 and 2009 (Figure 6.5B).

6.4 Discussion

To our knowledge, this is the first study to examine population based rates of major injury hospitalization across Canada. We found that between 2002 and 2009, elderly (≥ 65) individuals constituted an increasing proportion of hospital admissions for major trauma, with individuals between the ages of 75 - 84 years representing the highest number of major trauma admissions across all age groups in each year of the study. We also demonstrated a 21% relative increase and an average annual increase of 3.3% in the age-standardized rates of major trauma hospitalization for elderly patients over the period. Although other comparative data examining population-based temporal trends in major trauma hospitalizations are sparse, the findings of an increasing proportion of elderly in the trauma patient population align with previous reports.[179 166, 180-183] For example, a 2003 study from the US showed that from 1979-83 to 1996-2000, the proportion of individuals aged 75 and older admitted to hospital following an injury more than doubled.[179] This was accompanied by a marked decrease in the number of admissions for men under 40 years (from 41% in 1979-83 to 26% in 1996-2000). More recently based on data from the Netherlands, Hartholt and colleagues reported a 213% increase in the number of traumatic head-injury-related hospitalizations in individuals aged ≥ 65 years, between 1986 and 2008.[166] However, evidence regarding recent trends in trauma hospitalization rates is less consistent,[184, 185] largely due to the differences in the time period and the trauma population examined in these studies.

While explanations for the increasing numbers and rates of severe injury hospitalization, in particular among the elderly population, cannot be determined from these data, as suggested previously, plausible explanations include the concomitant increase in the proportion of the population that are elderly,[166,179, 186] the higher incidence of chronic conditions in this population that may predispose them to higher injury risk,[166] and functional declines that make the elderly more susceptible to injury, in particular fall related injury.[187, 188] Attention is drawn to our data demonstrating that, among the elderly, more than 78% of the severe injury hospitalizations were due to falls. Moreover, consistent with previous data,[166] we observed increasing age-standardized rates of fall-related major trauma hospitalization among the elderly, notably a 25% relative increase over the period examined. This suggests that an increased risk for fall related injuries may contribute, in part, to the increased rate of severe injury hospitalizations observed in the elderly during the study interval.

We demonstrated stable or declining rates in motor vehicle-related hospitalizations in the overall population and across both the younger (< 65 years) and older (≥ 65 years) populations. However, we found an increasing temporal trend in fall-related severe injury hospitalization rates among the elderly, a finding consistent with other reports.[166, 182] If the latter observed trends in injury hospitalization for the elderly population persist, then successful strategies aimed at reducing injury hospitalizations will need to include fall prevention amongst the elderly.

In addition to higher mortality rates as compared to younger patients,[189, 190] previous studies have established marked functional decline and disability [191] and increased risk of admission to a nursing home[192] among older population following injury. More recently, Fleischman and colleagues have reported significantly higher emergency medical services use and costs by the elderly in the year following an injury hospitalization.[193] The observed increases in both the absolute numbers and rate of severe injury hospitalizations in the elderly population noted in this study, therefore, have important practice and policy relevance. Importantly, these data supports the call for better strategies to manage this population, including the need to develop standardized evidence-based clinical protocols targeted specifically to the elderly trauma population.[186] Further, these data highlight the need for more proactive efforts to develop policies and supportive structures to improve trauma care organization across the provinces.

Our data on major injury hospitalization rates should be interpreted in light of certain limitations. First, information on patients dying prior to hospitalization is not included, therefore, hospitalization rates underestimates the true incidence of severe injury. A second and related limitation is the potential for over estimation of rates due to double counting of patients. We attempted to minimize counting the same injury more than once but our approach may have missed some patients. Finally, we included a relatively short observation period which might have masked distinct stages of trends in severe injury hospitalizations, as observed in similar studies of longer duration.[166, 179]

6.5 Conclusion

The results of the current study suggest that the burden of trauma, in particular severe trauma, may be shifting towards elderly patients. If this trend persists, the aging of the Canadian population will likely lead to future increases in the number of elderly trauma admissions. In the absence of strategies to mitigate the growing burden, current trauma resources are likely to become overwhelmed.[180, 186] Greater emphasize on preventive strategies aimed at the elderly population are warranted. Future population based studies aimed at understanding the reasons behind the increased rates, would be informative to both policy and injury prevention directions.

Tables and Figures Chapter 6

Table 6.1 Temporal trends in the characteristics of the study population

	All (n=98,937)	2002 (n=9,900)	2003 (n=10,497)	2004 (n=11,690)	2005 (n=12,064)	2006 (n=13,202)	2007 (n=13,651)	2008 (n=13,610)	2009 (n=14,323)
Female (%)	33,098 (33)	3,379 (34)	3,440 (33)	3,910 (33)	3,956 (34)	4,430 (33)	4,474 (33)	4,516 (33)	4,993 (35)
Median Age (IQR)	53 (42)	53 (42)	52 (42)	52 (42)	53 (42)	53 (42)	54 (42)	57 (42)	58 (40)
Age ≥ 65 yrs. (%)	38.5	37.5	36.5	36.7	37.4	37.3	38.0	41.2	42.1
Median ISS IQR)*	21 (9)	20 (9)	20 (9)	20 (9)	20 (9)	21 (9)	21 (9)	21 (9)	21 (9)
ISS (%)									
16 – 24	54,516 (55)	5,573 (56)	6,0012 (57)	6,603 (57)	6,717 (56)	7,280 (55)	7,319 (54)	7,315 (54)	7,697 (54)
25 – 47	41,273 (42)	4,000 (41)	4,131 (40)	4,704 (40)	4943 (41)	5,511 (42)	5,897 (43)	5,844 (43)	6,243 (44)
48 – 75	2,244 (2)	232 (2)	236 (2)	261 (2)	304 (2)	297 (2)	330 (2)	325 (2)	259 (2)
Missing[#]	904 (1)	95 (1)	118 (1)	122 (1)	100 (1)	114 (1)	105 (1)	126 (1)	124 (1)
AIS ≥ 3*									
Head	47,881 (48)	4,616 (47)	4,796 (46)	5,428 (47)	5,730 (47)	6,392 (49)	6,728 (49)	6,759 (50)	7,432 (52)
Chest	38,186 (39)	3,763 (38)	4,136 (40)	4,523 (39)	4,753 (40)	5,183 (39)	5,442 (40)	5,166 (38)	5,220 (37)
Abdomen	4,869 (5)	515 (5)	522 (5)	597 (5)	630 (5)	679 (5)	655 (5)	640 (5)	631 (5)
Spine	4,303 (4)	476 (5)	452 (4)	499 (4)	516 (4)	589 (4)	592 (4)	570 (4)	609 (4)
Mechanism n (%)									
MVC	35,292 (36)	3,815 (38)	3,999 (38)	4,270 (37)	4,429 (37)	4,759 (36)	4,838 (35)	4,545 (33)	4,637 (32)
Other Blunt	8,374 (8)	803 (8)	905 (9)	1,043 (9)	1,043 (9)	1,173 (9)	1188 (9)	1,067 (8)	1,152 (8)
Fall	45,932 (46)	4,445 (45)	4,650 (44)	5,292 (45)	5,415 (45)	5,989 (45)	6,307 (46)	6,702 (49)	7,132 (50)
Stabbing	4,170 (4)	371 (4)	444 (4)	486 (4)	547 (4)	595 (5)	610 (4)	540 (4)	577 (4)
Firearm	982 (1)	107 (1)	98 (1)	121 (1)	139 (1)	123 (1)	115 (1)	150 (1)	129 (1)
Other	4,187 (4)	359 (4)	401 (4)	478 (4)	491 (4)	563 (4)	593 (4)	606 (4)	696 (5)

ISS – Injury severity score; AIS – Abbreviated injury severity; MIZ – Metropolitan influenced zone; * excludes patients within missing ISS or ISS < 15 who died within 24 hours of hospitalization. The ISS values for these patients are assumed to be incomplete due to incomplete diagnostic workup. Percentages may add to over a 100 because of rounding

Table 6.1 (continued)

	All (n=98,937)	2002 (n=9,900)	2003 (n=10,497)	2004 (n=11,690)	2005 (n=12,064)	2006 (n=13,202)	2007 (n=13,651)	2008 (n=13,610)	2009 (n=14,323)
Comorbidities									
0	18,766 (19)	1,587 (16)	1,910 (18)	2,296 (20)	2,312 (19)	2,625 (20)	2,664 (20)	2651 (19)	2,721 (19)
1	20,941 (21)	1,905 (19)	2,288 (22)	2,544 (22)	2,576 (21)	2,749 (21)	2,877 (21)	2929 (22)	3,074 (21)
2	17,290 (17)	1,705 (17)	1,802 (17)	2,129 (18)	2,100 (17)	2,312 (18)	2,356 (17)	2333 (17)	2,553 (18)
3	12,489 (13)	1,294 (13)	1,361 (13)	1,418 (12)	1,489 (12)	1,699 (13)	1,680 (12)	1724 (13)	1,826 (13)
≥ 4	29,451 (30)	3,409 (34)	3,136 (30)	3,303 (28)	3,587 (30)	3,817 (29)	4074 (30)	3979 (29)	4,149 (29)
Location									
Urban	74,822 (76)	7,600 (77)	7,898 (75)	8,780 (75)	9,122 (76)	10,009 (76)	10,295 (75)	10,292 (76)	10,826 (76)
Rural	20,166 (20)	1,960 (20)	2,184 (21)	2,460 (21)	2,484 (20)	2,681 (20)	2,805 (21)	2,756 (21)	2,836 (21)
Missing	3,949 (4)	340 (4)	415 (4)	450 (4)	458 (4)	512 (4)	551 (4)	562 (4)	661 (5)
Location									
CMA	55,911 (56)	5,600 (57)	5,782 (55)	6,540 (56)	6,791 (56)	7,422 (56)	7,774 (57)	7,841 (58)	8,161 (58)
CA	17,354 (18)	1,758 (18)	1,908 (18)	2,090 (18)	2,141 (18)	2,315 (18)	2,386 (17)	2,335 (17)	2,439 (17)
Strong MIZ	4,682 (5)	502 (5)	523 (5)	554 (5)	552 (5)	625 (5)	671 (5Z)	619 (5)	636 (5)
Moderate MIZ	7,445 (8)	760 (8)	826 (8)	899 (8)	911 (8)	987 (7)	1,013 (7)	966 (7)	1,083 (7)
Weak/No MIZ	10,966 (11)	1,041 (11)	1,187 (11)	1,316 (11)	1,389 (11)	1,516 (11)	1,497 (11)	1,472 (11)	1,544 (11)
Territories	321 (<1)	36 (<1)	27 (<1)	35 (<1)	49 (<1)	48 (<1)	35 (<1)	44 (<1)	47 (<1)
Missing	2,258 (2)	198 (2)	244 (3)	256 (2)	231 (2)	289 (2)	293 (2)	334 (3)	413 (3)

ISS – Injury severity score; AIS – Abbreviated injury severity; MIZ – Metropolitan influenced zone;
* excludes patients within missing ISS or ISS < 15 who died within 24 hours of hospitalization. The ISS values for these patients are assumed to be incomplete due to incomplete diagnostic workup. Percentages may add to over a 100 because of rounding

Figure 6:1 Proportion of hospital admission by age group (2002 – 2009)

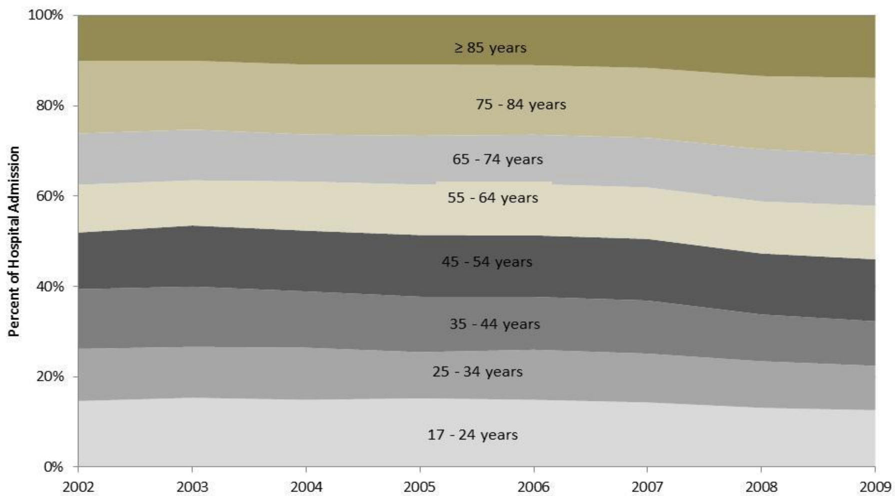


Figure 6.1A: All

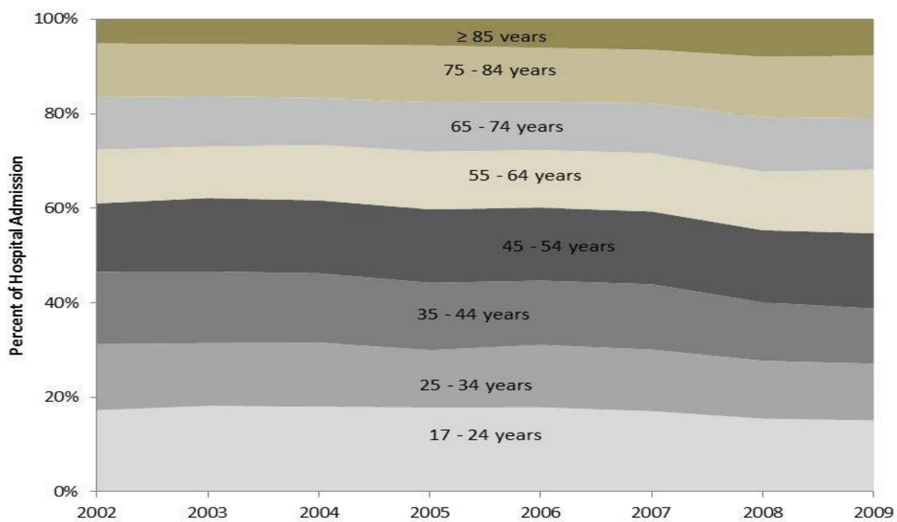


Figure 6.1B: Men

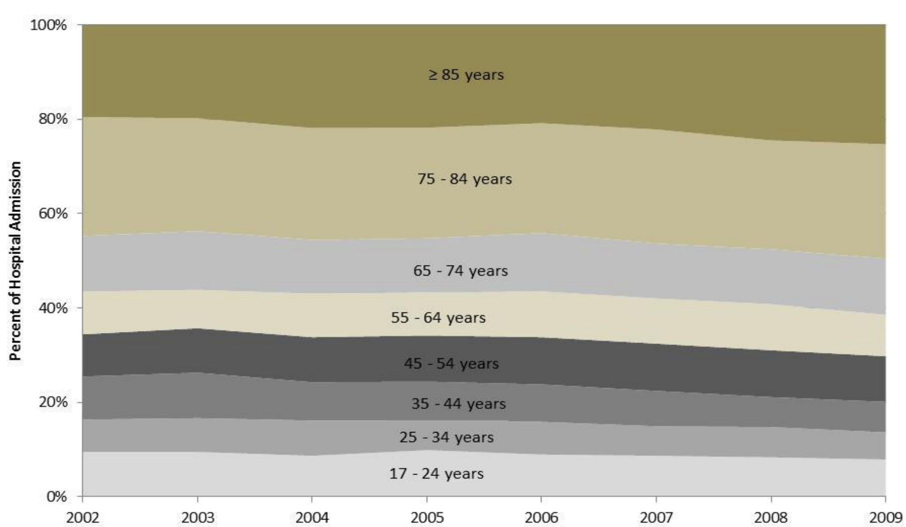


Figure 6.1C:

Figure 6:2 Temporal Trends in Age-standardized Hospitalization Rates for Major Trauma per 100,000 Population Stratified by Gender

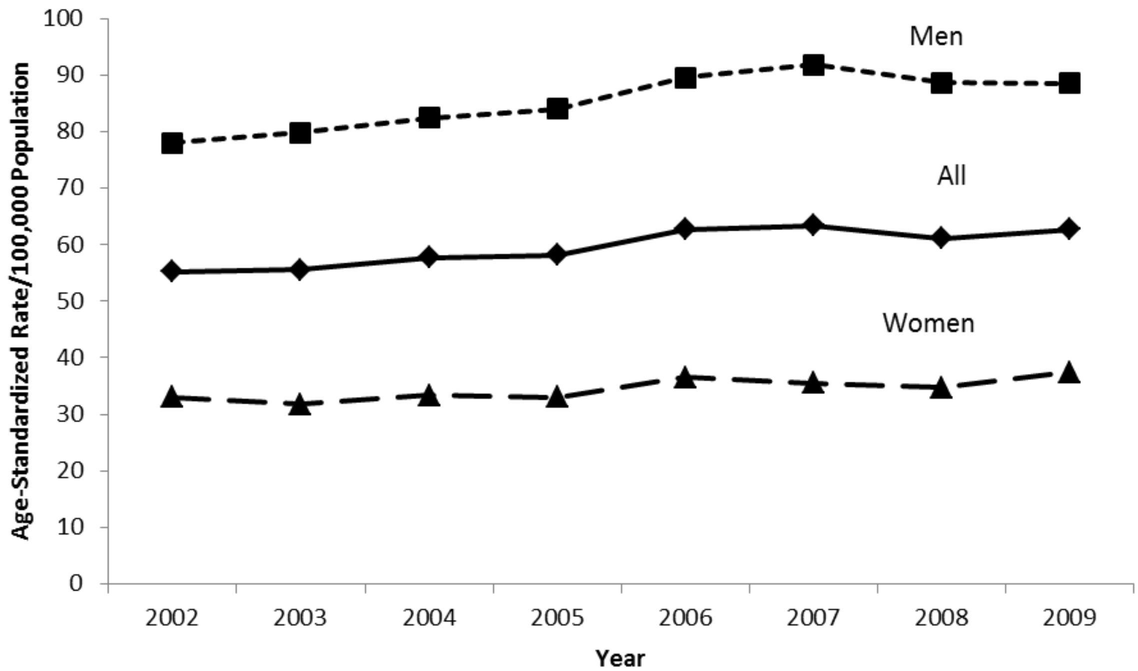


Figure 6:3 Temporal Trends in Age-standardized Hospitalization Rates for Major Trauma per 100,000 Population Stratified by age

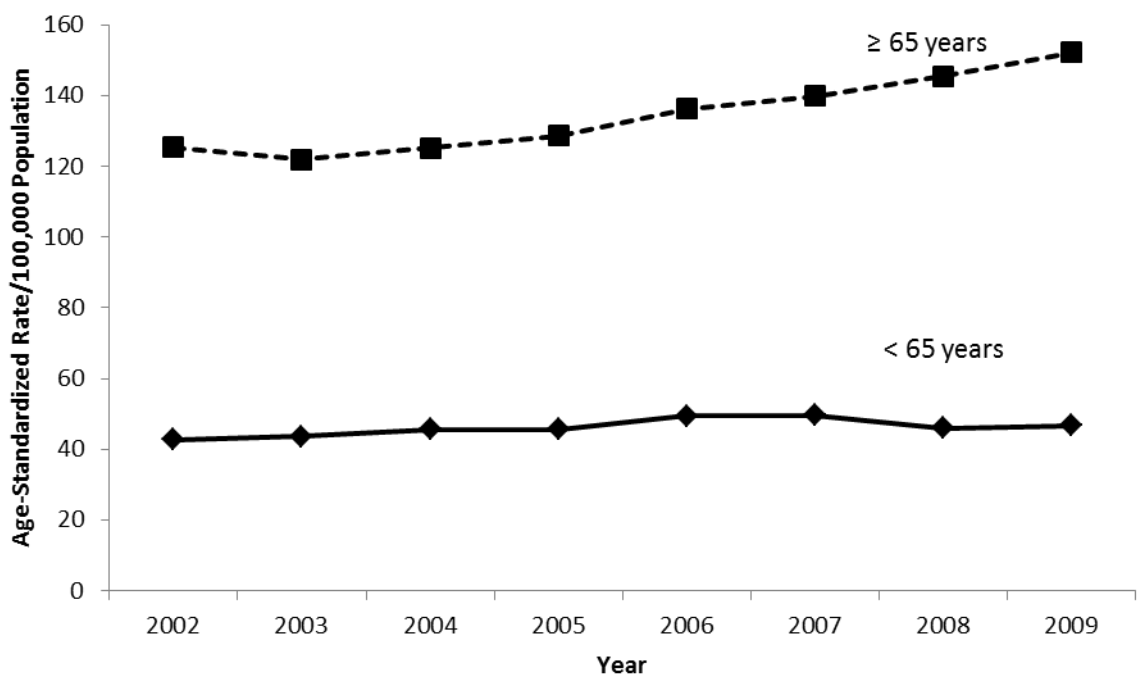


Figure 6:4 Age-specific Hospitalization Rates of Major Trauma Hospitalization per 100,000 Population (all years)

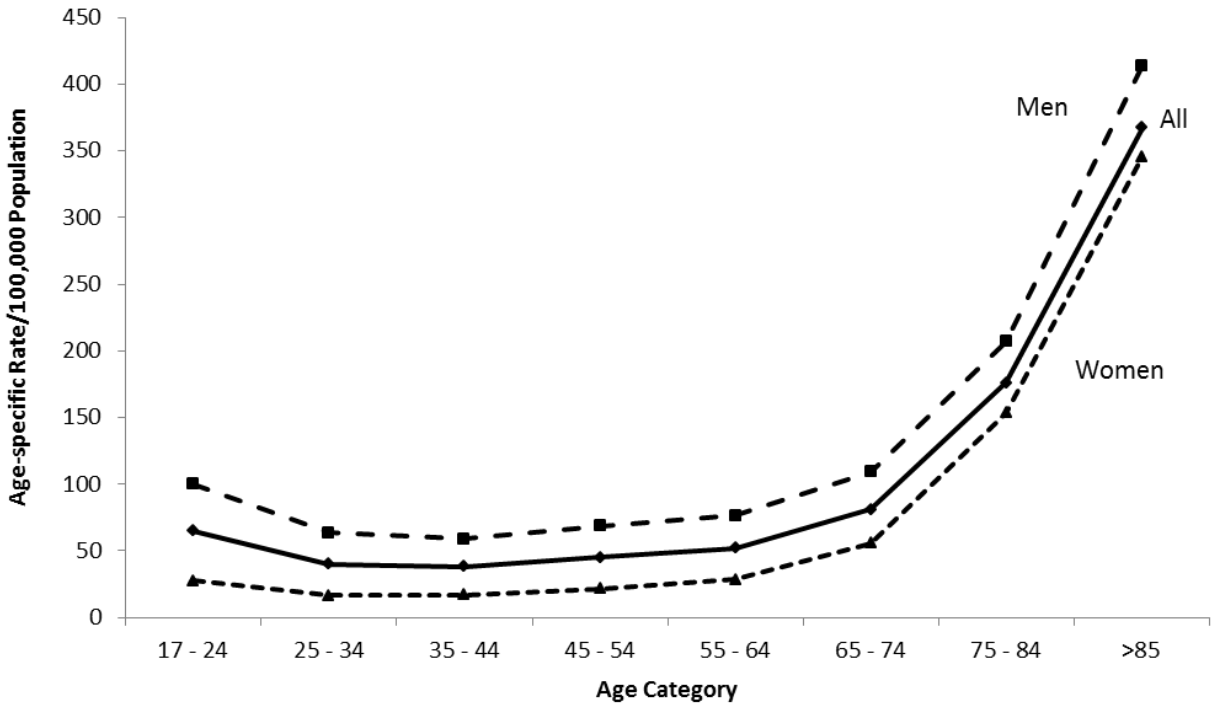


Table 6.2 Temporal Trends in Age-specific Rates of Hospitalization for Major Trauma per 100,000 Population Stratified by Gender

All

Age	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)	p value
17-24	59.9	63.3	64.2	67.0	70.6	69.0	62.2	62.1	4%	0.5%(-1.1 - 2.1)	0.54
25 - 34	37.1	37.3	40.6	37.1	43.9	43.6	40.6	39.8	7%	1.6% (-0.1 - 3.3)	0.07
35 - 44	35.3	36.9	36.9	37.7	39.7	41.8	37.3	38.0	8%	1.2% (0.0 -2.5)	0.05
45 - 54	39.2	42.1	43.4	44.3	47.1	47.6	45.8	48.2	23%	2.6% (1.7 - 3.4)	<0.0001
55 - 64	50.0	45.7	50.4	51.2	54.6	54.5	52.9	55.0	10%	2.0% (1.0 - 3.1)	<0.001
65 - 74	75.2	75.7	73.5	77.9	84.5	86.0	87.9	86.5	15%	2.8% (1.9 - 3.6)	<0.0001
75 - 84	166.2	156.0	162.6	168.2	176.5	181.2	186.5	205.9	24%	3.4% (2.4 - 4.5)	<0.0001
>85	328.1	323.9	355.2	345.3	359.0	369.7	405.0	418.2	27%	3.7% (2.9 - 4.6)	<0.0001

Men

Age	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)	p value
17-24	91.0	98.5	100.7	102.8	109.7	107.5	95.3	94.4	4%	0.4% (-1.4 - 2.3)	0.67
25 - 34	58.6	58.6	63.2	58.9	69.4	70.6	64.4	63.3	8%	1.8%(0.1 - 3.6)	0.04
35 - 44	53.7	56.1	57.4	58.5	61.0	65.7	59.2	58.4	9%	1.6% (0.2 - 2.9)	0.02
45 - 54	59.6	65.4	66.5	68.0	71.1	72.4	69.3	72.7	22%	2.3% (1.4 - 3.2)	<0.0001
55 - 64	71.4	67.6	73.0	75.8	78.8	80.0	77.0	82.8	16%	2.4% (1.4 - 3.4)	<0.0001
65 - 74	101.6	101.0	97.8	106.6	110.0	117.4	122.5	113.8	12%	2.8% (1.6 - 4.1)	<0.0001
75 - 84	188.3	183.2	190.0	205.0	204.6	206.6	227.3	238.9	27%	3.8% (2.7 - 4.8)	<0.0001
>85	353.8	365.9	372.2	373.5	410.0	429.0	491.0	460.9	30%	4.8% (3.4 - 6.3)	<0.0001

Women

Age	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)	p value
17-24	27.3	26.4	25.7	29.3	29.3	28.2	27.1	28.0	3%	0.7% (-0.9 - 2.3)	0.41
25 - 34	15.2	15.6	17.7	15.0	18.4	16.5	16.7	16.2	7%	0.9%(-0.09 - 2.8)	0.36
35 - 44	16.7	17.5	16.1	16.7	18.2	17.6	15.3	17.4	4%	0.01% (-1.7 - 1.7)	0.99
45 - 54	18.9	19.1	20.5	20.7	23.1	22.8	22.3	23.6	25%	3.3% (1.7 - 4.9)	<0.0001
55 - 64	28.9	24.2	28.3	27.0	31.0	29.6	29.4	28.0	-3%	1.1% (-0.7 - 3.40	0.22
65 - 74	51.1	52.6	51.2	51.8	61.3	57.2	56.1	61.4	20%	2.6% (1.2 - 4.0)	<0.001
75 - 84	150.8	136.8	143.1	141.4	155.8	162.2	155.4	180.4	20%	2.9% (1.3 - 4.5)	<0.001
>85	316.6	304.9	347.5	332.3	335.1	341.6	363.6	397.4	26%	3.0% (1.8 - 4.3)	<0.0001

* EAPC – estimated annual percentage change. EAPC and p-value from negative binomial or Poisson regression analyses, as appropriate

Table 6.3 Age-specific Rates of Major Trauma Hospitalization per 100,000 Population Stratified by Mechanism of Injury and Gender

Mechanism	Age Group	Rate Women	Rate Men	Male to Female Rate Ratio (95% CI)
BLUNT	17 - 24	1.4	15.2	11.2 (9.3 - 13.1)
	25 - 34	1.2	10.9	8.8 (7.4 - 10.2)
	35 - 44	1.4	9.7	7.1 (6.1 - 8.1)
	45 - 54	1.0	8.8	9.0 (7.5 - 10.5)
	55 - 64	0.8	6.7	8.0 (6.3 - 9.8)
	65 - 74	1.2	5.7	4.7 (3.6 - 5.8)
	75 - 84	2.0	5.6	2.8 (2.1 - 3.4)
	>85	4.0	5.9	1.5 (1.0 - 2.0)
FALL	17 - 24	2.8	11.3	4.0 (3.5 - 4.5)
	25 - 34	2.4	9.7	4.0 (3.5 - 4.5)
	35 - 44	3.8	13.8	3.6 (3.3 - 3.9)
	45 - 54	7.3	23.8	3.2 (3.0 - 3.5)
	55 - 64	14.1	37.4	2.7 (2.5 - 2.8)
	65 - 74	37.1	71.6	1.9 (1.8 - 2.0)
	75 - 84	124.8	158.4	1.3 (1.2 - 1.3)
	>85	312.1	349.5	1.1 (1.1 - 1.2)
MVC	17 - 24	21.5	51.5	2.4 (2.3 - 2.5)
	25 - 34	11.4	30.6	2.7 (2.5 - 2.8)
	35 - 44	10.1	26.4	2.6 (2.5 - 2.8)
	45 - 54	12.1	29.2	2.4 (2.3 - 2.6)
	55 - 64	12.1	26.5	2.2 (2.0 - 2.3)
	65 - 74	14.5	25.6	1.8 (1.6 - 1.9)
	75 - 84	20.5	31.9	1.6 (1.4 - 1.7)
	>85	14.7	39.3	2.7 (2.3 - 3.1)

Figure 6:5 Temporal Trends in Age-standardized Hospitalization Rate for Major Trauma per 100,000 Population Stratified by Mechanism of Injury

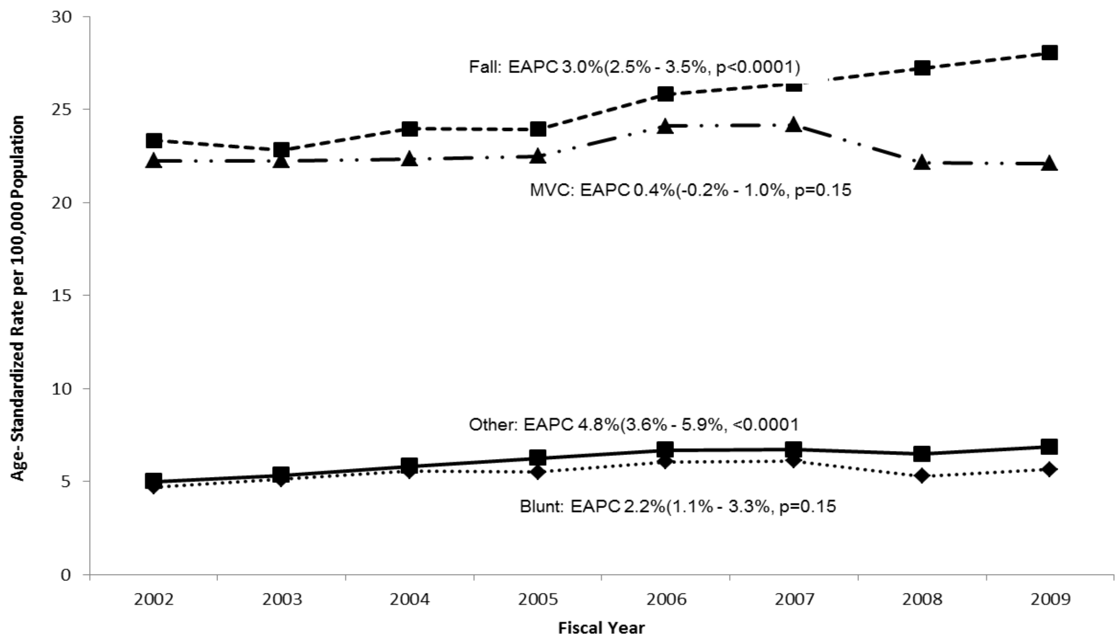


Figure 6:6 Temporal Trends in Age-standardized Hospitalization Rate for Major Trauma for Patients 17 – 64 years Stratified by Mechanism of Injury

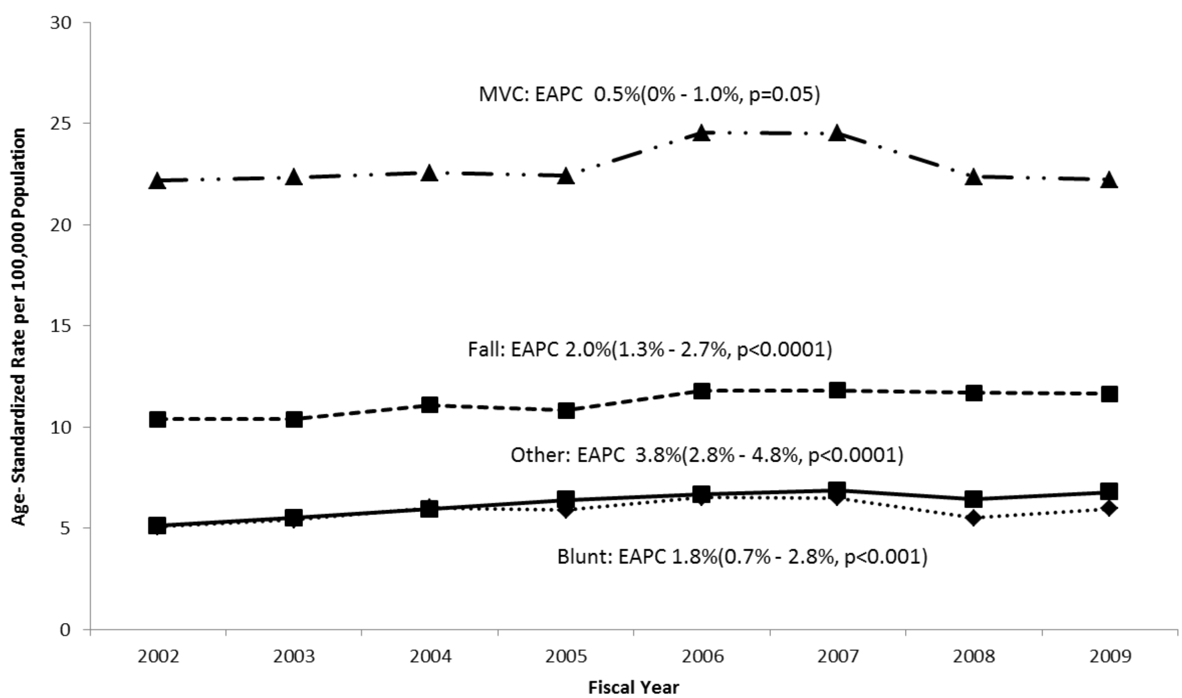
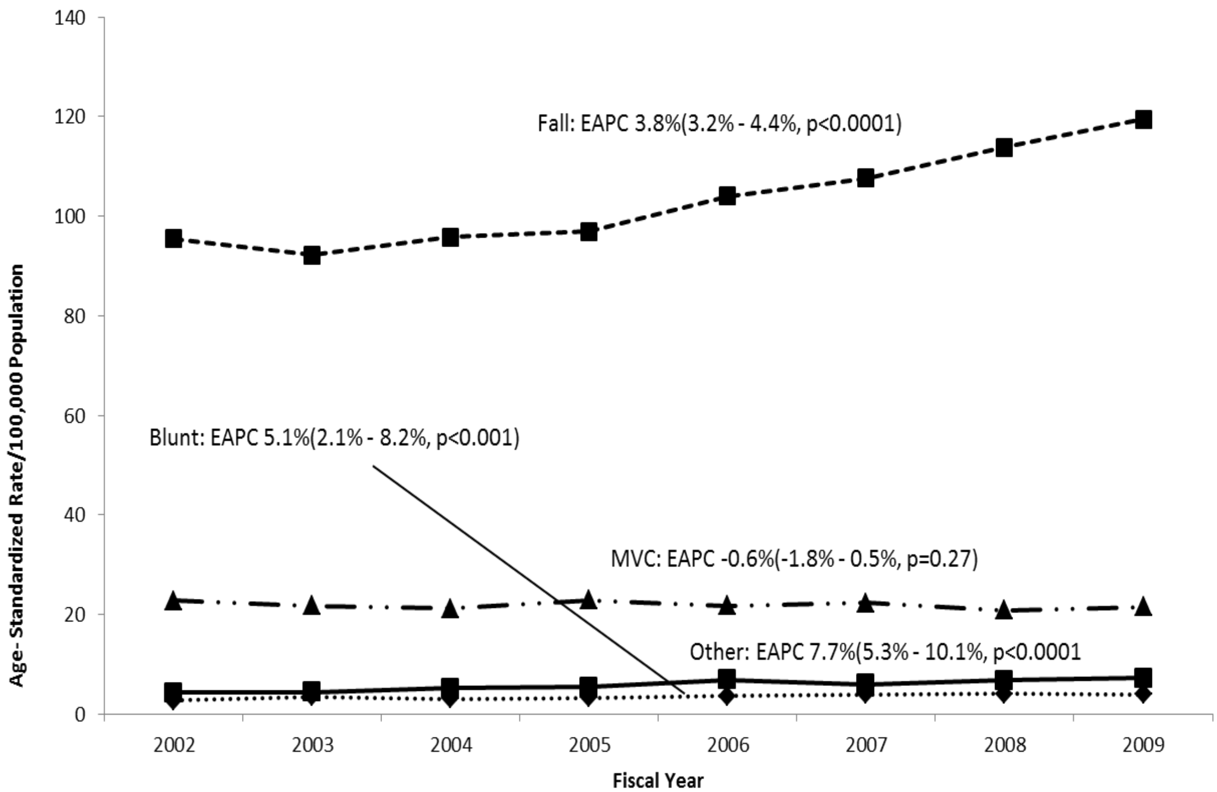


Figure 6:7 Temporal Trends in Age-standardized Hospitalization Rate for Major Trauma for Patients 65 years and older Stratified by Mechanism of Injury



MVC- Motor Vehicle Collision; EAPC – estimated average annual percent change based on Poisson or negative binomial regression analyses.

Chapter 7 : Temporal and Provincial Trends in Severe Injury Hospitalization in Canada: A Population-based Study (Paper 3)

7.1 Introduction

Despite the implementation of important injury prevention initiatives in recent decades, globally, injury remains a significant contributor to both mortality and morbidity.[177] In particular, injury is the leading cause of death in the first four decades of life[177] and as such this disease has primarily been regarded as a disease of the young. However, with the aging of the population, in particular in western countries, there is concern that elderly patients will comprise an increasing proportion of hospital injury admissions,[180, 186] with estimates from the United States (US) suggesting that this population will account for as much as 40% of the injury hospitalizations by 2050.[186]

Hospitalization for severe injury across Canadian provinces is not well characterized and the extent to which these findings are applicable to the Canadian setting is not known. Importantly, regional patterns of injury incidence, and therefore injury hospitalizations, will be influenced by injury risk factors such as population demographics and topography.[34, 37, 194] We found no reports comparing regional differences in severe injury hospitalization patterns in Canada within the peer reviewed literature. Knowledge of whether hospitalization for severe injury have changed over time or whether there are regional differences in injury hospitalizations can provide an indication of the extent to which severe injury remains a health issue in Canada, as well as inform injury prevention targets and health policy directions. Accordingly, we sought to describe patterns in patient demographics, mechanisms of injury, and severe injury hospitalization rates across several Canadian provinces. Given the evidence of changing patterns in age-related hospitalizations for severe injury,[179] we also sought to explore trends and regional differences across age.

7.2 Methods

The study methods have been described in detail in the methods chapter (Chapter 5) and summarized in the previous chapter (Chapter 6).

7.3 Results

7.3.1 Patient Demographics

Table 7.1 provides a description of the patients included in the study. There were 98,937 hospitalizations for severe injury across the nine provinces and territories, of which the most populous provinces (Ontario, British Columbia and Alberta) accounted for 81,299 (82.2%). Patients 65 years and older and males represented 38.5% and 66.6% of the cohort, respectively. As detailed in Table 7.2, elderly patients (≥ 65 years) represented an increasing proportion of patients in all provinces except Manitoba and Saskatchewan over the eight-year period. For Manitoba and Saskatchewan the relative decline in the proportion of admissions for elderly patients was 9.4% and 7.9%, respectively.

7.3.2 Temporal Trends and Regional Variation in Hospitalization Rates

The annual trends in hospitalization rates for severe injury, standardized to the age distribution of the 1991 Canadian population for each province (except Prince Edward Island and the Territories) are detailed in Table 7.2 and Figure 7.1. The lowest age-standardized hospitalization rates for severe injury were observed in Newfoundland and Labrador, ranging from 32.0 (95% CI: 26.5 – 37.4) per 100,000 population in 2002, to 41.9 (95% CI: 35.7 – 48.2) in 2009. Amongst the most populous provinces (Ontario, British Columbia and Alberta), Ontario experienced the lowest hospitalization rates for severe injury; from a low of 48.8 (95% CI: 47.5 – 50.2) per 100,000 population in 2002 to a high of 52.4 (95% CI: 51.1 – 53.8) per 100,000 population in 2009. The overall injury hospitalization rates increased in each province, with the increase being statistically significant in all provinces except New Brunswick (p=0.41, from negative binomial regression). Alberta experienced the most modest increase in major injury hospitalization rates, from 75.1 (95% CI: 71.6 – 78.6) in 2002 to 80.7 (95% CI: 77.4 – 84.0) per 100,000 population in 2009, (EAPC 1.6%, [95% CI: 0.8 – 2.4] p<0.001). In contrast, the largest EAPC of 4.4% (95% CI: 2.0 – 6.9, p<0.001) was observed in Newfoundland and Labrador:

Table 7.3 details the trends in major trauma hospitalization for younger and older individuals by province. Among the elderly population, increasing major trauma hospitalization rates were observed for all provinces; this trend was statistically significant for Alberta (EAPC 2.8%, p<0.001), British Columbia (EAPC 4.8%, p<0.0001), Newfoundland and Labrador (EAPC 6.6%, p =0.002), Nova Scotia (EAPC 3.7%, p=0.002), Ontario (EAPC 3.2%, p<0.001) and Saskatchewan (EAPC 2.5%, p=0.02).

Further, with the exception of Saskatchewan and Manitoba, the increase in major trauma hospitalization rates were more pronounced among the elderly compared to younger population, as reflected in the lower EAPC among younger individuals. Notably, while Manitoba experienced a non-significant increase in the severe injury hospitalization amongst the elderly, a statistically significant increase was observed amongst younger individuals in this province (EAPC 4.4%, $p<0.0001$).

Review of the age-standardized rates of major trauma hospitalization, stratified by gender and age (Figure 7.2) demonstrated diverging trends across the provinces. Severe injury hospitalization rates increased significantly in all four age-gender groups in British Columbia only, with estimated average annual increase ranging from a modest 1.7% (95% CI: 0.75% – 2.7%; $p < 0.001$) per year for young men to a high of 4.8% (95% CI: 3.4% - 6.3%; $p<0.0001$) per year amongst elderly men. While the estimates for the less populous provinces (Newfoundland and Labrador, Nova Scotia and New Brunswick) were less stable, consistent increases in major trauma hospitalization rates among elderly men were noted in all provinces. Importantly, as indicated by the regression analyses the time trends in hospitalization rates were statistically significant ($p < 0.05$) among elderly men in all provinces except Manitoba, New Brunswick and Saskatchewan. In Saskatchewan, there was a significant increase in the hospitalization rates for young women (EAPC 5.5% (95% CI: 2.3% – 8.8%; $p< 0.001$)) and young men (EAPC 3.7% (95% CI: 1.9% – 5.4%; $p< 0.0001$)).

7.3.3 Regional Trends in Cause of Injury

Severe injury hospitalizations due to motor vehicle collision and falls are described in Table 7.4. Between 2002 and 2009 Ontario had amongst the lowest severe injury hospitalization due to motor vehicle collision ranging from a high of 17.9 per 100,000 population in 2002 to 15.8 per 100,000 population in 2009. As estimated by negative binomial regression analysis, this change reflected a modest decline with an average annual decrease of -1.0 % per year (p=0.04). Among the remaining provinces, hospitalization rates for motor-vehicle related injuries increased significantly in Manitoba (EAPC 4.4%, p=0.007) and Saskatchewan (EAPC 4.2%, p<0.001), while the rates were stable in all other provinces. In contrast, over the study interval fall related injury hospitalization rates rose across all provinces, with the increase significant in all provinces except Manitoba and New Brunswick. Notably, the estimated EAPC in hospitalization rates for fall related injuries ranged from 2.0% (New Brunswick) to 4.5% (British Columbia and Newfoundland and Labrador).

7.3.4 Overall Pattern in Injury Hospitalization

Table 7.5 details the results of the multivariable negative binomial regression analysis examining province as an explanatory variable for injury hospitalization. The regression coefficients indicate that, compared to Ontario, severe injury hospitalization rates were higher in Alberta (rate ratio (RR) 1.55 [95% CI: 1.47 – 1.63]), British Columbia (RR 1.36 [95% CI: 1.29 – 1.43]), Manitoba (RR 1.20 [95% CI: 1.13 – 1.28]), New Brunswick (RR 1.09 [95% CI: 1.02 – 1.17]), and Saskatchewan (RR 1.45 [95% CI: 1.37 – 1.54]). In contrast, hospitalization rates for Newfoundland and Labrador was lower than that in Ontario (RR 0.75 95% CI: [0.70 - 0.81]). There were no significant difference in severe injury hospitalization rates between Ontario and Nova Scotia. For the age comparisons, a clear pattern of increasing hospitalization with increasing age was observed. Notably, after adjustment for gender, fiscal year and province of residence, compared to younger patients (17 – 24 years) hospitalization increased sharply above age 60 – 64 years.

7.4 Discussion

This population-based assessment of major trauma hospitalizations across Canadian provinces has two important findings. First, between 2002 and 2009, the age-standardized hospitalization rates for major trauma increased across all provinces. Second, there were marked regional variability in the patterns and rates of major trauma hospitalizations across the provinces. These findings are discussed below.

7.4.1 Temporal Trends in Major Trauma Hospitalization Rates

The estimated annual percent change in age-standardized major trauma hospitalization rates for the overall cohort in each province ranged from 1.6% to 4.4% over the period examined. The data suggest that, for the majority of the provinces, the observed increases in hospitalization rates are mainly associated with increasing rates in the elderly population. Notably across all provinces, the risk of hospitalization for major trauma was greater in the elderly with a sharp increase in risk in each age group above 59 – 64 years of age. Further, with the exception of Manitoba, New Brunswick and Saskatchewan, the study highlighted that elderly men (≥ 65 years) experienced the largest annual percent increase in age-standardized hospitalization rates over the period.

Contrary to the findings of Shinoda-Tawaga and Clark[179] we were unable to demonstrate decreasing injury hospitalizations among younger adults over time. However, our population based focus on major trauma (ISS > 15) and the more contemporary nature of our study timeframe limits the comparability between studies. Notwithstanding, the present findings suggests that an increase in major trauma hospitalization for younger patients has occurred in most provinces, with highest average annual changes observed in Saskatchewan and Manitoba. The reasons for the observed increase among the younger population are mostly unclear. While a number of provinces have implemented injury prevention programs and legislations primarily targeted at younger Canadians[195-198] the data suggest that either these programs have not have appreciably influenced hospitalization rates for severe injury amongst this group or that while these efforts may have been effective in reducing injury rates in young adults in the early period after implementation,[197, 198] the impact of these injury prevention activities may have attenuated over the intervening years and any gains made might have not been sustained.[198]

7.4.2 Regional Variation in Injury Hospitalization Rates

Our data provide evidence of regional variability in the pattern of injury hospitalizations across the country. Importantly, we observed a west to east gradient in hospitalizations for severe injury, with the more westerly provinces experiencing the highest injury hospitalization rates over the period examined. While the underlying cause of this variability cannot be determined from our study, plausible explanations include differences in injury risk profiles including for example, geography, population demographics such as age, gender and socioeconomic status.[34, 53, 54, 159, 199] An example of the differing injury risk profile is underscored by the data suggesting that differences in injury mechanisms appear to influence the variation in injury hospitalizations across the provinces. Notably, age-adjusted rates of motor vehicle-related severe injury hospitalization were highest in Saskatchewan and Manitoba. Further, data from within Canadian context have suggested important differences in the proportion of trauma patients that die in the pre-hospital setting.[53, 54] It is likely that these differences explain, in part, some of the variability in hospitalization rates seen across the provinces. Moreover, although unexplored in this study, it is also possible that provincial differences in the types of injury prevention programs implemented and the extent to which these programs are effective in reducing injury rates[197, 198] will influence injury rates within the provinces.

7.5 Limitations

Important strengths of our study include our use of population-based data and the pan-Canadian perspective taken. The findings, however, have some limitations. First, the administrative data used in our study did not include injury severity scores and we used ICD-10 diagnostic codes to generate these scores. The estimates of trends and regional variation in severe injury hospitalization rates are, therefore, dependent on the correct reporting of ICD-10 codes to prevent misclassification of patients. There is, however, no reason to suspect that there may be systematic differences in coding practice across the provinces or inconsistencies in coding practice over time. Further, to mitigate the possibility of excluding patients who were severely injured, we included all patients who died within 24 hours of hospitalization. As well, the period of observation included in our study was selected to reflect all data available since coding practices in the NTR was changed from International ICD-9 to ICD-10, and therefore obviates the potential impact of changes between the revisions. Second, we attempted to minimize the impact of multiple hospitalizations for a given patient by creating episode of care data based on encrypted health card numbers and admission dates. It is, however, possible that patients with multiple hospitalizations were included in our cohort which may result in an overestimation of the rates of severe injury hospitalizations. Third, in the absence of location of injury for each patient, estimates of injury hospitalization rates were based on patient residence. The bias this introduces in our estimates of provincial injury hospitalization rates is expected to be minimal given recent evidence to suggest that a majority of individuals are injured within10 km of their residence.[200]

7.6 Conclusions

To our knowledge, this is the first study to examine regional and temporal trends in severe injury hospitalizations within the pan-Canadian setting using a comprehensive dataset that captures all injury hospitalizations across the provinces. We demonstrated important variations across provinces, including much higher severe injury hospitalization rates in the more western regions of the country. Moreover, we found that the rates of injury hospitalizations have increased across most provinces over the recent eight year period, particularly among the elderly population. Understanding the reasons contributing to both regional and temporal trends will be important next steps in building on these findings. As important, our findings suggest the need for more targeted policies and injury prevention initiatives to address this continued public health problem. The provincial variation identified in this study will be informative to these activities.

Tables and Figures Chapter 7

Table 7.1 Patient characteristics by province (2002 – 2009)

Characteristics	BC	AL	SK	ON	MB#	NB#	NS	NL	PEI	TER	Total
Cases	20,892	17,408	5,300	42,999	3,920	2,631	3,417	1,336	457	577	98,937
Male (%)	14,142 (68)	12,144 (70)	3,663 (69)	27,516 (64)	2,691 (69)	1,729 (66)	2,266 (66)	937 (70)	312 (68)	439 (76)	65,839 (67)
Median Age (IQR)	53 (41)	47 (40)	48 (46)	60 (40)	47 (43)	54 (40)	57 (42)	54 (35)	56 (45)	39 (27)	54 (42)
Age ≥ 65 years n (%)	7,683 (37)	5,033 (29)	1,750 (33)	19,302 (45)	1,237 (32)	976 (37)	1,404 (41)	453 (34)	181 (40)	80 (14)	38,099 (39)
Median ISS* (IQR)	21 (9)	21 (9)	20 (9)	21 (9)	20 (9)	20 (9)	20 (9)	20 (9)	20 (9)	20 (9)	21 (9)
ISS (%)											
16 – 24	11,625 (56)	9,825 (56)	2,990 (56)	22,776 (53)	2,293 (58)	1,538 (58)	2,064 (60)	786 (59)	281 (61)	338 (58)	54,516 (55)
25 – 47	8,630 (41)	6,965 (40)	2,167 (41)	18,858 (44)	1,518 (39)	998 (37)	1,238 (36)	505 (38)	161 (35)	224 (38)	41,273 (42)
48 – 75	480 (2)	523 (3)	101 (2)	885 (2)	74 (2)	64 (2)	71 (2)	27 (2)	9 (2)	10 (2)	2,244 (2)
Missing#	157 (1)	95 (1)	33 (1)	480 (1)	35 (1)	31 (1)	44 (1)	18 (1)	6 (1)	5 (1)	904 (1)
Severe Injury AIS ≥ 3*											
Head	10,080 (48)	7,624 (44)	2,537 (48)	22,338 (52)	1,673 (43)	1,116 (42)	1,447 (42)	620 (46)	196 (43)	250 (43)	47,881 (48)
Chest	8,095 (39)	7,831 (45)	2,022 (38)	15,303 (36)	1,650 (42)	1,098 (42)	1,283 (38)	506 (38)	169 (37)	229 (40)	38,186 (39)
Abdomen	1,008 (5)	1,100 (6)	266 (5)	1,893 (4)	209 (5)	117 (4)	162 (5)	65 (5)	19 (4)	30 (5)	4,869 (5)
Spine	982 (5)	820 (5)	249 (5)	1,732 (4)	172 (4)	107 (4)	145 (4)	53 (4)	18 (4)	25 (4)	4,303 (4)
Mechanism (%)											
MVC	7,749 (37)	7,230 (42)	1,942 (37)	13,760 (32)	1,340 (34)	1,120 (43)	1,168 (34)	561 (42)	191 (42)	231 (40)	35,292 (36)
Other Blunt	2,000 (10)	1,677 (10)	609 (11)	2,978 (7)	411 (11)	191 (7)	271 (8)	101 (8)	31 (7)	105 (18)	8,374 (8)
Fall	9,280 (44)	6,519 (37)	2,060 (39)	22,649 (53)	1,525 (39)	1,183 (45)	1,758 (51)	613 (46)	212 (46)	133 (23)	45,932 (46)
Stabbing	773 (4)	1,016 (6)	385 (7)	1,400 (3)	384 (10)	40 (2)	90 (3)	22 (2)	6 (1)	54 (9)	4,170 (4)
Firearm	216 (1)	174 (1)	44 (1)	422 (1)	45 (1)	18 (1)	37 (1)	10 (1)	--¥	15 (3)	982 (1)
Other	874 (4)	792 (4)	260 (5)	1,790 (4)	215 (5)	79 (3)	93 (3)	29 (2)	16 (4)	39 (7)	4,187 (4)

BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NF – Newfoundland and Labrador; PEI – Prince Edward Island; TER - Territories; * excludes patients within missing ISS or ISS < 15 who died within 24 hours of hospitalization. # Data were not available for Manitoba in fiscal 2002 to 2003 and New Brunswick in 2003. ¥ dash indicates counts less than 5.

Table 7:1 (continued)

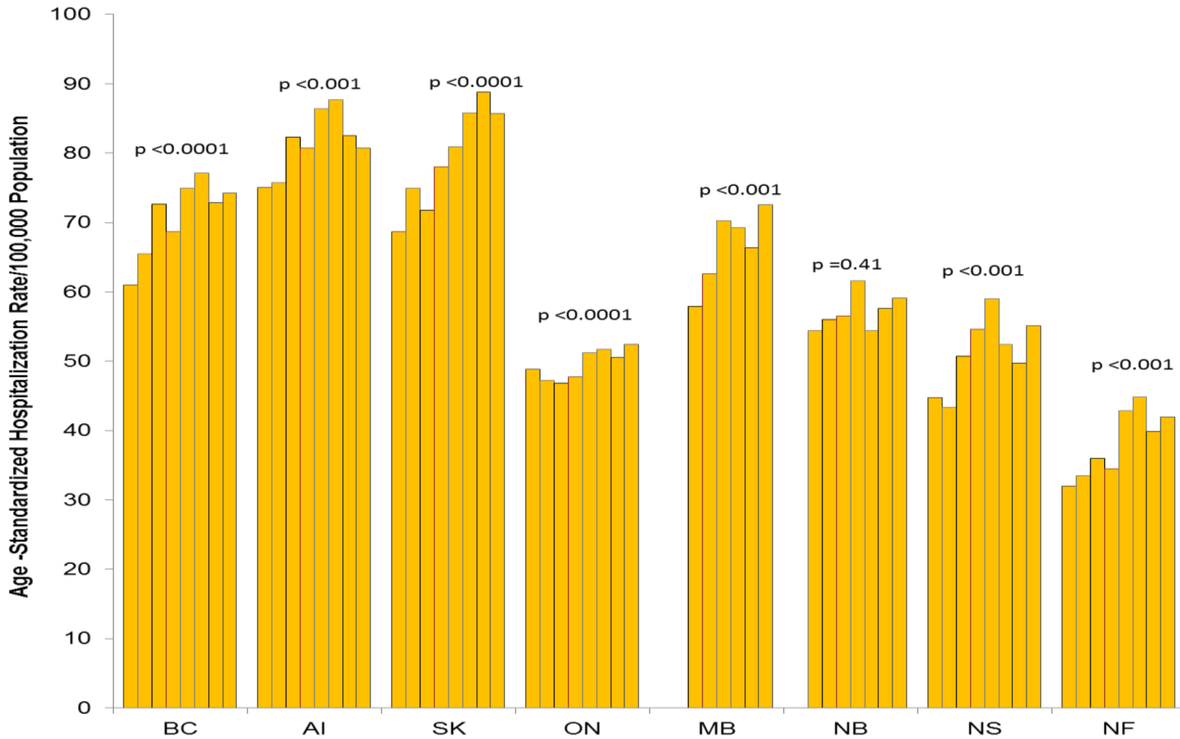
Characteristics	BC	AL	SK	ON	MB	NB	NS	NL	PEI	TER	Total
Comorbidities											
0	3,847 (18)	3,065 (18)	1,137 (21)	8,172 (19)	824 (21)	447 (17)	736 (22)	295 (22)	112 (25)	121 (21)	18,766 (19)
1	4,542 (22)	3,465 (20)	1,154 (22)	8,993 (21)	878 (22)	545 (21)	799 (23)	318 (24)	115 (25)	132 (23)	20,941 (21)
2	3,770 (18)	2,858 (16)	869 (16)	7,641 (18)	710 (18)	460 (17)	574 (17)	233 (17)	77 (17)	98 (17)	17,290 (17)
3	2,710 (13)	2,180 (13)	612 (12)	5,387 (13)	468 (12)	356 (13)	427 (13)	170 (13)	62 (13)	67 (12)	12,489 (13)
> 3	6,023 (29)	5,630 (33)	1,528 (29)	12,806 (30)	1,040 (26)	813 (31)	881 (26)	320 (24)	91 (20)	159 (28)	29,451 (30)
Location											
Urban	16,743 (80)	13,698 (79)	3,409 (64)	34,180 (79)	2,592 (66)	1,237 (47)	1,760 (52)	719 (54)	221 (48)	263 (46)	74,822 (76)
Rural	3,400 (16)	2,842 (16)	1,790 (34)	7,250 (17)	1,220 (31)	1,215 (46)	1,446 (42)	508 (38)	222 (49)	273 (47)	20,166 (20)
Missing	749 (3)	868 (5)	101 (2)	1,569 (4)	108 (3)	179 (7)	211 (6)	109 (8)	14 (3)	41 (7)	3,949 (4)
Location											
CMA	11,548 (55)	9,985 (57)	2,131 (40)	28,275 (66)	2,020 (52)	381 (14)	1,137 (33)	434 (32)	-		55,911 (58)
CA	5,358 (26)	2,089 (12)	718 (14)	6,689 (16)	251 (6)	1,210 (32)	773 (23)	174 (13)	216 (47)	-	17,354 (18)
Strong MIZ	367 (2)	650 (4)	129 (2)	2,973 (7)	144 (4)	184 (7)	109 (3)	40 (3)	83 (18)		4,682 (5)
Moderate MIZ	1,302 (6)	1,342 (8)	549 (10)	2,455 (6)	407 (10)	562 (22)	414 (12)	320 (24)	75 (16)		7,445 (8)
Weak/No MIZ	1,851 (9)	2,981 (17)	1,694 (32)	1,627 (4)	1,023 (26)	551 (21)	852 (25)	301 (23)	73 (16)		10,966(11)
Missing	431 (2)	361 (2)-	79 (1)	980 (2)	71 (2)	54 (2)	132 (4)	57 (5)	10 (2)		2,258 (2)
Income											
Quintile 1 (Poorest)	5,003 (24)	4,459 (26)	1,384 (26)	9,107 (21)	1,346 (34)	594 (23)	675 (20)	303 (23)	117 (26)	115 (20)	23,103 (23)
Quintile 2	4,107 (20)	3,549 (20)	1,029 (19)	8,555 (20)	874 (22)	515 (20)	724 (21)	204 (15)	66 (14)	118 (20)	19,741 (20)
Quintile 3	3,768 (18)	3,211 (18)	773 (15)	7,984 (19)	555 (14)	475 (18)	660 (19)	229 (17)	102 (22)	86 (15)	17,843 (18)
Quintile 4	3,487 (17)	2,556 (15)	688 (13)	7,223 (17)	510 (13)	460 (18)	578 (17)	222 (17)	88 (19)	85 (15)	15,888 (16)
Quintile 5 (Richest)	3,266 (15)	2,300 (13)	628 (12)	7,492 (17)	425 (11)	412 (16)	577 (17)	234 (18)	58 (13)	70 (12)	15,462 (16)
Missing	1,270 (6)	1,333 (8)	798 (15)	2,638 (6)	210 (5)	175 (7)	203 (6)	144 (11)	26 (6)	103 (18)	6,900 (7)
Median LOS (IQR)	6.6 (13.6)	6.8 (12.9)	6.4 (11.3)	6.8 (12.6)	6.4 (14.9)	7.6 (12.9)	7.2 (14.5)	8.8 (15.4)	7.0 (12.9)	3.6 (6.2)	6.7 (12.9)
Mortality	1,987 (10)	1,527 (9)	484 (9)	5,340 (12)	385 (10)	310 (12)	412 (12)	143 (11)	44 (10)	30 (5)	10,662 (11)

Table 7.2 Relative change in frequency of hospitalization and hospitalization rates

	BC	AL	SK	ON	MB	NB	NS	NF	Canada
Number of admissions 2002/03	2,098	1,788	567	4,835	554	350	355	135	9,900
Number of admission 2008/09	3,009	2,403	744	6,202	731	399	487	194	14,323
Relative change (%)*	30%	26%	23%	22%	24%	12%	27%	30%	30%
Proportion ≥ 65 years 2002/03	35%	28%	38%	42%	35%	34%	41%	29%	37%
Proportion ≥ 65 years 2008/09	42%	32%	35%	49%	32%	42%	43%	37%	42%
Relative change	20%	14%	- 8%	17%	- 9%	24%	5%	28%	14%
Age-standardized hospitalization rate (95% CI) 2002/03	61.0 (58.3, 63.7)	75.1 (71.6 , 78.6)	68.7 (62.7, 74.6)	48.8 (47.5, 50.2)	57.9 (52.9, 62.9)	54.4 (48.6, 60.3)	44.7 (39.9, 49.5)	32.0 (26.5, 37.4)	54.2 (53.1, 55.3)
Age-standardized hospitalization rate (95%CI) 2008/09	74.3 (71.5, 77.0)	80.7 (77.4, 84.0)	85.7 (79.2, 92.3)	52.4 (51.1, 53.8)	72.5 (71.5, 77.0)	59.1 (52.9, 65.2)	55.1 (49.9, 60.3)	41.9 (35.7, 48.1)	61.1 (60.0, 62.1)
Relative change	22%	7%	25%	7%	25%	9%	23%	31%	13%

BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NF – Newfoundland and Labrador. * Relative change is calculated relative to 2002 for all provinces except Manitoba and New Brunswick. Data were not available for Manitoba in fiscal 2002 to 2003 and New Brunswick in 2003. Percent changes are calculated relative to 2004 and 2003 for Manitoba and New Brunswick, respectively. Prince Edward Island and the Territories due to small sample size (calculation of annual standardized rates).

Figure 7:1 Temporal Trends in Age-standardized Rates per 100,000 population of Severe Injury Hospitalization by Province (2002 – 2009)



P-values are for the beta coefficients for year in the negative binomial regression analyses. Rates and p-values for Manitoba and New Brunswick are from 2004 and 2003, respectively.

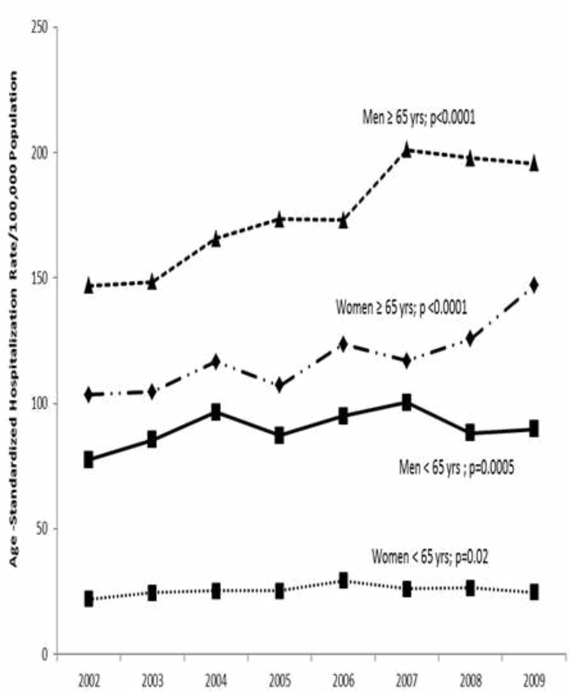
Table 7.3 Temporal Trends in severe injury hospitalizations rates per 100,000 population

	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)	P-value
British Columbia											
17 - 64 years	49.8	54.9	60.8	56.2	62.1	63.2	57.3	57.2	15%	1.8% (0.9, 2.7)	<0.0001
≥ 65 years	123.1	124.1	138.6	138.4	146.3	155.3	159.6	169.7	38%	4.8% (3.8, 5.8)	<0.0001
Alberta											
17 - 64 years	62.1	63.0	68.2	66.6	71.1	73.1	65.7	64.0	3%	1.0% (0.05, 2.0)	0.04
≥ 65 years	147.7	147.0	161.2	159.7	171.8	169.4	176.5	173.6	18%	2.8% (1.3, 4.3)	<0.001
Saskatchewan											
17 - 64 years	57.9	68.4	63.5	69.7	72.8	79.3	81.0	74.9	29%	4.0% (2.4, 5.66)	<0.0001
≥ 65 years	128.9	110.9	118.0	124.1	125.7	122.0	132.5	146.4	14%	2.5% (0.4, 4.6)	0.02
Ontario											
17 - 64 years	35.0	33.7	33.3	33.9	36.9	36.1	33.6	34.6	-1%	0.5% (-0.1, 1.1)	0.12
≥ 65 years	126.3	123.0	122.4	125.1	131.6	138.8	144.9	151.7	20%	3.2% (2.4, 3.9)	<0.0001
Manitoba											
17 - 64 years	-	-	49.4	54.2	62.3	63.9	57.7	65.0	32%	4.4% (2.1, 6.8)	<0.001
≥ 65 years	-	-	105.5	109.9	114.3	99.4	115.0	114.4	8%	1.7% (-1.6, 5.1)	0.32
New Brunswick											
17 - 64 years	-	46.1	46.4	46.1	50.1	44.6	47.0	46.4	1%	- 0.1% (-2.5,2.3)	0.9
≥ 65 years	-	101.1	109.6	114.4	125.9	109.1	116.4	129.8	28%	2.4% (-0.7, 5.7)	0.13
Nova Scotia											
17 - 64 years	34.7	32.7	42.5	44.1	46.2	38.8	38.2	42.5	23%	2.3% (0.2, 4.6)	0.04
≥ 65 years	100.6	103.0	96.2	113.6	130.5	128.4	114.2	125.4	25%	3.7% (1.4, 6.1)	0.002
Newfoundland & Labrador											
17 - 64 years	27.2	29.7	29.5	24.8	33.9	39.2	30.8	33.2	22%	3.3% (0.3, 6.3)	0.03
≥ 65 years	58.8	54.4	71.9	88.5	92.9	76.7	90.5	90.7	54%	6.6% (2.4, 11.1)	0.002
Canada											
17 - 64 years	41.7	42.4	44.0	43.8	47.8	47.8	44.2	45.2	8%	1.6% (1.1, 2.1)	<0.0001
≥ 65 years	124.0	120.8	123.6	126.9	134.3	137.8	143.9	149.8	21%	3.3% (2.8, 3.8)	<0.0001

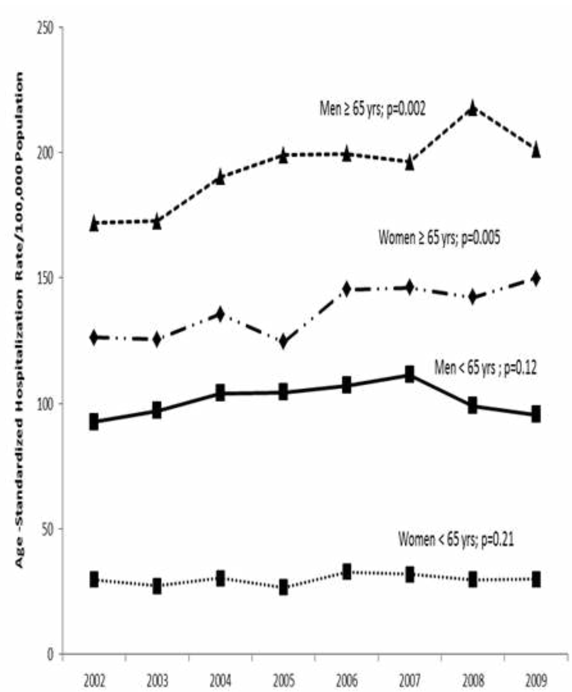
* EAPC – estimated annual percentage change - and p-values are derived from the beta coefficients for year in the Poisson or negative binomial regression analyses. Percent changes are calculated relative to 2004 and 2003 for Manitoba and New Brunswick, respectively and to 2002 for all other provinces.

Figure 7:2 Temporal Trends in age-standardized hospitalization rates per 100,000 population for severe injury stratified by age and gender

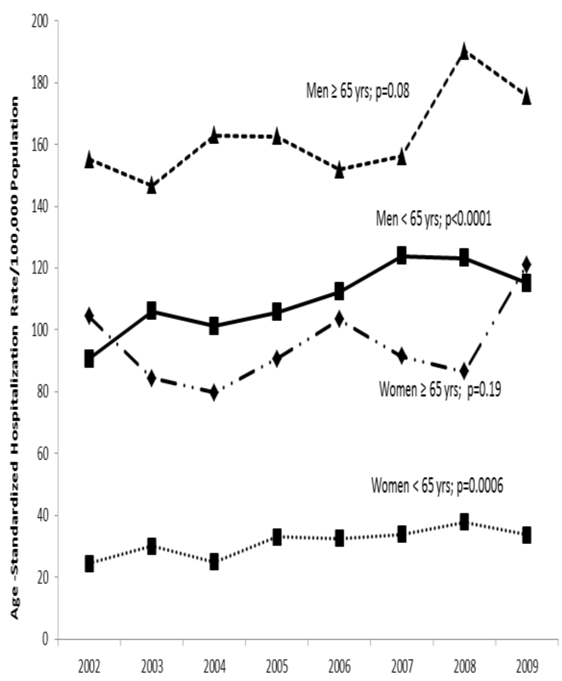
British Columbia



Alberta



Saskatchewan



Ontario

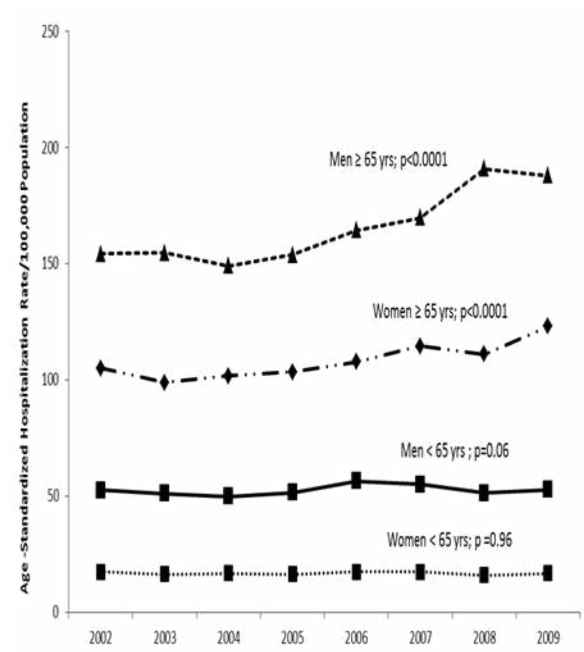
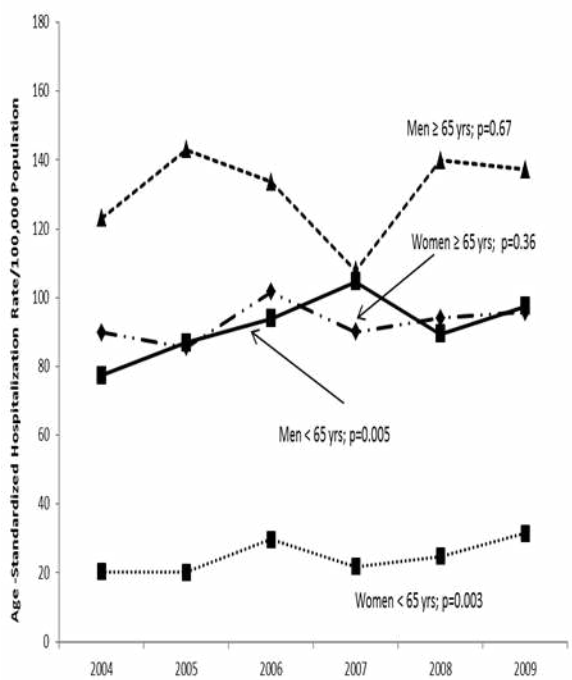
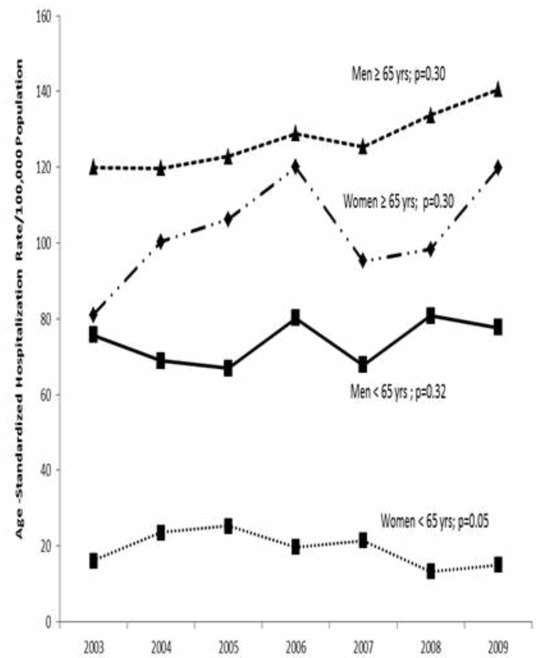


Figure 7:2 (continued)

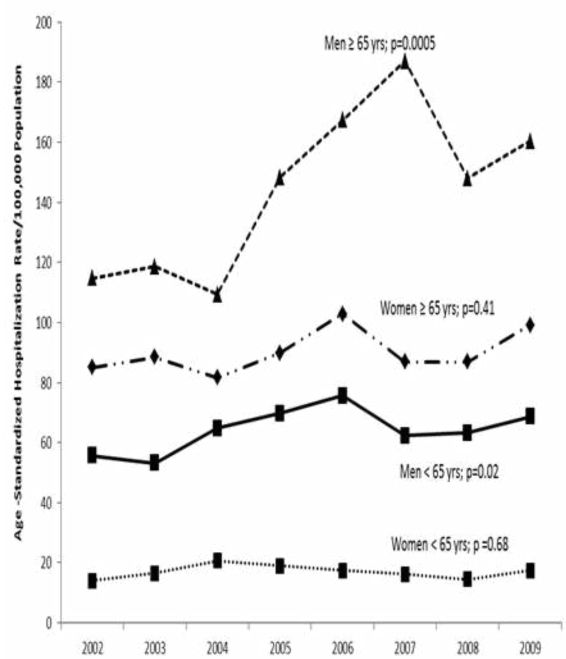
Manitoba



New Brunswick



Nova Scotia



Newfoundland and Labrador

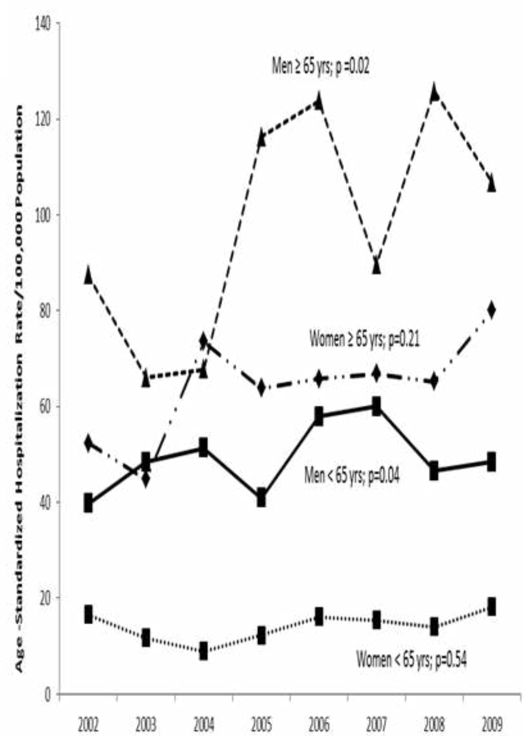


Table 7.4 Temporal Trends in Age-standardized Hospitalization Rates per 100,000 population for Severe Injury Stratified by Mechanism

	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)	P-value
British Columbia											
Fall	23.1	24.3	27.7	26.5	29.5	30.7	30.7	31.2	35%	4.5% (3.4, 5.5)	<0.0001
MVC	26.4	28.2	29.5	28.3	29.4	29.9	27.3	28.2	7%	0.5% (-0.5, 1.6)	0.32
Alberta											
Fall	26.4	27.2	31.0	29.5	30.9	32.9	32.6	31.7	20%	2.8% (1.6, 3.9)	<0.0001
MVC	34.2	32.8	33.3	32.5	36.3	36.4	33.4	31.7	-7%	0.1% (-0.9, 1.1)	0.9
Saskatchewan											
Fall	23.9	24.1	22.4	26.2	26.0	25.9	27.2	27.6	15%	2.5% (0.5, 4.4)	0.01
MVC	27.5	30.7	27.6	29.5	29.6	36.7	37.9	33.9	23%	4.2% (2.0, 6.5)	<0.001
Ontario											
Fall	23.4	22.1	22.7	22.6	24.2	24.8	26.4	27.4	17%	2.8% (2.1, 3.5)	<0.0001
MVC	17.9	17.3	16.9	17.0	18.2	18.0	15.9	15.8	-11%	-0.9% (-1.7, -0.1	0.04
Manitoba											
Fall			19.9	22.2	23.7	19.6	23.8	22.8	15%	2.4% (-0.6, 5.4)	0.12
MVC			20.3	21.6	27.3	26.0	21.8	27.4	35%	4.4% (1.2, 7.8)	0.007
New Brunswick											
Fall		20.3	23.1	21.0	26.9	22.2	21.9	24.3	20%	2.0% (-0.9, 5.0)	0.17
MVC		25.9	26.9	29.4	29.0	26.3	26.1	27.7	7%	-0.1% (-3.0, 2.8)	0.93
Nova Scotia											
Fall	20.9	20.2	20.7	24.5	25.7	25.8	21.4	25.4	22%	3.4, (1.3, 5.5)	0.001
MVC	15.9	15.2	21.9	23.5	23.6	17.7	20.7	21.0	33%	3.1% (0.3, 6.0)	0.03
Newfoundland & Labrador											
Fall	18.8	14.7	18.8	18.9	17.7	17.1	18.8	24.7	31%	4.5% (0.9, 8.2)	0.01
MVC	15.9	16.1	16.5	14.4	19.1	22.8	19.7	18.1	14%	3.4% (-0.3, 7.3)	0.07

* EAPC – estimated annual percentage change - and p-values are derived from the beta coefficients for year in the Poisson or negative binomial regression analyses. Percent changes are calculated relative to 2004 and 2003 for Manitoba and New Brunswick, respectively and to 2002 for all other provinces.

Table 7.5 Results of Negative Binomial Model for Adjusted Hospitalization Rates

Variable	Estimate	95% CI	P-value
Gender			
Female	Reference		
Male	2.50	2.42 – 2.58	<0.0001
Province			
Ontario	Reference		
Alberta	1.55	1.47 - 1.63	<0.0001
British Columbia	1.36	1.29 - 1.43	<0.0001
Manitoba	1.20	1.13 - 1.28	<0.0001
New Brunswick	1.09	1.02 - 1.17	0.008
Newfoundland and Labrador	0.75	0.70 - 0.81	<0.0001
Nova Scotia	1.00	0.94 - 1.06	0.98
Saskatchewan	1.45	1.37 - 1.54	<0.0001
Age			
17 - 24	Reference		
25 - 29	0.68	0.63 - 0.74	<0.0001
30 - 34	0.57	0.53 - 0.62	<0.0001
35 - 39	0.58	0.54 - 0.63	<0.0001
40 - 44	0.63	0.58 - 0.68	<0.0001
45 - 49	0.65	0.60 - 0.71	<0.0001
50 - 54	0.70	0.65 - 0.76	<0.0001
55 - 59	0.74	0.68 - 0.80	<0.0001
60 - 64	0.86	0.80 - 0.93	0.0003
65 - 69	1.08	0.99 - 1.17	0.08
70 - 74	1.46	1.35 - 1.59	<0.0001
75 - 79	2.30	2.13 - 2.49	<0.0001
80 - 84	3.59	3.32 - 3.88	<0.0001
>85	6.15	5.70 - 6.63	<0.0001
Year	1.02	1.01 - 1.03	<0.0001

* Interaction between province and fiscal year not significant and results are not included in the table.

Chapter 8 : Major Trauma in Canada: Case Fatality, Mortality and Bed-days Utilization (Paper 4)

8.1 Background

Globally, severe injury represents a leading cause of preventable morbidity and mortality.[177] Recent investigations into injury-related mortality trends have identified fluctuations in these rates over the past several decades.[201, 202] For example, in examining U.S. data for the 27 year period from 1981 to 2007, Sorenson found that while intentional injury mortality rates decreased over time, unintentional injury mortality decreased between 1981 to 1991, but remained relatively stable until 2000, and increased through 2007.[201] Increasing rates in overall and unintentional injury-related mortality in the U.S. have been noted in other studies.[202] While the experience of other jurisdictions has important implications for informing priorities and strategies aimed at injury prevention in Canada, jurisdictional differences in injury-related deaths underscores the importance of using Canadian data to guide these efforts. Importantly, recently Minei et al reported age-sex adjusted mortality rates of 7.3 per 100,000 population for Vancouver and 5.2 per 100,000 population for both Ottawa and Toronto.[35] While comparisons across cities and states are difficult, the rates in these Canadian cities was notably different from the US data, where age-sex adjusted mortality rates from major trauma range from 3.8 per 100,000 population in Portland to 29.2 per 100,000 population in Alabama.[35] Further, in contrast to the U.S. data demonstrating increasing injury-related mortality rates in recent years, a recent report identified a relative decrease of 10% in the injury death rate between 1995 to 2005, for the Canadian population.[2] Although this report offers insights into the trends in injury-related death in Canada, methodological limitations, including variations in the data collected across the two study years, and a lack of information detailing the trends in injury-mortality at the provincial level, underscores the need for further studies on this issue. Importantly, more nuanced and updated information regarding time trends in injury-related mortality among subpopulations, at the national and provincial levels will more appropriately inform injury resource allocation and prevention strategies across Canadian jurisdictions. Against this background, we sought to describe and compare recent time trends in hospital mortality following hospitalization for severe injury across Canada.

8.2 Methods

A detailed description of the study methods is provided in Chapter 5. Briefly, the study cohort included all adult (> 16 years) major injury admissions (ISS > 15 or death within 24 hours of hospitalization) to an acute care hospital between April 1, 2002 and March 31, 2010. Population data, by age, gender and year were obtained from Statistics Canada's intercensal population estimates.[151] Crude and age-standardized case fatality rates were calculated and were expressed per 1000 major trauma discharges. Crude and age-standardized population-based mortality and hospital bed-day utilization rates were expressed per 100,000 population. The direct method was used to standardize the case fatality rates using the total population of major trauma admission as the standard population, while age-standardized mortality and hospital bed-day rates used the 1991 Canadian population as the standard population.

8.3 Results

Over the 8 year period 98,937 major trauma hospitalizations were identified, with patients 65 years and older accounting for 38.5% of the cohort. There were 10,662 (10.8%) in-hospital deaths among these patients, this reflected 5.8% and 19% in patients 17 – 64 years and those 65 years and older, respectively. Patients 65 years and older accounted for the majority of deaths in each year of the study, with patients ≥ 85 accounting for 24.3% and 32.8% of all deaths in 2002 and 2009, respectively.

8.3.1 National Trends in Hospital Mortality by Age and Gender

Table 8.1 detail the overall national crude and age-standardized case fatality rates per 1000 discharges. The overall age-standardized case fatality rate ranged from 100.0 to 116.8 per 1000 major trauma discharges over the study period. Over the eight year period there was a 10.8% relative decline (2002 to 2009) in the overall age-standardized case fatality rate, reflecting an estimated annual average percent change (EAPC) of -1.7% (95% CI: -0.8%, -2.6%). The relative decline in rates was highest among individuals 17 – 64 years old: relative decrease of 19.1% versus 6.7% among those aged 17 – 64 years and ≥ 65 years old respectively. Notably, however, the relative decline in age-standardized case fatality rate was largely driven by decreasing rates in younger men. Among elderly women, a small non-significant increase in age-standardized injury case fatality rates was observed, EAPC of 0.05% (95% CI: -1.5%, 1.5%). Across all years, age-standardized case fatality rates were higher among the elderly; in particular, rates were highest among older men. In contrast, among the younger population (< 65 years) younger women experienced higher age-standardized case fatality rates than young men in all but three of the study years.

Table 8.2 details the age-standardized mortality rates by gender and age groups. The overall age-standardized mortality rates ranged from 5.7 per 100,000 population in 2002 to 6.0 per 100,000 in 2009, with no significant change over the study period ($p = 0.86$). Women experienced increasing mortality rates over the eight year period: from 3.4 per 100,000 population in 2002 to 3.9 per 100,000 population in 2009 (reflecting a 2.0% estimated annual percent increase; $p=0.004$). In contrast, mortality rates remained stable for men. For both elderly women and elderly men we found an increase in the age-standardized mortality rate over time: by 2.9% among elderly women and a more modest 1.8% among elderly men ($p=0.0002$ and $p=0.01$, respectively). For both genders, rates amongst younger individuals remained relatively stable over time.

Trends in age-specific population case fatality and mortality are detailed in Table 8.3 and 8.4, respectively. Consistent with the evidence of higher injury case fatality rates amongst older individuals, across both measures of mortality the pattern showed a strong association between age and death, with age-specific rates increasing sharply with advancing age. For both men and women, the annual age-specific mortality rate per 100,000 population increased gradually from ages 17-24 years to 65 -74 years, followed by a steep increasing gradient thereafter. For both men and women, individuals aged 85 years and older experienced significant increases in age specific mortality: the overall EAPC for this group was 4.0% ($p < 0.0001$). Over the same period the age-specific case fatality rate for this age group remained stable (EAPC 0.3%, p=0.74)

Figure 8.1 shows the overall age-specific case fatality by mechanism of injury. Across all mechanisms, we observed a striking increase in age-specific case-fatality rates with increasing age. For example, amongst hospitalizations for fall related injuries, which accounted for the majority of deaths (65%), case fatality rate increased from 34.4 to 255.9 per 1000 discharges for individuals aged 17 – 29 years and ≥ 80 years, respectively. This pattern was consistent across the study period (Figure 8.2 and 8.3). As detailed in Figure 8.4, there was an increase in age-standardized mortality rate following falls, from 3.4 to 4.0 per 100,000 population in 2002 and 2009, respectively (estimated annual percent increase of 2.8%, 95% CI: 1.7- 3.8). This increase was largely driven by patients ≥ 65 years, where deaths following falls rose from 18.1 to 22.5 per 100,000 population in 2002 and 2009, respectively; estimated annual percent increase of 3.4%, (95% CI: 2.3, 4.6). The corresponding rates for young individuals remained stable for the period examined (p=0.51). For both age groups, the age-standardized mortality rate per 100,000 population following motor vehicle collision decreased moderately but significantly for the eight year period. Specifically, for individuals 65 years and older, the estimated annual percent change was - 4.8% (95% CI: - 2.0, - 7.5). For individuals under the age of 65 years these figures were – 2.4% (95% CI: -0.33, - 4.5).

To explore these age related relationships further, we compared age-standardized mortality rate ratios for younger and older individuals, estimated from the Poisson regression analysis. For fall related injuries, the old to young rate ratio was

19.9 (95% CI: 17.4 – 22.9) (Table 8.5). For motor vehicle related injuries the standardized-mortality rate was higher in older individuals (rate ratio 1.86 (95% CI: 1.71 – 2.01).

8.3.2 Provincial Variations in Injury Mortality by Age and Gender

In general, provincial injury mortality data were consistent with the overall pan-Canadian profile. However, there were notable differences across the provinces. As detailed in Figure 8.5, the age-standardized case fatality rates were higher among men than women in all provinces, ranging from 107.3 per 1000 discharges in Saskatchewan to 136.5 per 1000 discharges in New Brunswick. Amongst women, the highest case fatality rate was observed in New Brunswick and the lowest in Saskatchewan: 113.7 and 85.1 per 1000 discharges, respectively. The age-specific case fatality rates highlighted in Figure 8.6 provides further gradation of these age and gender patterns. Notably, we observed that case fatality rates increased sharply with increasing age across all provinces, with men in age groups older than 64 years experiencing the highest injury fatality rate across all provinces. Consistent with the national pattern, we confirmed that population mortality rates increased with increasing age, with rates being higher for older men compared to older women across all provinces (Table 8.6).

In addition to these gender and age patterns, we found moderate variation in the population mortality and case fatality rates across the provinces (Table 8.6). For example, the extremal quotient for age-standardized mortality rate for the overall population was 1.9, indicating a 1.9-fold difference in age-standardized mortality rates between the highest province (Alberta, 7.1 per 100,000 population) and the lowest province (Newfoundland and Labrador, 3.8 per 100,000 population). Similar variations were noted across all age-gender groups, with the extremal quotients ranging from 1.7 to 2.8. Examination of case fatality rates revealed similar results, with the largest variation, as measured by the extremal quotient, occurring in younger men and older women.

Figures 7.8 and 8.8 detail the death rates by injury mechanisms. Fall related injury case fatality rates ranged from 95.3 to 119.0 per 1000 discharges, with the lowest and highest rates observed in British Columbia and Manitoba, respectively. Motor vehicle related injury case fatality rate was highest in New Brunswick, followed closely by Newfoundland and Labrador with age-standardized rates of 127.2 and 123.5 per 1000 discharges, respectively. Despite having amongst the lowest case fatality rates for both motor vehicle and fall related injuries, Alberta had the highest population based mortality rate for both fall and motor vehicle related injuries: age-standardized rates of 4.0 and 2.2 per 100,000 population for falls and motor vehicle related injuries, respectively. For fall related injuries there was a 1.7-fold difference in the age-standardized population mortality rate ratio between Alberta, and Newfoundland (the province with the lowest rate). Similarly for motor vehicle related mortality, there was a 1.8-fold difference in age-standardized motor vehicle related mortality rates between Alberta and Newfoundland and Labrador (province with the lowest motor vehicle related mortality rate per 100,000 population).

8.3.3 Hospital Bed-days Utilization by Age and Gender

Admissions following major trauma utilized a total of 1,460,266 bed-days in hospitals providing definitive care over the 8-year period. Of these, 46.0% (67,237 days) were attributed to patients 65 years and older. Figure 8.9 details the use of hospital bed-days by the elderly cohort. Of note, throughout the study period, patients 80 years and older consumed an increasing proportion of the total hospital bed-days, with the proportion of bed-days attributed to this group increasing by 30% (2009 relative to 2002).

Table 8.7 shows the annual age-standardized gender-specific bed-day utilization rates for younger and older patients. Amongst both men and women, the age-standardized hospital bed-day utilization rates were highest amongst older patients, with these individuals experiencing an overall 13.3% relative increase in the total number of hospital bed-days per 100,000 population between 2002 to 2009. In contrast, these rates remained stable amongst younger patients (-0.5% relative decrease from 2002 to 2009). This pattern of higher hospital bed-day utilization amongst the elderly was consistent across the provinces (Table 8.8). Moreover, there was a 2-fold variability in the age-standardized bed-day utilization rates for the overall patient population across the provinces, with Ontario (671 bed-days per 100,000 population) and Alberta (1309 bed-days per 100,000 population) experiencing the lowest and highest overall bed-day rates, respectively.

8.4 Discussion

8.4.1 Case Fatality, Mortality and Bed Utilization Trends by Age and Gender

Overall injury case fatality rates declined modestly, while overall mortality rates remained stable between 2002 and 2009. However, consistent with the experience elsewhere[201-203] we found important variation in the trends in death rates by age, gender and mechanism of injury. With the exception of women 65 years and older, we observed marginal declines in age-standardized case fatality rates across all age-gender groups over the eight year period. Several factors may contribute to the difference in case fatality trends experienced by older women. Evidence suggests that a lower proportion of women, in particular elderly women, receive care in a trauma centre compared to men.[19] It is therefore possible that differences in access to trauma centre care may influence the case fatality observed amongst older women. Additionally, differences in provider decisions regarding treatment offered, and patient preferences regarding treatment and end-of-life care may contribute to the observed differences. Notably, gender disparities in the receipt of life-supporting therapies have been observed in other critically ill patient populations.[204] The extent to which variations in access to trauma centre care and differences in treatment offered to patients contribute to these observations is unknown.

We found that among individuals age 65 years and older, mortality rates (per 100,000 population) increased, in particular among elderly women, over the period examined. As highlighted by the age-specific trends in injury mortality, the finding for older women was largely attributed to women between 65 – 74 years old and those 85 years and older, for whom the relative increase in death was 37% and 31%, respectively. While direct comparisons with data from other studies are challenging, similar findings of increasing injury mortality rate amongst the elderly have been reported,[205, 206] with as much as a 100% relative increase in age-standardized mortality for individuals over 80 years old.[206]

Patterns in the incidence of and hospitalizations for major trauma may affect the observed mortality trends. Importantly, emerging evidence supports an increasing number of hospitalizations following injury amongst the elderly,[179, 180, 207] with the proportion of elderly women outpacing elderly men.[179] Moreover, striking increases in fall-related injury hospitalization rates over the recent decade have been reported.[181, 182] While other factors such as temporal changes in pre-hospital injury deaths and changes in coding practices over time cannot be excluded as competing explanations for our findings of increasing mortality rates among the elderly given available data, it is unlikely that such biases would differential affect older patients. Further, given the evidence from the aforementioned studies and our own observation of relatively stable case fatality rates among the elderly population, it is more likely that the observed increasing mortality rates among older women and older men can be explained, in part, by increases in the incidence of injury, and in particular fall related injuries.

Our findings are in keeping with previous reports which have demonstrated that men have higher injury mortality rates compared to women.[201] This finding was consistent across all study years for both elderly and young patients. Although the reasons underlying the observed gender differences in injury mortality remains largely unknown, patient related factors such as physiological, socio-demographic and behaviour differences have been previously suggested.[201, 208, 209]

The findings of increasing fall related injury mortality with concomitant declining motor vehicle related injury rates lends support to the shifting patterns of injury mortality evidenced elsewhere. [205, 210, 211] Notably, in addition to confirming that fall-related mortality increases with age, our data revealed significant increases in fall-related age standardized mortality among the elderly, an observation consistent with previous studies.[205, 211] We did not find a similar increase in fall-related case fatality rate amongst this group, which indicates that the observed increasing mortality rates are likely not explained by changes in case fatality rate. Consistent with our present findings of a 24% relative increase in the age-adjusted mortality from falls, we have previously shown a 25% relative increase in fall-related injury hospitalizations among elderly individuals over the same period (Chapter 6). This suggests, that changes in the risk of fall related injury and attendant increases in fall-related hospitalizations among the elderly may contribute to the observed increases. To our knowledge, this is the first population-based study to provide evidence of the contribution of increasing trends in fall-related injury hospitalizations with subsequent increases in-hospital mortality rates.

The elderly increasingly constitute a large proportion of the trauma patient population.[179, 180] Among this group, falls remain the most common cause of injury with significant morbidity and costs consequences.[205, 212] This, coupled with the pattern of increasing fall related injury mortality rates amongst elderly men and women identified in this and earlier studies,[166, 182] is concerning and warrants further attention and study.

Consistent with our data on mortality, we found increased use of hospital bed-days among elderly patients following major trauma. Importantly, the trends in the absolute number of bed-days demonstrated that the oldest of the old consumed an increasing proportion of the hospital bed-days attributed to patients hospitalized for major trauma, with patients 80 years and older experiencing a 30% relative increase in hospital bed-day utilization over the period. While factors such as the increasing number of trauma hospitalizations[179] and greater comorbidities[175] may contribute to the higher bed-day utilization amongst the elderly, in light of the aging population, these data underscore the increasing importance of the elderly on major trauma hospital resources,[180] a finding consistent with similar evidence from other trauma patient populations.[213, 214]

8.4.2 Provincial Variation

Our observation of marked interprovincial variation in injury death rates is consistent with previous studies examining regional variability in injury mortality.[48, 215] Notably, we found that while elderly men and women experienced higher mortality rates than their younger counterparts in all provinces, the rates varied in magnitude. For example, elderly women in Alberta, Ontario and New Brunswick experienced the highest age-standardized mortality rates. Potential factors explaining regional variability in injury mortality rates have been suggested[35, 48, 215] and include the local environment including size and topography differences between regions, population characteristics, and differences in trauma care organizations. Hameed and colleagues have recently characterized trauma care organization within Canada, and found marked variability across the provinces.[17] These differences, including infrastructure and support for trauma systems, have led to differential access to trauma care across the provinces,[17] and this may contribute to the observed mortality differences. Further, while limited data examining interprovincial population risk for major injury exists, previous work within the Canadian setting as well as other jurisdictions has established a role for gender, age, and other socio-demographic factors in influencing injury mortality.[33, 34, 216] It is therefore likely that differences in the prevalence of these risk factors across the provinces may partially explain the observed mortality differences.

Higher age-standardized rates of hospital bed-day utilization were noted among the elderly, across all provinces. However, similar to the pattern with mortality, there was a 2-fold variability in the bed-day utilization by major trauma patients across the provinces. While the provincial variability may be explained by such factors as patient characteristics and local care practices, this finding coupled with data on mortality suggest that there are important opportunities for improving the delivery of trauma care across the provinces. Notably, the interprovincial variation in age-standardized case fatality, mortality, and bed-day utilization rates underscores the importance of exploring the reasons for these differences. Such an understanding could further efforts aimed at leveraging provincial experiences to inform improvements in injury prevention and trauma care across the country, including for example the efforts of the Trauma Association of Canada.[63]

Several methodological limitations of our population-based study should be acknowledged. First, we did not have data on pre-hospital injury deaths and as such our study cannot speak to overall injury death rate. Further, temporal variations in patient demographics and other changes in system factors that impacts pre-hospital deaths following injury (for example changes to emergency transport services or injury severity) have the potential to impact our analysis of trends in mortality and case fatality rates over time. The direction of this bias is unknown. Finally, our study does not include data from Quebec, and as such our profile of injury mortality across the provinces must be interpreted in light of this limitation.

8.5 Conclusion

These results suggest that injury mortality rates continue to be highest amongst the elderly and rates are increasing amongst this population, in particular elderly women. Further, the elderly population requires an increasingly greater proportion of the hospital bed-day used by patients following major trauma. In view of the ongoing growth in the elderly population within industrialized countries, it can be expected that these trends will continue. This group should be an immediate target for injury prevention efforts. Further, the evidence of interprovincial differences in injury death rates and bed-day utilization rates argue for better collaboration across the provinces in delineating the factors contributing to these differences with the goal of informing priorities for injury healthcare policies and interventions.

Tables and Figures Chapter 8

Table 8.1 Temporal Trends in In-hospital Case Fatality per 1000 Major Trauma Discharges (April 1, 2002 – March 31, 2010)

	In-hospital Mortality per 1000 Major Trauma Discharges									
	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)*
All										
Crude	108.9	113.0	104.8	108.4	106.7	104.6	110.4	106.6		
Standardized	112.1	116.8	107.4	110.2	108.7	105.1	105.3	100.0	-10.8	-1.7 (-0.83, -2.6)
< 65 years										
Crude	59.4	65.4	57.5	60.0	53.8	54.0	55.6	49.5		
Standardized	60.2	65.9	57.9	60.1	53.8	53.9	54.8	48.7	-19.1	-3.3 (-1.8, -4.7)
≥ 65 years										
Crude	191.5	195.8	186.3	189.4	195.6	186.9	188.7	185.2		
Standardized	194.9	198.2	186.4	190.2	196.4	186.7	186.1	181.9	-6.7	-0.94 (-1.9, 0.07)
Women										
Crude	115.4	129.9	126.3	125.4	126.0	129.4	128.7	122.4		
Standardized	93.1	108.4	101.0	102.7	104.4	102.5	96.6	89.1	-4.3	-0.60 (-1.9, 0.74)
Women < 65 years										
Crude	55.8	66.9	60.0	65.4	69.5	60.6	54.2	47.8		
Standardized	55.1	66.9	59.4	64.6	68.7	59.4	52.3	46.9	-15.0	-2.8 (-5.7, 0.16)
Women ≥ 65 years										
Crude	161.3	179.2	176.5	171.2	169.5	179.3	180.0	169.2		
Standardized	153.6	174.6	167.3	163.6	161.5	171.4	167.4	156.5	1.9	0.05 (-1.5, 1.5)
Men										
Crude	105.5	104.7	94.0	100.1	96.9	92.5	101.3	98.2		
Standardized	134.4	128.3	119.5	122.2	122.5	113.6	115.2	111.8	-16.8	-2.6 (-1.5, -3.6)
Men < 65 years										
Crude	60.6	65.0	56.7	58.4	49.0	52.2	56.0	50.0		
Standardized	62.4	65.5	57.6	59.1	49.4	52.6	55.8	49.4	-20.7	-3.5 (-1.8, -5.1)
Men ≥ 65 years										
Crude	223.5	212.6	196.7	207.4	222.5	194.5	196.6	201.7		
Standardized	249.4	228.5	218.3	222.8	239.3	211.0	210.0	211.5	-15.2	-2.0 (-0.7, -3.4)

Annual rates age-standardized using the total cases of major trauma as the standard population. EAPC – estimated annual average percentage change - from Poisson or negative binomial regression as appropriate. Relative change calculated as the relative percent difference between 2009 and 2002. A negative change indicates a decline

Table 8.2 Temporal Trends in Age-standardized in-hospital Mortality Rate per 100,000 Population (April 1, 2002 – March 31, 2010)

	Standardized Mortality per 100,000 Population									
	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change	EAPC (95% CI)*
Women										
All	3.4	3.8	3.7	3.7	4.0	4.0	3.8	3.9	14.5	2.0 (0.7, 3.4)
< 65 years	1.1	1.3	1.2	1.3	1.5	1.3	1.1	1.0	-9.6	-1.5 (-4.4, 1.5)
≥ 65 years	16.1	17.5	17.8	17.0	18.1	19.4	19.0	19.9	23.9	2.9 (1.4, 4.5)
Men										
All	8.5	8.6	7.9	8.4	8.6	8.3	8.7	8.5	-0.2	0.2 (-1.1, 1.4)
< 65 years	3.9	4.4	3.9	3.9	3.6	3.9	3.8	3.5	-10.4	-1.8 (-3.4, -0.1)
≥ 65 years	34.3	32.0	30.0	33.4	36.6	33.0	36.2	36.4	6.3	1.8 (0.2, 3.3)

Rates are age-standardized to the 1991 Canadian population. EAPC – estimated annual average percentage change from Poisson or negative binomial regression as appropriate. A negative change indicates a decline.

Table 8.3 Temporal Trends in Age-specific Case Fatality per 1000 Major Trauma Discharges (April 1, 2002 – March 31, 2010)

Age (year)	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change (%)	EAPC (95% CI)
Men										
17 - 25	47.0	62.3	51.4	45.6	43.3	45.3	49.6	41.8	-11.0	-3.0 (-6.7,0.7)
25 - 34	53.8	68.3	54.9	39.6	37.1	39.3	44.0	42.8	-20.4	-5.9 (-10.1,-1.6)
35 - 44	44.0	57.0	38.6	44.2	43.6	42.6	36.5	45.0	2.4	-2.3 (-6.5,2.1)
45 - 54	61.6	63.9	60.0	69.0	53.8	62.2	55.4	44.4	-27.9	-3.7 (-7.1,-0.2)
55 - 64	110.7	78.1	85.6	99.1	70.0	73.5	95.8	76.3	-31.0	-2.8 (-6.7,1.3)
65 - 74	139.3	138.1	115.0	146.9	137.6	105.5	108.6	134.8	-3.2	-2.0 (-5.3,1.4)
75 - 84	243.6	250.6	200.0	215.4	236.0	213.7	197.1	196.5	-19.4	-2.9 (-4.9,-0.8)
>85	362.5	284.6	342.2	305.6	340.9	308.0	324.5	305.3	-15.8	-0.9 (-3.3,1.5)
Women										
17 - 25	49.7	57.9	70.4	68.9	77.9	56.4	58.0	42.9	-13.6	-2.0 (-8.1,4.6)
25 - 34	51.7	77.2	47.9	56.2	42.3	60.7	27.7	52.3	1.0	-5.0 (-12.5,3.2)
35 - 44	55.2	63.4	34.7	49.2	59.8	38.8	41.8	37.2	-32.7	-5.2 (-12.4,2.5)
45 - 54	49.7	61.7	59.0	64.6	79.0	64.7	58.0	37.3	-24.8	-2.4 (-8.4,4.0)
55 - 64	71.9	78.6	83.1	83.3	79.1	77.1	72.6	68.5	-4.7	-1.4 (-6.9,4.4)
65 - 74	90.5	140.2	110.4	123.3	107.9	136.3	106.7	102.9	13.7	-0.5 (-4.5,3.6)
75 - 84	152.8	163.0	169.4	155.3	152.3	151.9	164.3	144.5	-5.4	-0.9 (-3.3,1.5)
>85	215.2	223.2	218.7	213.5	225.4	231.9	229.7	224.1	4.1	0.8 (-1.4,2.9)
All										
17 - 25	47.6	61.4	55.1	50.5	50.3	47.5	51.4	42.1	-11.6	-2.8 (-5.9,0.5)
25 - 34	53.4	70.2	53.4	43.0	38.2	43.4	40.7	44.7	-16.2	-5.7 (-9.6,-1.7)
35 - 44	46.6	58.5	37.7	45.3	47.3	41.8	37.6	43.2	-7.3	-3.0 (-6.7,0.8)
45 - 54	58.7	63.4	59.8	68.0	60.0	62.8	56.0	42.7	-27.3	-3.4 (-6.4,-0.2)
55 - 64	99.3	78.2	84.9	94.9	72.6	74.5	89.3	74.3	-25.2	-2.4 (-5.3,0.6)
65 - 74	122.0	138.9	113.3	138.7	126.3	116.2	107.9	123.0	0.8	-1.5 (-3.8,0.8)
75 - 84	195.1	205.6	184.3	186.1	193.5	182.1	181.6	170.8	-12.5	-1.9 (-3.4,-0.3)
>85	264.4	244.8	259.1	244.8	267.4	260.3	267.0	253.4	-4.1	0.3 (-1.3,1.9)

EAPC – estimated annual average percentage change - from Poisson or negative binomial regression as appropriate. Relative change calculated as the relative percent difference between 2009 and 2002. A negative change indicates a decline.

Table 8.4 Temporal Trends in Age-specific Mortality Rate per 100,000 Population (April 1, 2002 – March 31, 2010)

Age (year)	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change (%)	EAPC (95% CI)
Men										
17 - 25	4.3	6.1	5.2	4.7	4.8	4.9	4.7	3.9	-7.7	-2.6 (-6.2,1.1)
25 - 34	3.2	4.0	3.5	2.3	2.6	2.8	2.8	2.7	-14.0	-4.2 (-8.2,0.0)
35 - 44	2.4	3.2	2.2	2.6	2.7	2.8	2.2	2.6	11.2	-0.7 (-4.9,3.7)
45 - 54	3.7	4.2	4.0	4.7	3.8	4.5	3.8	3.2	-12.1	-1.5 (-4.9,2.1)
55 - 64	7.9	5.3	6.3	7.5	5.5	5.9	7.4	6.3	-20.0	-0.5 (-4.5,3.6)
65 - 74	14.2	14.0	11.3	15.7	15.1	12.4	13.3	15.3	8.4	0.7 (-2.3,3.9)
75 - 84	45.9	45.9	38.0	44.2	48.3	44.1	44.8	46.9	2.4	0.8 (-1.4,2.9)
>85	128.3	104.1	127.4	114.1	139.8	132.1	159.3	140.7	9.7	3.8 (1.2,6.6)
Women										
17 - 25	1.4	1.5	1.8	2.0	2.3	1.6	1.6	1.2	-11.3	-1.3 (-7.5,5.3)
25 - 34	0.8	1.2	0.8	0.8	0.8	1.0	0.5	0.8	8.2	-4.0 (-11.5,4.1)
35 - 44	0.9	1.1	0.6	0.8	1.1	0.7	0.6	0.6	-29.7	-5.2 (-12.3,2.5)
45 - 54	0.9	1.2	1.2	1.3	1.8	1.5	1.3	0.9	-6.2	1.0 (-5.8,8.2)
55 - 64	2.1	1.9	2.4	2.3	2.4	2.3	2.1	1.9	-7.7	-0.3 (-5.8,5.5)
65 - 74	4.6	7.4	5.7	6.4	6.6	7.8	6.0	6.3	36.8	2.0 (-2.0,6.3)
75 - 84	23.0	22.3	24.2	22.0	23.7	24.6	25.5	26.1	13.1	2.1 (-0.4,4.6)
>85	68.1	68.0	76.0	70.9	75.5	79.2	83.5	89.0	30.7	3.9 (1.7,6.1)
All										
17 - 25	2.9	3.9	3.5	3.4	3.5	3.3	3.2	2.6	-8.4	-2.3 (-5.4,0.9)
25 - 34	2.0	2.6	2.2	1.6	1.7	1.9	1.6	1.8	-10.0	-4.2 (-7.9,-0.4)
35 - 44	1.6	2.2	1.4	1.7	1.9	1.7	1.4	1.6	-0.3	-1.8 (-5.6,2.2)
45 - 54	2.3	2.7	2.6	3.0	2.8	3.0	2.6	2.1	-10.6	-0.8 (-4.4,2.9)
55 - 64	5.0	3.6	4.3	4.9	4.0	4.1	4.7	4.1	-17.6	-0.4 (-3.4,2.6)
65 - 74	9.2	10.5	8.3	10.8	10.7	10.0	9.5	10.6	15.9	1.2 (-1.2,3.6)
75 - 84	32.4	32.1	30.0	31.3	34.2	33.0	33.9	35.2	8.5	1.5 (-0.1,3.2)
>85	86.7	79.3	92.0	84.5	96.0	96.2	108.1	106.0	22.2	4.0 (2.4,5.7)

EAPC – estimated annual average percentage change - from Poisson or negative binomial regression as appropriate. Relative change calculated as the relative percent difference between 2009 and 2002. A negative change indicates a decline.

Figure 8:1 Overall Age-specific Case Fatality Rate per 1000 Discharges by Mechanism of Injury (April 1, 2002 – March 31, 2010)

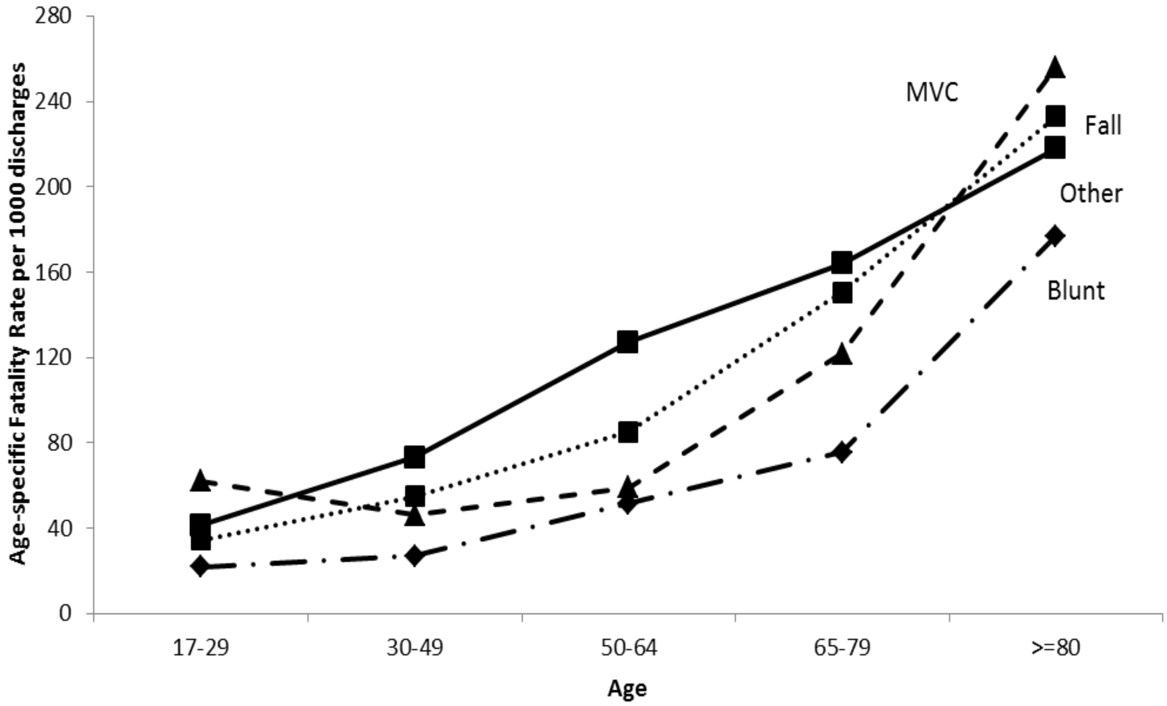
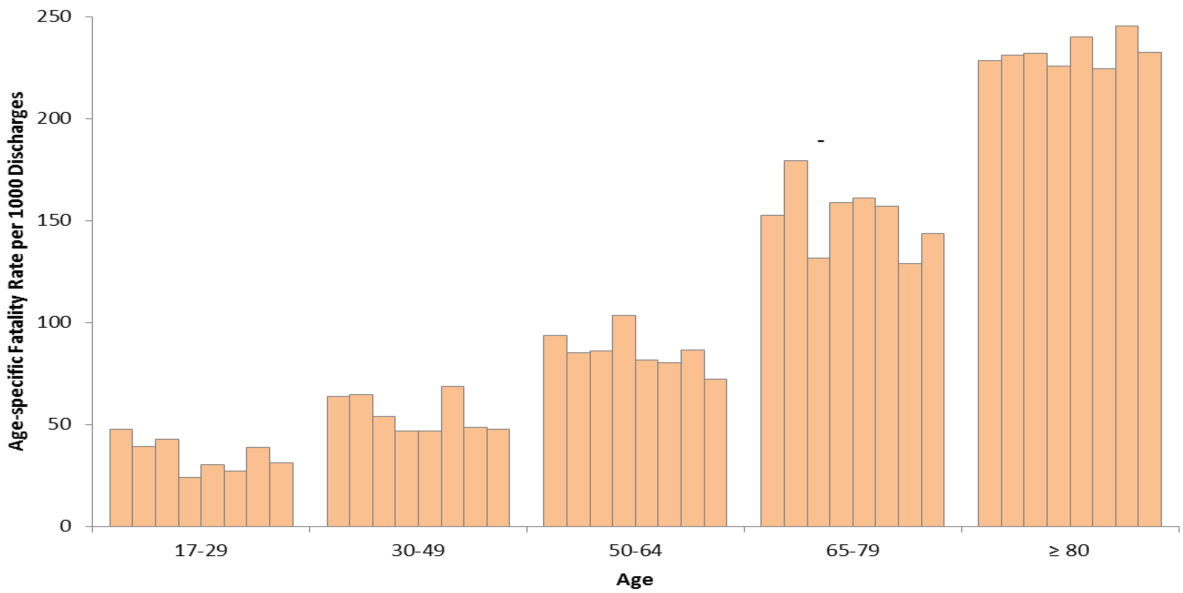
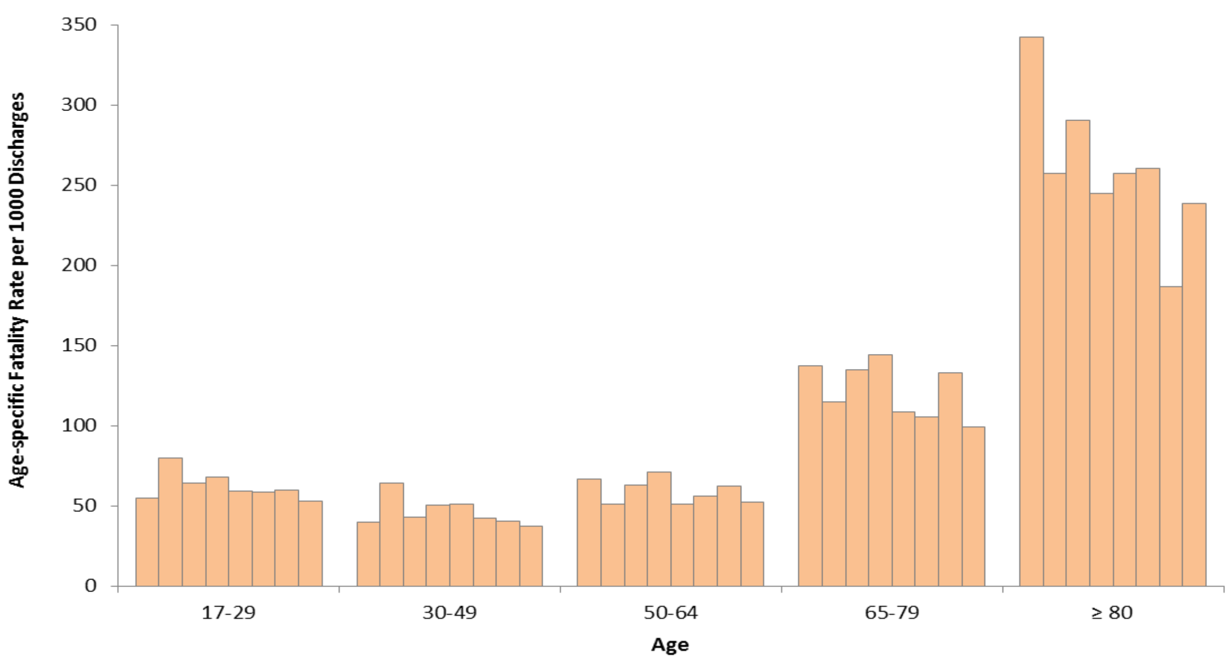


Figure 8:2 Annual Age-specific Case Fatality Rate per 1000 Discharges and for Fall Related Injuries (April 1, 2002 – March 31, 2010)



Columns represent each year from 2002 to 2009

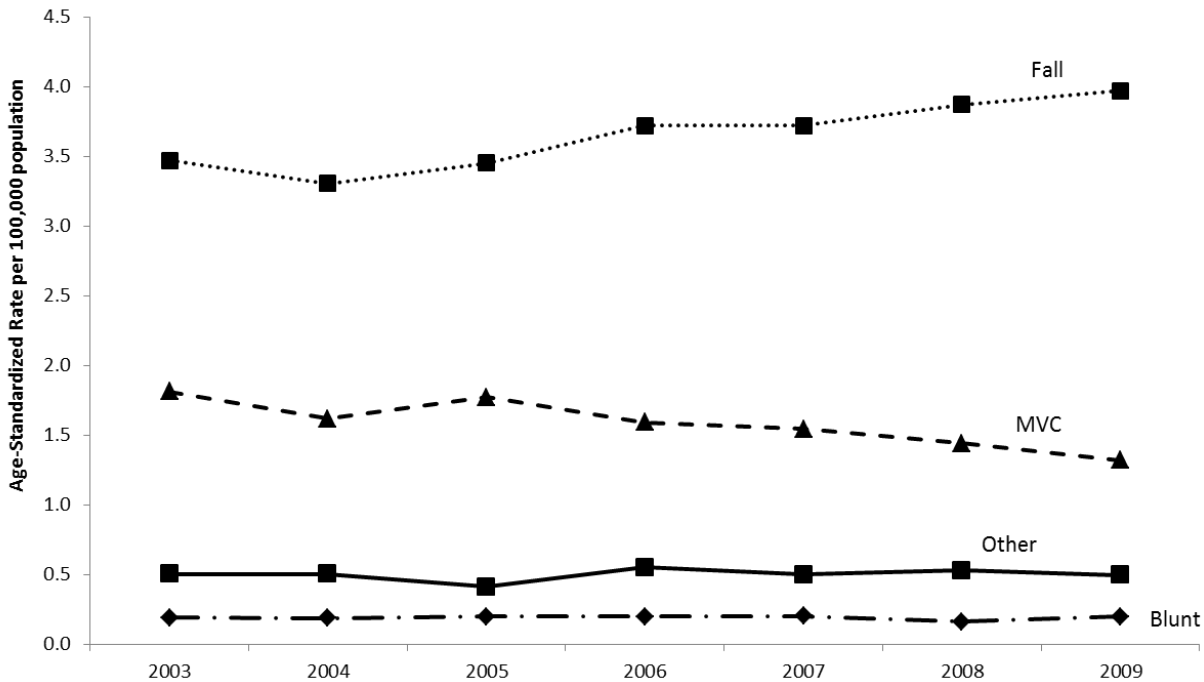
Figure 8:3 Annual Age-specific Case Fatality Rate per 1000 Discharges for Motor Vehicle Related Injuries (April 1, 2002 – March 31, 2010)



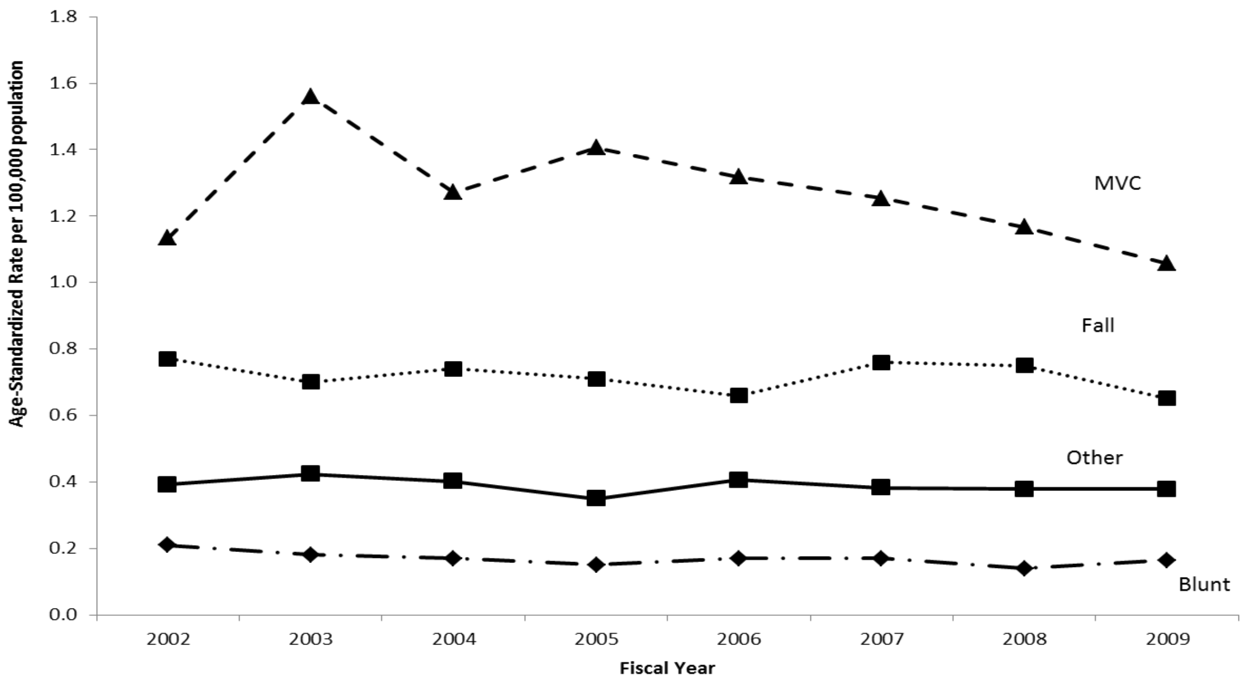
Columns represent each year from 2002 to 2009

Figure 8:4 Temporal Trends in Age-standardized Mortality Rate per 100,000 population Stratified by Mechanism of Injury (April 1, 2002 – March 31, 2010))

A. All Patients



B. Patients 17 – 64 years



C. Patients ≥ 65 years

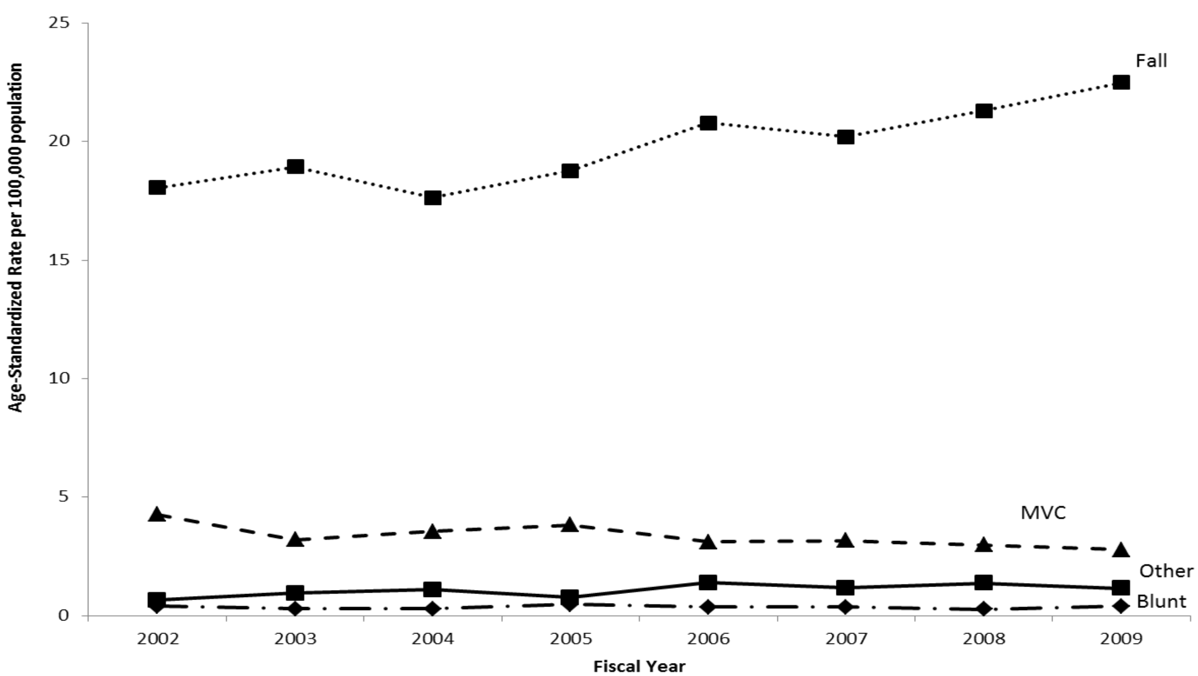
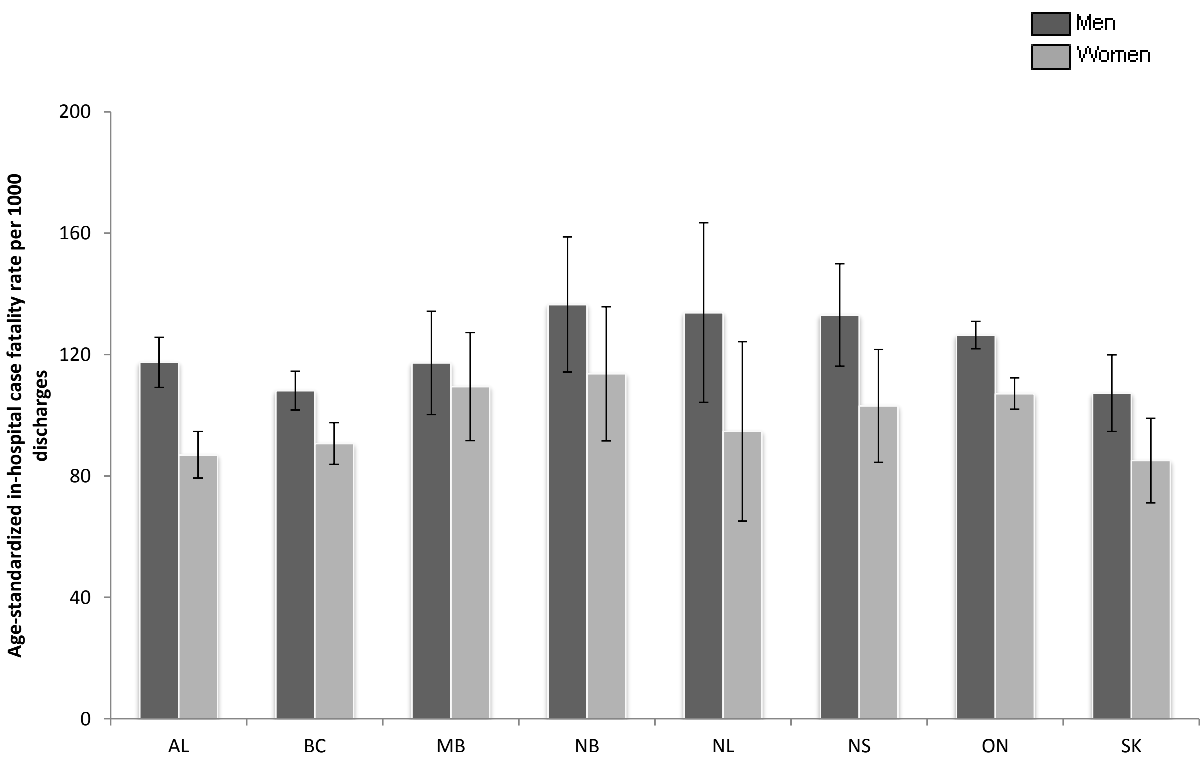


Table 8.5 Estimates of Old: to Young Rate Ratios for Fall and Motor Vehicle Related Injuries (April 1, 2002 – March 31, 2010)

	In-hospital mortality per 100,000 population		
	n (%)	old:young ratio	95% CI
Blunt	320 (3)	2.4	1.9 - 3.1
Fall	6,976 (65)	19.9	17.4 - 22.9
MVC	2,551 (24)	1.9	1.7 - 2.0
Other	815 (8)	3.0	2.6 - 3.6

Poisson regression used to estimate rate ratios. Models included age, gender and fiscal year.

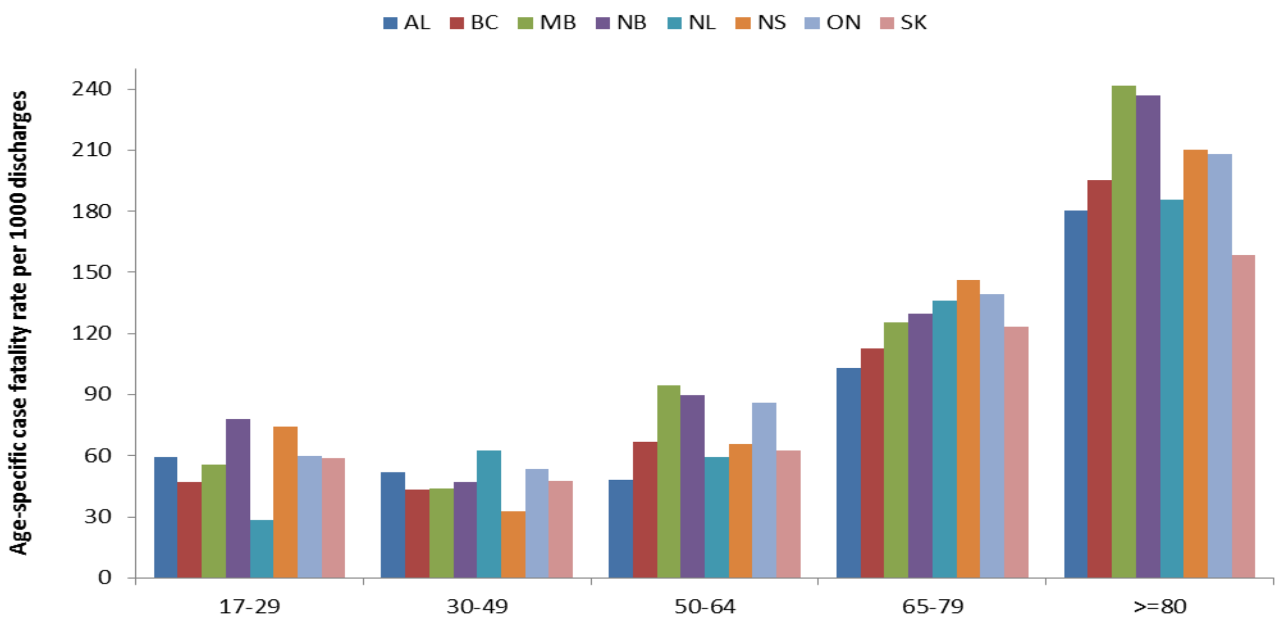
Figure 8:5 Provincial Age-standardized Case Fatality per 1000 Discharges Stratified by Gender (April 1, 2002 – March 31, 2010)



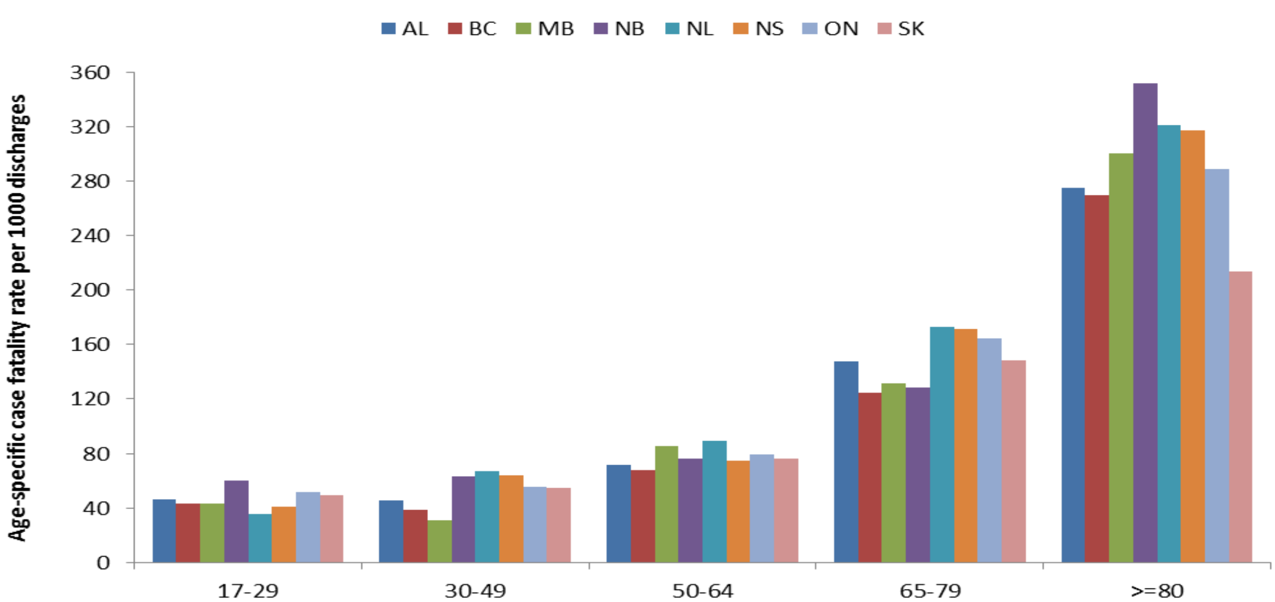
BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NF – Newfoundland and Labrador. The Territories and Prince Edward Island excluded from the analysis due to few deaths. Error bars represent 95% confidence interval.

Figure 8:6 Provincial Age–specific Case Fatality Rate per 1000 Discharges by Gender (April 1, 2002 – March 31, 2010)

A. Women



B. Men



BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NF – Newfoundland and Labrador. The Territories and Prince Edward Island excluded from the analysis due to few deaths.

Table 8.6 Crude and Age-standardized Case Fatality and Mortality Rate– Stratified by Province (April 1, 2002 – March 31, 2010)

	Alberta	British Columbia	Manitoba	New Brunswick	Newfoundland and Labrador	Nova Scotia	Ontario	Saskatchewan	EQ
Women (< 65 yrs)									
Crude case fatality*	53.2	52.1	62.9	71.0	54.6	56.4	67.4	55.7	
Standardized case fatality**	53.2	51.1	62.7	69.1	51.2	57.0	65.3	55.1	1.4
Standardized mortality***	1.6	1.3	1.5	1.4	0.6	1.0	1.1	1.8	2.8
Women (≥65 yrs)									
Crude case fatality	152.2	163.4	197.9	196.4	162.0	187.9	181.6	146.4	
Standardized case fatality	140.9	153.9	184.2	184.9	164.2	176.7	174.0	132.9	1.4
Standardized mortality	19.6	18.3	16.8	19.1	9.8	16.1	19.1	12.6	2.0
Men (< 65 yrs)									
Crude case fatality	52.0	48.1	47.4	66.0	64.3	59.2	61.8	57.2	
Standardized case fatality	53.8	48.4	50.2	65.8	61.9	58.9	61.3	60.1	1.4
Standardized mortality	5.2	4.1	4.1	4.8	3.0	3.5	3.2	6.1	2.0
Men (≥65 yrs)									
Crude case fatality	198.6	185.0	205.2	213.6	223.6	231.3	216.9	175.0	
Standardized case fatality	219.1	203.5	224.4	249.4	248.7	251.5	230.5	182.7	1.4
Standardized mortality	38.9	32.2	25.9	27.1	22.7	33.4	36.4	27.3	1.7

EQ – extremal quotient - calculated as the ratio of the highest to the lowest provincial age-standardized rate; *crude rates are per 1000 major trauma discharges. **case fatality rates are per 1000 discharges and are age-standardized using the total cases of major trauma as the standard population. ***mortality rates are per 100,000 population and are age-standardized to 1991 Canadian population. The Territories and Prince Edward Island excluded from the analysis due to few deaths.

Figure 8:7 Provincial Age-standardized Case Fatality Rates per 1000 Discharges Stratified by Mechanism of Injury (April 1, 2002 – March 31, 2010)

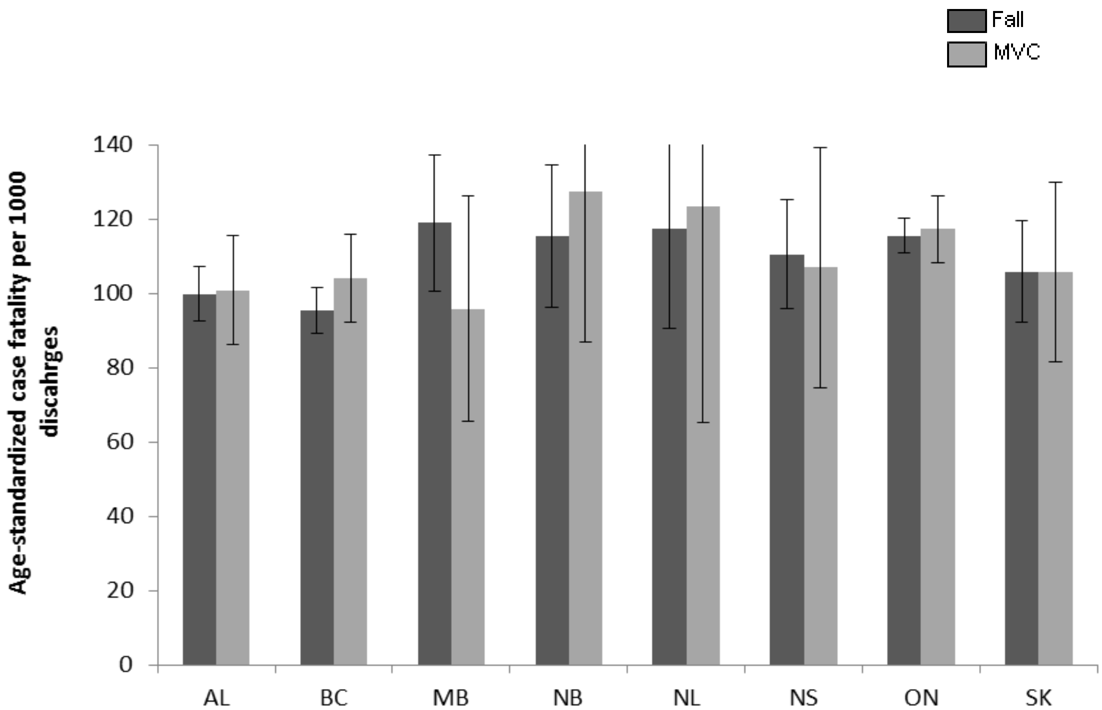
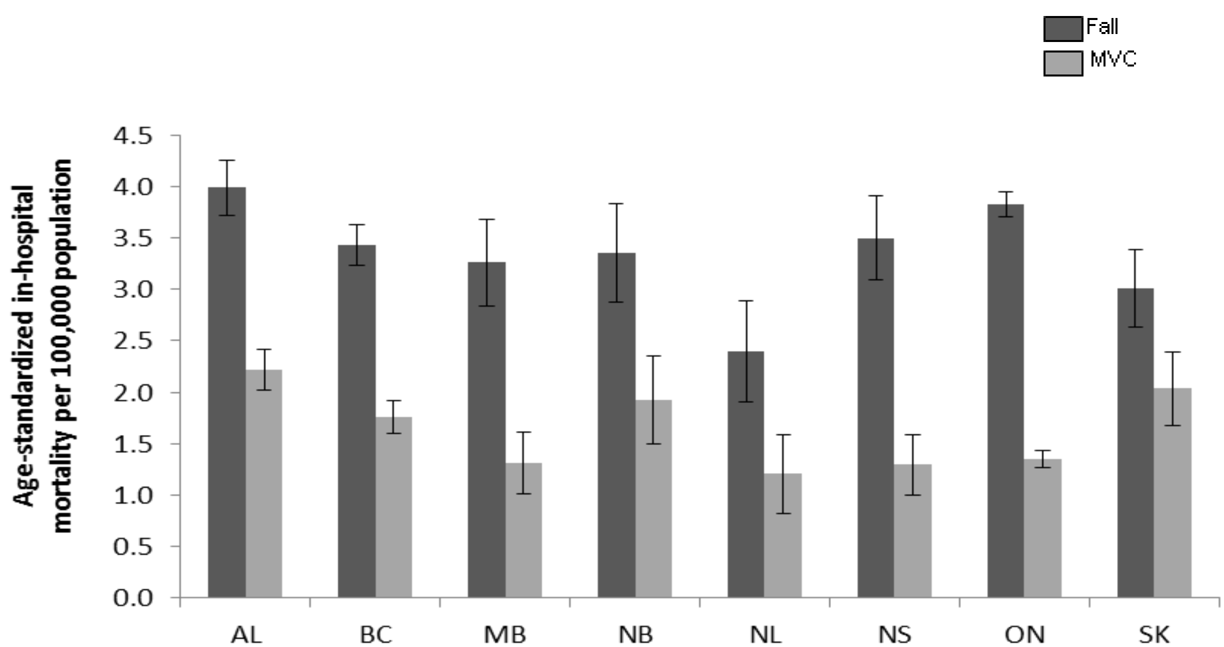


Figure 8:8 Provincial Age-standardized Mortality Rates per 100,000 Population Stratified by Mechanism of Injury (April 1, 2002 – March 31, 2010)



BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NF – Newfoundland and Labrador. The Territories and Prince Edward Island excluded from the analysis due to few deaths. Case fatality rates are age-standardized using the total cases of major trauma as the standard population. Mortality rates are age-standardized to 1991 Canadian population. Error bars represent 95% confidence interval.

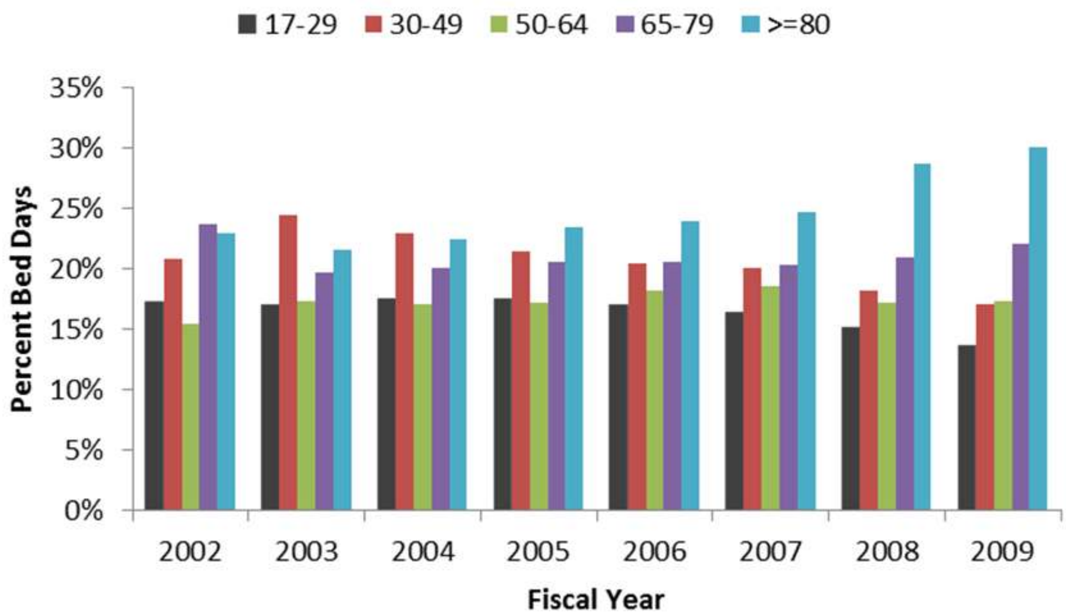
Table 8.7 Annual Crude and Age-standardized Hospital Bed-day Utilization (April 1, 2002 – March 31, 2010)

	2002	2003	2004	2005	2006	2007	2008	2009	Relative Change
All (< 65 yrs)									
Crude	565.4	572.5	619.4	593.2	639.5	663.3	607.6	586.1	
Standardized	563.8	562.6	610.9	579.9	632.3	650.0	593.9	561.0	-0.5%
All (> 65 yrs)									
Crude	2600.2	2104.0	2363.3	2384.5	2606.5	2737.1	2986.4	3131.2	
Standardized	2425.2	1945.7	2171.1	2168.0	2360.1	2452.8	2637.1	2747.4	13.3%
Women (< 65 yrs)									
Crude	302.2	275.4	290.4	276.9	324.9	335.0	310.2	292.9	
Standardized	300.3	268.7	287.8	265.0	315.5	319.0	297.8	282.2	-6.0%
Women (≥ 65 yrs)									
Crude	2528.9	2017.8	2226.8	2168.6	2494.8	2471.2	2717.5	3019.9	
Standardized	2150.2	1713.6	1870.0	1782.9	2081.8	2000.0	2178.2	2385.5	10.9%
Men (< 65 yrs)									
Crude	826.3	867.4	946.0	907.1	951.9	989.2	903.0	877.5	
Standardized	823.8	853.7	930.2	890.8	945.4	977.6	887.4	837.9	1.7%
Men (≥ 65 yrs)									
Crude	2692.3	2215.1	2539.4	2662.0	2749.3	3075.0	3325.5	3270.4	
Standardized	2734.2	2235.7	2546.3	2629.9	2708.4	3006.2	3221.6	3158.2	15.5%

Table 8.8 Crude and Age-standardized Hospital Bed-day Utilization per 100,000 population – Stratified by Province (April 1, 2002 – March 31, 2010)

	Alberta	British Columbia	Manitoba	New Brunswick	Newfoundland and Labrador	Nova Scotia	Ontario	Saskatchewan
All Patients								
Total Bed-days	279,319	318,149	80,537	35,901	24,155	59,852	586,402	65,080
Crude	1320.6	1155.7	1447.6	842.9	720.8	982.5	734.1	1048.6
Standardized	1309.1	1052.4	1308.1	745.5	672.5	846.4	671.1	954.0
Women (< 65 yrs)								
Crude	456.4	360.0	451.5	297.5	177.9	269.9	232.6	388.5
Standardized	393.3	310.1	303.1	208.7	147.4	224.7	196.3	343.4
Women (≥65 yrs)								
Crude	3816.9	2878.7	3595.2	2296.9	1994.6	3045.6	2000.5	1841.8
Standardized	2729.7	2088.9	1857.3	1437.9	1486.6	2051.7	1474.9	1259.6
Men (< 65 yrs)								
Crude	1402.1	1160.1	1556.6	788.1	801.6	852.2	635.3	1199.4
Standardized	1213.4	1005.8	1041.4	597.6	692.9	744.0	546.1	1062.6
Men (≥65 yrs)								
Crude	3749.4	3247.0	3354.7	2146.3	1799.7	2750.5	2592.8	2440.3
Standardized	3260.3	2773.8	2109.9	1649.3	1619.4	2387.4	2255.7	2026.6

Figure 8:9 Annual Trends in the Proportion of Bed-days Used by Patients Following Hospitalization for Major Trauma (April 1, 2002 – March 31, 2010)



Chapter 9 : Undertriage in Patients with Major Trauma (Paper 5)

9.1 Background

The primary aim of an organized system of trauma care is to ensure that injured patients have timely access to resources to meet their care needs.[57] The designation of trauma centres and mechanisms to identify, triage and rapidly transport severely injured patients appropriately to these hospitals are important aspects of these systems.[57, 64] Despite the evidence that supports improved outcomes for severely injured patients that are managed in trauma centres[6, 7, 11] several authors have demonstrated that a considerable proportion of patients with major trauma do not receive care in trauma centres[12, 14, 19, 28, 78] Furthermore, these studies have documented substantial age and gender variation in access to trauma centre care.[19, 78] Most recently, Gomez and colleagues demonstrated that only 57% of severely injured patients in the province of Ontario, Canada received care in a trauma centre.[19] Despite universal access to acute hospital care within this province, these authors also identified marked gender-based differences in access to trauma centre care. The extent to which these observations are applicable to the wider Canadian population is unknown.

In Canada, the support for trauma care organization varies across provinces, with some having government mandates that ensure province-wide trauma service, while in other provinces trauma system implementation is primarily facilitated by local hospital initiatives.[15-17] As a consequence, there is marked variation in the organization of trauma care across and within individual provinces, with variable integration to fully organized systems.[16, 17] The impact of this variability on the receipt of trauma centre care for severely injured Canadians has not been fully characterized. Accordingly, the purposes of this study were to (1) determine the extent of undertriage (severely injured patients not receiving care in a trauma centre) among Canadians; (2) describe regional differences in undertriage; and (3) explore age and gender related differences in the receipt of trauma centre care and identify potential factors contributing to any observed associations.

9.2 Methods

9.2.1 Data and Study Population

The detailed methodology for this study is provided in Chapter 5. Briefly, the study population consisted of 98,871 severely injured adult (> 16 years) trauma patients managed in acute care hospitals in all provinces/territories except Quebec between April 1, 2002 and March 31, 2010. Information on eligible patients was extracted from the NTR-MDS[29] and included demographic and clinical data. Province level data including percent of the population over 65 years and population density were obtained from 2006 census data from Statistics Canada.[151] The number of trauma centres in each province was obtained from a national survey conducted in 2010.[17]

The rate of undertriage (proportion of patients not receiving care in a trauma centre) was calculated for the overall population and by groups defined by province, study years, gender and age group. Multivariable logistic regression models were used to examine the association of gender, age and province of residence, with receiving care in a trauma centre. Hierarchical logistic regression models were fitted to the data to examine the independent association of individual and contextual level variables (Table 9.1) on receiving care in a trauma centre.

9.3 Results

9.3.1 Characteristics of the Study Cohort

The clinical and demographic characteristics of the study cohort are presented in Table 9.2. Women represented 33.5% of the cohort, 38,099 (38.5%) were aged ≥ 65 years, and the mean ISS for the overall cohort was 22.9 (8.4). There were significant differences in the clinical and demographic characteristics between younger (< 65 years) and older patients (≥65 years). Notably, elderly patients were more likely to be female, have slightly but significantly lower injury severity as measured by the ISS, and were more likely to sustain injuries as a result of a fall. Similarly, compared to men, women had significantly higher proportion of injuries due to falls.

9.3.2 Characteristics and Outcomes of Undertriaged Patients

Over the eight-year period 40,852 severely injured patients (41.7%) were not treated in an adult Level I or Level II trauma centre. As detailed in Table 9.3, the majority (52.7%) of these individuals were over 65 years old, with median age of 67 (37) years. Of individuals 80 years and older, representing 20% of the overall cohort, 63% were not managed in a trauma centre. These patients (≥ 80 years) accounted for 30.5% of patients managed in a non-trauma centre and 12.6% of those managed in a trauma centre ($p < 0.0001$). Women represented 40.8% of individuals admitted to a non-trauma centre and only 28.3% of those seen in a trauma centre ($p < 0.0001$). Patients in more remote areas or smaller regions of the country (weak/no metropolitan influenced zone

(MIZ)) accounted for 9.8% and 13% of patients managed in a trauma centre and non-trauma centre, respectively ($p < 0.001$). Approximately half of the patients treated in a non-trauma centre resided beyond 50km from the nearest trauma centre, compared to just under a quarter of those individuals managed in a trauma centre. However, there were no statistically significant differences between trauma and non-trauma centres in either the proportion of patients residing in a province with a high percentage of elderly patients ($p = 0.17$) or a high trauma centre density ($p=0.18$).

In-hospital mortality was similar in patients who were undertriaged and those who received care in trauma centre: 10.9% versus 10.7%, respectively. After adjusting for confounders, mortality remained similar between the two groups for the overall cohort. Among younger patients the odds of death was higher for patients treated in a trauma centre compared to those patients treated in non-trauma centres (OR 2.09; 95% CI: 1.74 - 2.50), possibly reflecting residual unadjusted confounding. There was no significant mortality difference for older patients in the adjusted analysis.

9.3.3 Trends in Undertriage

Among undertriaged patients, there was no significant change in the proportion of females between the first period of the study (fiscal year 2002 – 2005) and the second study period (fiscal year 2006 – 2009) (Table 9.4). The proportion of individuals 65 years and older in the undertriaged population increased slightly but significantly during the second period: from 50.4% in 2002-05 to 54.6% in 2006-09 ($p<0.0001$). An increase in the proportion of patients with fall related injuries among the undertriage population was also noted over the period ($p < 0.001$). There were no substantial changes in the distribution of province of residence, urban/rural location of residence or distance to the nearest trauma centre for patients who were undertriaged over the time period (Table 9.4).

Figure 9.1 summarizes the trends in undertriage by age and gender. Among all age and sex groups, the proportion of individuals not receiving care in a trauma centre remained relatively similar over the eight-year period. Of note, however, was that consistently in each year, a higher proportion of patients 65 years and older did not receive care in a trauma centre compared to their younger counterparts (Figure 9.1A). The pattern of higher proportion of older patients not receiving care in a trauma centre was consistent across all study years when age was categorized into five groups (Figure 9.1B). The trends in receipt of trauma centre care by gender and age is detailed in Figure 9.2. Across all years, compared to men, a significantly higher proportion of women did not receive care in a trauma centre in each year of the study. However, the proportion of patients not receiving care in trauma centre remained stable over the period for all age-gender groups (p-value for trend > 0.05 in all cases).

9.3.4 Regional Patterns in Undertriage

9.3.4.1 Provincial

Over the eight-year period the proportion of patients that did not receive care in a trauma centre ranged from 27.8% in Alberta to 75.9% in Prince Edward Island (Appendix I). For each province, the proportion of patients who did not receive care in a trauma centre was significantly higher for patients 65 years and older compared with those < 65 years (Figure 9.3): the absolute difference in proportion ranging from 7.8% to 40.1% across the provinces. Figure 9.4 shows the proportion of men and women who did not receive care in a trauma centre by province of residence over the duration of the study. Consistent with the pan-Canadian profile, compared to men, a significantly higher proportion of women did not receive care in a trauma centre (p-value < 0.05 in all cases), with the difference being more pronounced among patients 65 years and older.

9.3.4.2 Urban-Rural

As detailed in Figure 9.5, individuals residing in the most urban areas of the country (Census Metropolitan Areas), had the lowest undertriaged rates (34.6%); however, there were no apparent urban to rural gradient across the continuum. Importantly, the undertriage rate was highest amongst individuals residing in more urban/suburban Census Agglomeration areas (56.2%), differing significantly from the rates of those individuals living in smaller towns and more rural areas (44.9%, 47.6%, 49.6% and 42.4% in strongly MIZ, moderately MIZ, weakly MIZ and no MIZ zones, respectively). These findings were consistent across age and gender groups. Of import, similar to the provincial data, we found that the proportion of elderly patients (≥ 65 years) that did not receive care in a trauma centre was higher than younger patients across all areas (Figure 9.5). This pattern was consistent for both men and women (Figure 9.6).

9.3.5 <u>Determinants of Undertriage</u>

Table 9.5 details the results of the multivariable analysis examining the association between patient and provincial characteristics and receipt of care in a trauma centre. All patient-related factors examined including age, gender, ISS and mechanism of injury, were significantly associated with receiving care in a trauma centre. Compared to women, the odds of receiving care in a trauma centre were higher for men, adjusted odds ratio 1.27 (95% CI: 1.22 - 1.32). Similarly, after adjusting for potential confounders (gender, injury severity, mechanism of injury, comorbidity, details regarding time of admission, urban/rural location of residence, income, distance to a trauma centre, and province of residence), compared to patients 17 – 29 years old, the odds of receiving care in a trauma centre were 36% lower for patients 50 – 64 years old (adjusted OR, 0.64; 95% CI: 0.61 – 0.68). Further, the adjusted odds of receiving care in a trauma centre was 73% lower amongst those 80 years and older, compared to individuals younger than 30 years old (adjusted OR 0.27; 95% CI: 0.25 - 0.28). Other factors significantly associated with receipt of trauma centre care included distance from patient's residence to a trauma centre, province of residence, urban/rural location of patient's residence and time of admission (day versus night). Interestingly, we observed that compared to patients admitted during the night, patients admitted during the day had lower odds of receiving care in a trauma centre (OR 0.71; 95% CI: 0.69, 0.73). As detailed in Figure 9.7, the pattern of lower odds of receiving care in a trauma centre for elderly patients (compared to younger patients) was consistent across all years of the study. Similarly, compared to men, the odds of receiving care in a trauma centre was lower among women across all study years (Figure 9.8).

9.3.5.1 Multilevel Analysis

In the models adjusting for provincial level variables, the attenuation in the estimates of the association of patient-level variables was generally moderate (Table 9.5). Moreover, the individual level variables remained statistically significant - age and gender remained strong predictors of receipt of care in a trauma centre. We found that none of the provincial level indicators examined were significantly associated with receiving care in a trauma centre. These findings were robust to the removal of patients residing in Prince Edward Island and the Territories, and restriction of the analysis to patients treated within their own province of residence.

9.3.5.2 Age and Gender Patterns in the Receipt of Care in a Trauma Centre

<u>Mechanism of Injury and Injury Severity</u>

Notwithstanding the trends in the overall data, we observed some variation among age and gender ($p < 0.0001$ for age*gender interaction), age and mechanism of injury ($p < 0.0001$ for age*mechanism interaction) and age and severity of illness ($p < 0.0001$ for age*ISS). In all three instances, stratification revealed a consistent pattern of decreasing trauma centre care with increasing age; however, there were differences in the magnitudes of the association (Table 9.6). For example, we found that, in general, there were greater differences in the odds of receiving care in a trauma centre with increasing age among individuals sustaining a fall, as compared with other mechanisms of injury. Notably, patients aged 80 years and older who sustained a fall had a 75% lower odds of receiving care in a trauma centre compared to patients under the age of 30 who sustained a fall (adjusted OR 0.25; 95% CI: 0.22 - 0.27). For patients injured in a motor vehicle collision the trend of decreasing trauma centre care with increasing age was also apparent. For example, compared to patients less than 30 years old, the odds of receiving care in a trauma centre were 59% lower for patients aged 80 years and older (adjusted odds ratio 0.41; 95% CI: 0.36, 0.46).

When we stratified by age to further explore gender differences in receiving care in a trauma centre, we found that the overall adjusted odds ratio between women and men was higher in patients older than 65 years, with the difference narrower in the younger age group: 1.38 (95% CI: 1.31 – 1.45) and 1.14 (95% CI: 1.09 – 1.20) in older and younger patients, respectively.

Province of Patient Residence

We next sought to examine whether the observed relationships were maintained across geographical regions. As there were too few cases among residents of the Territories and Prince Edward Island to allow for stable estimates in the adjusted logistic regression models the data for these regions are excluded from these analyses. Tables 9.7 and 9.8 depict the results of the multivariable analysis for receipt of trauma centre care by province. As demonstrated, the relationship between trauma centre care and both age and gender was consistent across province of residence; however, after adjusting for covariates, women in the province of New Brunswick had similar odds of receiving care in a trauma centre when compared to men (OR 1.20; 95% CI: 0.97 – 1.51). For all other provinces, the lower odds of receiving care in a trauma centre among women, as compared to men, remained significant in the adjusted analyses (Table 9.7). Similarly, the sharp decline in the odds of receiving care in a trauma centre with increasing age observed for the overall pan-Canadian data was less pronounced among the provinces of British Columbia, Nova Scotia and New Brunswick (Table 9.8). The age and gender patterns by mechanism of injury (fall and motor vehicle collision) are also detailed in Tables 9.7 and 9.8.

Urban-Rural Location of Patients' Residence

We found marked differences in the receipt of care in a trauma centre for women and older individuals across all levels of the urban rural continuum (Table 9.9). Importantly, older patients residing in the most remote regions (no MIZ) had amongst the lowest odds of receiving care in a trauma centre compared to younger patients. For example, of individuals residing in these remote areas, compared to patients younger than 30 years old, individuals between the ages of 30 – 49 had 35% lower odds of receiving care in a trauma centre. In contrast, this value was 26% for similarly aged patients residing in the most urban regions of the country. Interestingly, however, the gradient of declining receipt of trauma centre care with advancing age was flatter in the more remote areas of the country compared to a sharper decline within the other regions. For example, among individuals 80 years and older in more remote areas (No MIZ) the odds of receiving care in a trauma centre was 63% lower than their younger counterparts (17 – 29 years). However, of the individuals residing in metropolitan areas, the adjusted odds of receiving care in a trauma centre was 72% lower for patients ≥ 80 years old compared with patients under the age of 30 years. Compared to men, women had lower odds of receiving care in a trauma centre across all urban-rural areas (Table 9.9).

9.3.6 Discussion

Two important aspects of the results of this population-based study are highlighted. First, our data demonstrates that older patients and females were less likely to receive care in a trauma centre following severe injury. This pattern was consistent across the provinces. Second, we found marked regional variability in the receipt of care in a trauma centre (access) for Canadians, with residence in a province without a Level I or Level II trauma centre resulting in the highest undertriage rates across the country.

Consistent with previous studies[19, 20, 78] our findings allude to substantial disparities in access to trauma centre care for older patients, with a sharply decreasing gradient of access with increasing age. In their cohort of mild to severely injured patients, Hsia and colleagues reported that patients 65 years and older were as much as 77% less likely to receive care in a trauma centre compared to patients under the age of 65 years.[78] Similar to our data, these authors also found that this finding was consistent across injury severity and mechanism of injury. Building on these earlier reports, our data also demonstrates that differential access to trauma centre care for younger and older patients was consistent across geographical areas. This, to our knowledge, is the first population-based study that reports on a broader pan-Canadian perspective on disparities in trauma centre access and the first study to confirm a pattern of disproportionate access to trauma centre care based on age within defined geographical areas within a country. We found that across all provinces, patients 65 years and older had almost 2-fold lower odds of receiving care in a trauma centre compared to younger patients, with the difference being more pronounced in the province of Manitoba. Furthermore, this pattern of decreased access for elderly patients was evident across geographical boundaries defined by urban-rural area of a patient's residence.

Several authors have proffered possible explanations for the observed age disparity, including unconscious or conscious provider bias against referring elderly patients to a trauma centre, underestimation of the severity of illness in elderly patients during initial field triage, increased proportion of isolated hip fracture among the elderly and the corresponding potential that severity of illness related to falls and fractures is viewed as less relevant than motor vehicle-related fractures, patient preference, time of day, and non-compliance with field triage protocols.[14, 18, 19, 69, 78, 217] Consistent with previous report,[78] we suggest that the observed difference in receiving trauma centre care for elderly patients in our study is not explained by differences in the prevalence of patients with isolated hip fracture, predominantly elderly patients and for whom the need for trauma centre care is debated.[218] Of necessity, our definition of need for trauma centre care (ISS > 15) results in the exclusion of many of these patients with truly isolated fall-related fractures. Further, differences in access to trauma centre care remained after controlling for season, admission time variables, and contextual factors (such as the proportion of elderly patients in area of residence) in our analysis.

Recently, Gage and colleagues demonstrated that while pre-hospital providers adhered to the physiologic, anatomic and mechanistic parameters outlined in the Centers for Disease Control and Prevention's trauma field triage guideline, they were, noncompliant with the section recommending transporting patients based on age.[217] Whether this reflects an age-related bias regarding perception of the benefits of trauma centre care for these patients, or a lack of recognition of severe injuries in this population was not determined in this study. Hsia and colleagues have similarly identified gaps in pre-hospital providers' triaging of older patients.[14] While the underlying mechanism are yet to be elucidated, taken together, the evolving evidence suggests that provider-related factors may play a large role in differential access to trauma centre care for severely injured elderly patients.

Our finding that, compared to men, women had lower odds of receiving care in a trauma centre following severe injury lends support to and extends emerging evidence from within the Canadian population by demonstrating differential access for women and men across regions. Gomez and colleagues recently demonstrated that women had a 12% lower odds than men of receiving care in a trauma centre in the province of Ontario.[19] While a direct comparison with this study is problematic given that the databases used, time frame examined and adjustment for potential confounders vary from the present study, our finding of a 20% lower odds of receiving care in a trauma centre is consistent with this evidence. Moreover, while we found that the gender disparity was attenuated among younger individuals as compared to older individuals, the proportion of young women who did not receive care in a trauma centre remained significant. Thus indicating that the characteristically older age of female patients compared to men did not significantly confound the observed gender inequities.

In keeping with the overall pan-Canadian trend of decreased likelihood of receiving care in a trauma centre with being female, our findings suggest that while the magnitude differed across provinces, the overall pattern for women was consistent across all provinces examined, with the largest disparity observed in the province of Newfoundland and Labrador. As demonstrated by our results, gender differences in access to trauma centre care by geography were not restricted to the provinces. Rural areas present unique challenges to developing successful trauma systems,[50, 127] therefore providing consistent access to a trauma centre may be challenging.

Accordingly, several studies have identified urban-rural disparities in access to trauma centre care.[12, 17, 67] What has not previously been shown, however, is that gender differences persist across the urban-rural continuum. Of note, similar to the pattern seen with age, our data suggest that while there were differences in the magnitude of the estimates of receiving care in a trauma centre, women across all six geographical areas defining the urban-rural continuum experienced a decreased likelihood of receiving care in a trauma centre compared to their male counterparts. All differences, except those for more isolated rural areas (no MIZ zones) were statistically significant. Whether our findings reflect pre-existing field and inter-hospital triage and transfer algorithms, type and availability of emergency medical services, or clinical decisions made during either initial field triage or at peripheral hospitals following stabilization cannot be determined from our study. However, while not explicitly identified as transfers from more rural hospitals, Gomez and colleagues found marked gender disparities in decisions to transfer severely injured patients from lower level hospitals to a trauma centre. These authors found that compared to men, women had a 15% lower odds of being transferred to a trauma centre following initial stabilization at outlying hospitals.[19] This was consistent with their data on decreased access for women during initial field triage.

Our findings establish a clear association between gender and receiving care in a trauma centre, with disparities across geographical areas, injury severity, and mechanisms of injury. Reasons for these observations are largely unclear. While there is some evidence from our data that age may partly explain some of the observed differences (women younger than 30 years had similar access to trauma centre care as their male counterparts, and the odds ratios for gender increased substantial in higher age groups), other unmeasured factors likely account for the differences. Gender disparities in access to healthcare services, in particular lower likelihood of access for women, have been reported in other critically ill patient populations.[204, 219] There is evidence to suggest that gender-based differences in access to care may reflect, in part, the unintentional or more conscious explicit gender bias influences on provider decision-making.[220] Such influences might include, for example, societal attitudes and norms that promote gender inequities, or provider perceptions of the need for trauma centre care.[220-222] In the former case, societal attitudes, for example value-based judgments regarding gender roles within society, may influence provider decision-making.[222] The possibility that healthcare providers may underestimate the mortality risk in severely injured women, hence their need for higher level care cannot be ignored. There is data to suggest that compared to women, men are more likely to die following severe injury after controlling for important confounding.[201] This has spurred a number of investigations into the possible protective effective of female sex hormone on outcomes following trauma, with inconsistent results.[208, 223] It is, however, plausible that such evidence might promote the perception, conscious or unconscious, that women are less likely to need and or benefit from trauma centre care than men, despite similar risk profile. Using social cognitive theory as a basis for their argument, Gomez and colleagues have similarly suggested that provider perceptions regarding benefit of trauma centre care may explain, in part, the observed gender differences.[19] While the underlying reasons regarding the observed gender differences are unquestionably more complex than has been offered here, attention to these findings are warranted given that women, in particular older women, are becoming an increasingly larger proportion of the trauma population.[179, 180]

As previously noted, we report the first study examining the pan-Canadian experience regarding receipt of trauma centre care for severely injured patients. The data confirms that access to trauma centre care is less than optimal across the country. Undertriage rate ranged from 27.8% to 75.9% within the provinces, substantially higher than the optimal 5% undertriage rate advocated elsewhere.[224] We also found marked interprovincial variations in the receipt of trauma centre care for severely injured patients. Importantly, while Hameed and colleagues have previously shown that 84.8% of Ontario's population reside within 1 hour of a Level I or Level II trauma centre (second only to Quebec at 86.5%), these results show that receiving care in a trauma centre was particularly low in this province. Of note, patients residing in Ontario had statistically significant lower odds of receiving care in a trauma centre compared to patients in all other provinces except British Columbia and New Brunswick (Prince Edward Island and the Territories excluded from this analysis). The reasons underlying these variations are unclear but, as articulated previously, may relate to several contextual, provider and patient level factors, including the organization and availability of trauma resources such as trauma centres and emergency medical services, and population demographics of the province. Unexpectedly given available evidence,[12] the present study was unable to demonstrate an association between such contextual level factors as trauma centre availability, population density and percent of the province age 65 years and older with the likelihood of trauma centre care. There are several plausible reasons for this finding. First, it may be that the patient demographic and clinical factors included in our analysis explained the majority of the variations in trauma centre access, such that these factors are not as important. Second, it is reasonable to assume that other unmeasured contextual level variables might have a stronger association with trauma centre access than those included in our analysis. For example, within regions with a greater number of large-size community hospitals (non-trauma centre) it is possible that such hospitals play a greater role in the care of patients in these regions. For example, in Ontario, the most populous province in Canada, the population is largely concentrated in more urban and urban-fringe areas.[150] While the province functions within what might be referred to as a primarily exclusive system,[17] that is, Level I and Level II trauma centres are responsible for providing care for severely injured patients with little to no formal role for other hospitals,[60] larger community hospitals within these urban areas likely play a *de facto* role in the trauma system within the province. That is, emergency medical service providers may be more likely to transport patients to these more proximal hospitals than to a trauma centre. The findings of decreased likelihood of care in a trauma centre for the cohort of patients residing in census agglomerations (more suburban areas) when compared to individuals in more rural areas lends support to this speculation. Moreover, this hypothesis is supported by the recent study by Doumouras and colleagues who examined the effect of the additional distance to a trauma centre, compared with a closer non–trauma centre, on emergency medical services providers' compliance with triage criteria in the most urban areas of Ontario.[20] These authors found that differential distances greater than one mile between the closest non–trauma centre and the closest trauma centre were associated with a decreased likelihood of triage to a trauma centre. The authors concluded that their data suggests that even within a setting where trauma centre access is more immediate (within 30 minutes) emergency medical services providers preferentially transferred patients to closer non-trauma centres.[20]

Although not the focus of this study, for the overall cohort and older patients we found no mortality difference between patients receiving definitive care in a trauma centre and those cared for in non-trauma centres. In contrast, mortality was higher in younger patients receiving care in a trauma centre. These findings, must be interpreting in light of the observational nature of this study, in particular we cannot exclude the influence of confounding by indication – that is sicker patients were more likely to be directed to a trauma centre because they might have had a higher risk of death. Moreover, mortality is but one outcome measure with which the benefits of trauma centre care for severely injury patients should be evaluated.[225, 226] Mackenzie and colleagues have previously demonstrated greater improvements in physical functioning and overall vitality amongst trauma patients managed in trauma centres compared to similar patients managed in non-trauma centres.[225] More recently, these authors have demonstrated that a trauma centre approach to providing care for injured patients is cost-effective both in terms of life-year gained and quality adjusted life-years gained.[226] These findings underscore the need for further studies that expands the examination of the benefits of trauma centre care to include outcomes other than mortality. Because of the observational nature of our study, there may yet be unmeasured variables that influence the association between location of care delivery and mortality. For example, we are unable to know details of clinical decision-making at the pre-hospital and in-hospital provider level. Such factors may influence the association of trauma centre care and mortality in either direction. On the one hand, clinicians may decide to transfer patients or not due to unmeasured patient or family factors that could put patients at higher risk of death if not transferred; or, clinicians may well be able to identify patients at higher and lower risks of near-term death and incorporate these factors into their clinical decision-making about transferring or not; altering the relationship between trauma centre care and outcomes that we have observed.

The findings of this study should be interpreted in light of the following limitations. First, in accordance with noted limitations of administrative datasets,[227] we did not have available data to adjust for all factors that may influence triage decisions. As a consequence, we cannot definitively rule out these factors as likely explanations for the observed gender, age or provincial level variations in the receipt of trauma centre care. For example we did not have data on patient, or family preferences. It is plausible that older women sustaining severe injury might preferentially select to receive care in the local setting rather than be transferred to a trauma centre that may be some distance away. Similarly, we could not establish from the available data the extent to which provincial variations in the receipt of trauma centre care reflect differences in such factors as provincial funding for trauma care or regional policies and protocols that govern the organization and deliverable of trauma services. A second limitation is the use of ICD-10 coding to define the incidence of severe trauma. It is plausible that variations in coding practices across centres and provinces may result in under-or-over reporting of undertriage rate. While this might impact interprovincial comparisons, there is no evidence to suggest that there would be systematic differences in coding practices by gender or age. Our comparisons of differences by these patient demographics should, therefore, be robust to differences in coding practices. Finally, we restricted our comparison of outcomes differences between patients receiving care in a trauma centre and those managed in other non-trauma hospitals to in-hospital mortality. As such, the relationship between receipt of trauma centre care and more long-term mortality in these patients is unknown. Further, consideration of other outcomes for these patients, including assessment of functional status, quality life, cost-effectiveness and healthcare utilization following hospital discharge[193, 225, 226] may prove more informative.

9.3.7 Conclusion

Our study represents one of the largest population-based examinations to date of differential access to trauma centre care. The findings demonstrate that despite theoretical universal availability of these services, there are marked disparities in access to trauma centre care for subsets of the Canadian population. Notably, this pattern has been consistent over the past 8 years with no evidence of progress towards improved access to trauma centre care. While further underlying factors for these inequities remain to be elucidated, this study lends support to the need for strategies that will encourage efforts to develop and strengthen trauma systems across the provinces,[17] with the view of better aligning trauma services to meet the needs of Canadians. This will require a comprehensive approach that includes furthering our understanding of the provider and system level practices and policies, at both the national and provincial levels, that are inconsistent with appropriate management of severely injured patients.

Table 9.1 Provincial Description

	Alberta	British Columbia	Manitoba	New Brunswick	Newfoundland & Labrador	Nova Scotia	Ontario	Prince Edward Island	Saskatchewan	Territories
Trauma Centre (N)	3	5	1	2	1	1	10	0	2	0
Trauma centre density (trauma centre/1,000,000 population)	0.91	1.22	0.87	2.74	1.98	1.09	0.82	0	2.06	0
Population density (population per km^2)	5.14	4.45	2.08	10.2	1.36	17.26	13.4	23.9	1.65	0.08
Population ≥ 65 years (%)	10.74	14.58	14.10	14.74	13.90	15.13	13.56	14.86	15.42	5.01

Table 9.2 Characteristics of Patients Hospitalized with Major Trauma between April 1, 2002 and March 31, 2010

Characteristics	All (n=98,8871)	Women (n=33,080)	Men (n=65,791)	Age < 65 (n=60,772)	Age ≥ 65 (n=38,099)
Men (%)	66.54	-	-	77.07	49.76
Mean age (SD)	54.72 23.26)	64.28 (23.14)	49.91 (21.79)	39.08 (14.30)	79.66 (8.07)
≥ 65 years (%)	38.53	57.87	28.81	-	-
ISS* Mean (SD)	23.0 (8.4)	22.3 (8.0)	23.3 (8.3)	23.8 (9.2)	21.7 (6.5)
ISS*					
16 – 24	55.61	58.90	53.96	57.01	53.32
25 – 47	42.10	39.03	43.63	39.74	45.94
48 - 75	2.29	2.06	2.4	3.25	0.73
Mechanism					
Fall	46.44	59.20	40.03	26.34	78.50
MVC	35.66	32.86	37.07	48.70	14.87
Blunt	8.46	3.12	11.14	12.25	2.40
Other	9.44	4.82	11.76	12.70	4.23
Comorbidities					
0	18.97	20.32	18.29	15.88	23.89
1	21.17	22.30	20.60	19.61	23.65
2	17.47	17.40	17.51	16.96	18.29
> 2	42.39	39.98	43.60	47.54	34.18
Province					
Alberta	17.60	15.91	18.45	20.35	13.21
British Columbia	21.13	20.40	21.49	21.73	20.17
Manitoba	3.96	3.72	4.09	4.41	3.25
New Brunswick	2.66	2.73	2.63	2.72	2.56
Newfoundland & Labrador	1.35	1.21	1.42	1.45	1.19
Nova Scotia	3.46	3.48	3.44	3.31	3.69
Ontario	43.44	46.76	41.77	38.91	50.66
Prince Edward Island	0.46	0.44	0.47	0.44	0.48
Saskatchewan	5.36	4.95	5.57	5.84	4.59
Territories	0.58	0.42	0.67	0.82	0.21
Area					
Urban	75.63	78.86	74.0	72.32	80.91
Rural	20.38	17.70	21.73	22.96	16.26
Missing	3.99	3.44	4.27	4.72	2.83
Classification Area					
CMA	56.69	58.21	55.92	54.66	59.90
CA	17.60	17.95	17.43	17.54	17.70
Strong MIZ	4.74	4.39	4.92	4.99	4.36
Moderate MIZ	7.55	7.51	7.58	7.68	7.35
Weak MIZ	9.39	8.70	9.74	10.16	8.16
No MIZ	1.73	1.36	1.92	2.17	1.05
Missing	2.29	1.88	2.50	2.79	1.49
Income Quintile					
Quintile 1 (poorest)	23.35	22.92	23.57	24.56	21.42
Quintile 2	19.96	20.49	19.69	19.71	20.35
Quintile 3	18.04	18.20	17.96	17.50	18.90
Quintile 4	16.05	16.28	15.94	15.63	16.74
Quintile 5 (richest)	15.62	16.02	15.42	14.69	17.10
Missing	6.98	6.08	7.43	7.91	5.49

Table 9:2 (continued)

Characteristics	All (n=98,8871)	Women (n=33,080)	Men (n=65,791)	Age < 65 (n=60,772)	Age ≥ 65 (n=38,099)
Proximity to Trauma Centre					
0 -10 km	33.16	34.49	32.49	31.30	36.12
11- 25 km	14.91	14.63	15.06	14.83	15.05
26 – 50 km	12.39	12.93	12.12	12.48	12.24
50 – 100 km	15.45	15.98	15.18	14.87	16.38
100+ km	22.20	20.53	23.04	24.10	19.16
Missing	1.89	1.44	2.12	2.42	1.04
Fiscal Year					
2002/05	44.62	44.35	44.76	45.69	42.91
2006/09	55.38	55.64	55.4	54.31	57.09
Admission Time (Night)	60.51	58.68	61.43	62.56	57.25
Admission Day (Weekend)	41.40	38.79	42.70	45.32	35.12
Admission Season (Winter)	29.83	31.57	28.96	28.14	32.53
Undertriaged (%)	41.32	50.37	36.76	31.81	56.49
Mortality	10.78	12.55	9.98	5.65	18.96

* ISS < 15 or missing removed; MIZ – metropolitan influenced zone; ISS – injury severity score; CA – census agglomeration; CMA census metropolitan area; MVC – motor vehicle collision.

Table 9.3 Characteristics of Patients Receiving Care in a Level I-II Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre (April 1, 2002 and March 31, 2010)

Characteristics	Non-Trauma Centre (n=40,852)	Trauma Centre (n=58,019)	p - value
Age median (IQR)	67 (37)	48 (39)	<0.0001
Age > 65 years	52.68	28.57	<0.0001
Age			<0.0001
17 -29 years	12.3	25.7	
30 – 49 years	18.3	27.2	
50 – 64 years	16.8	18.5	
65 – 79 years	22.2	16.0	
> 80 years	30.5	12.6	
Male (%)	59.2	71.7	<0.0001
ISS* Mean (SD)	20.27 (6.46)	24.86 (8.99)	<0.0001
ISS*			
16 – 24	69.46	45.97	
25 – 47	29.81	50.65	
48 - 75	0.72	3.38	
Mechanism			<0.0001
Fall	60.63	36.45	
MVC	24.14	43.78	
Blunt	7.71	8.89	
Other	7.52	10.79	
Comorbidities			<0.0001
0	24.1	15.3	
1	27.0	17.1	
2	19.9	15.8	
3	12.0	13.1	
> 3	17.0	38.7	
Province			<0.0001
Alberta	11.82	21.66	
British Columbia	22.22	20.36	
Manitoba	3.64	4.20	
New Brunswick	3.15	2.32	
Newfoundland & Labrador	1.18	1.47	
Nova Scotia	3.38	3.51	
Ontario	49.10	39.45	
Prince Edward Island	0.85	0.19	
Saskatchewan	3.71	6.52	
Territories	0.95	0.33	
Area			<0.0001
Urban	75.23	75.91	
Rural	21.55	19.56	
Missing	3.22	4.54	
Classification Area			<0.0001
CMA	47.48	63.15	
CA	23.99	13.12	
Strong MIZ	5.17	4.45	
Moderate MIZ	8.72	6.73	
Weak MIZ	11.28	8.06	
No MIZ	1.78	1.70	
Missing	1.58	2.79	

Table 9.3 (continued)

Characteristics	Non-Trauma Centre (n=40,852)	Trauma Centre (n=58,019)	p – value
Income Quintile			
Quintile 1 (poorest)	22.21	24.15	
Quintile 2	20.61	19.49	<0.0001
Quintile 3	18.27	17.88	
Quintile 4	16.71	15.59	
Quintile 5 (richest)	15.88	15.44	
Missing	6.32	7.44	
Proximity to Trauma Centre			
0 -10 km	19.28	42.93	
11- 25 km	14.47	16.26	<0.0001
26 – 50 km	14.99	15.23	
50 – 100 km	19.47	10.55	
100+ km	30.64	12.62	
Missing	1.14	2.42	
Admission Time (Night)	54.52	64.73	<0.0001
Admission Day (Weekend)	38.47	43.45	<0.0001
Admission Season (Winter)	30.93	29.06	<0.0001
High Trauma Centre Density (trauma centre/1,000,000 population) (%)	30.27	30.66	0.18
High Proportion of Elderly (≥ 65) Population (%)	33.31	32.89	0.17
High Population Density (population per km^2) (%)	56.48	45.47	<0.0001
Mortality	10.86	10.72	0.48

Table 9.4 Time Trends in Characteristics of Patients Not Receiving Care in a Trauma Centre (April 1, 2002 and March 31, 2010)

Characteristics	Year (2002/05) (n=18, 254)	Year (2006/09) (n =22,598)	P-value
Age mean	60.9 (22.9)	63.3 (22.4)	<0.0001
Age ≥ 65 years	50.40	54.55	<0.0001
Age 17 -29 years	13.27	11.42	
Age 30 – 49 years	20.11	16.86	
Age 50 – 64 years	16.25	17.17	<0.0001
Age 65 – 79 years	21.81	22.56	
Age > 80 years	28.56	31.99	
Male (%)	59.58	58.91	0.18
ISS* Mean (SD)	20.15 (6.73)	20.37 (6.23)	0.0004
ISS* 16 – 24 25 – 47 48 - 75	70.78 26.58 0.85 1.78	66.32 31.53 0.59 1.56	0.0003
Mechanism			
Fall	58.18	62.62	<0.0001
MVC	26.45	22.27	
Blunt	7.89	7.56	
Other	7.47	7.56	
Comorbidities			
0	23.46	24.67	0.009
1	26.98	27.04	
2	19.87	19.86	
> 2	29.69	28.44	
Province			
Alberta	12.25	11.47	
British Columbia	22.84	21.71	
Manitoba*	2.49	4.56	
New Brunswick*	2.95	3.31	0.39#
Newfoundland & Labrador	1.12	1.23	
Nova Scotia	3.41	3.35	
Ontario	49.27	48.97	
Prince Edward Island	0.88	0.82	
Saskatchewan	3.82	3.62	
Territories	0.95	0.94	
Area			
Rural	22.13	21.08	<0.0001
Missing	2.79	3.56	

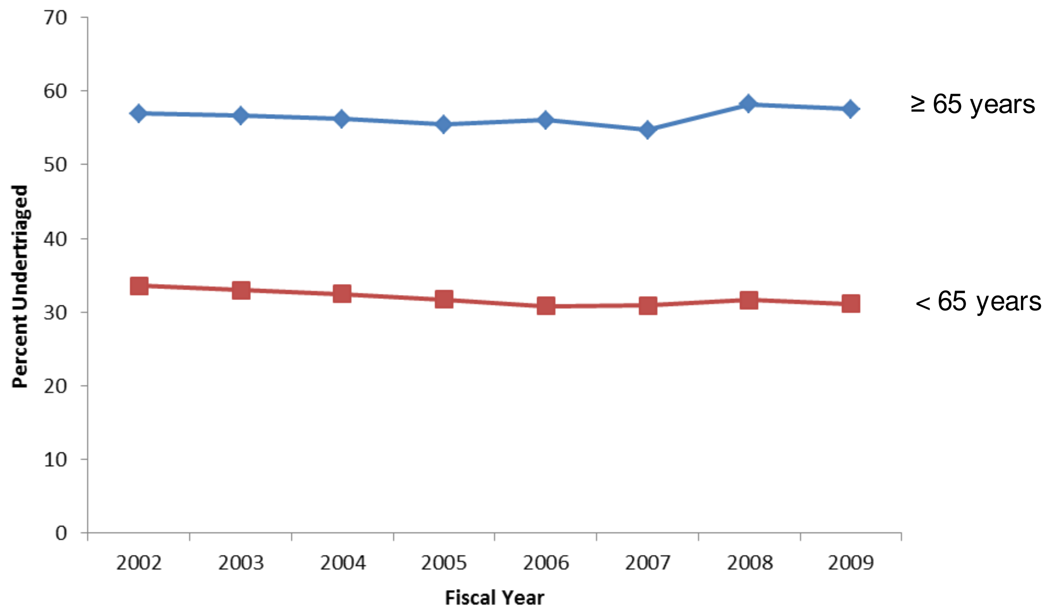
*Manitoba and New Brunswick did not contributed data for all years in fiscal 2002/2005; #p-value reflects analysis that excludes these two provinces

Table 9.4 (continued)

Characteristics	Year (2002/05) (n=18, 254)	Year (2006/09) (n =22,598)	P-value
Classification Area			
CMA	46.37	48.38	
CA	24.60	23.41	
Strong MIZ	5.16	5.17	
Moderate MIZ	9.02	8.48	
Weak MIZ	11.62	11.00	<0.0001
No MIZ	1.87	1.71	
Missing	1.23	1.85	
Income Quintile			
Quintile 1 (poorest)	22.90	21.66	
Quintile 2	20.44	20.75	
Quintile 3	18.46	18.12	
Quintile 4	16.68	16.73	0.01
Quintile 5 (richest)	15.38	16.28	
Missing	6.14	6.47	
Proximity to Trauma Centre			
0 -10 km	18.98	19.53	
11- 25 km	13.37	15.35	
26 – 50 km	14.67	15.26	
50 – 100 km	20.14	18.94	<0.64
100+ km	31.61	29.86	
Missing	1.23	1.07	
Admission Time (Night)	53.97	54.96	0.05
Admission Day (Weekend)	38.17	38.71	0.27
Admission Season (Winter)	31.69	30.31	0.003
Mortality	10.13	11.45	<0.0001

Figure 9:1 Annual Trends in Undertriage by Age

9:1A: Age Dichotomized (65 years used as cut-off)



9:1B: Age defined as a categorical variable based on age distribution of included patients

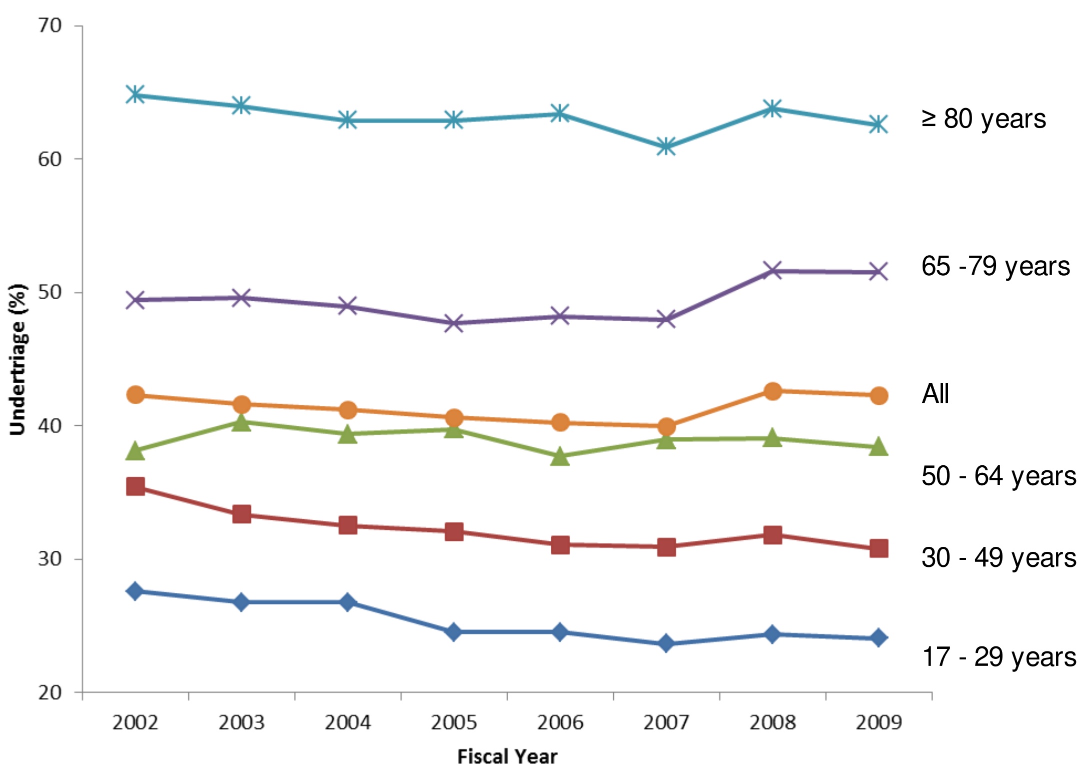


Figure 9:2 Annual Trends in Undertriage by Age Stratified by Gender

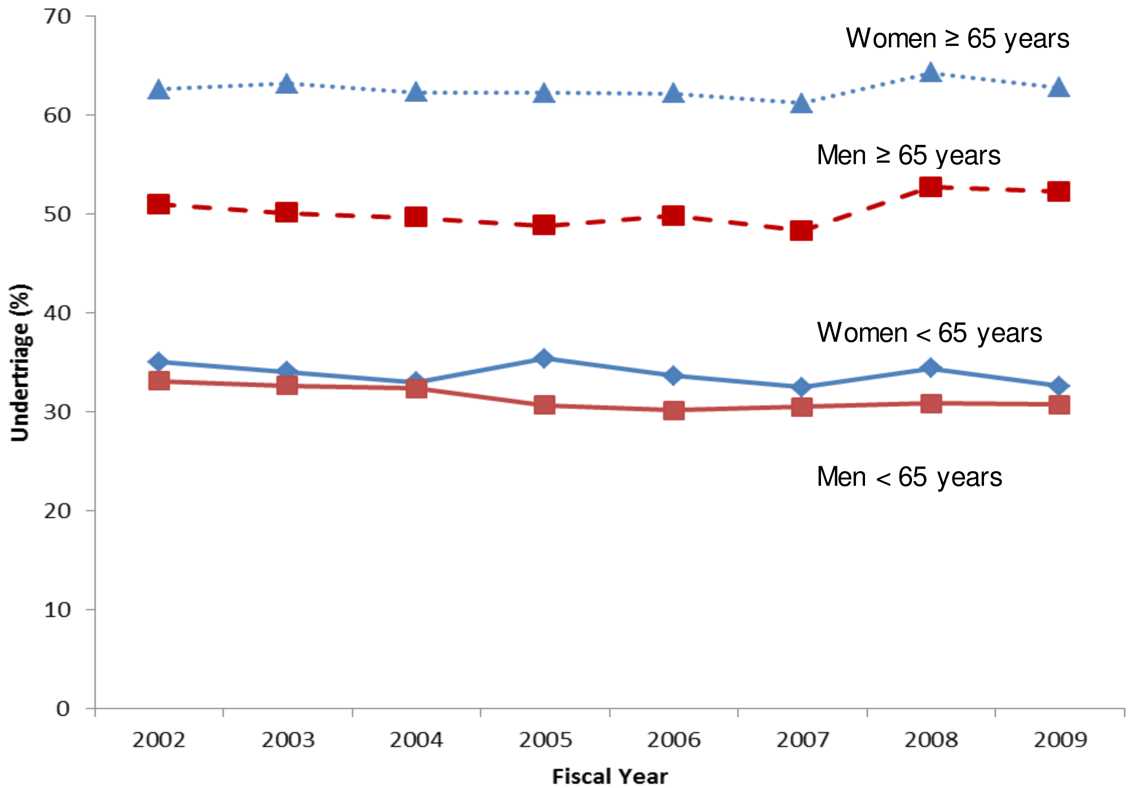
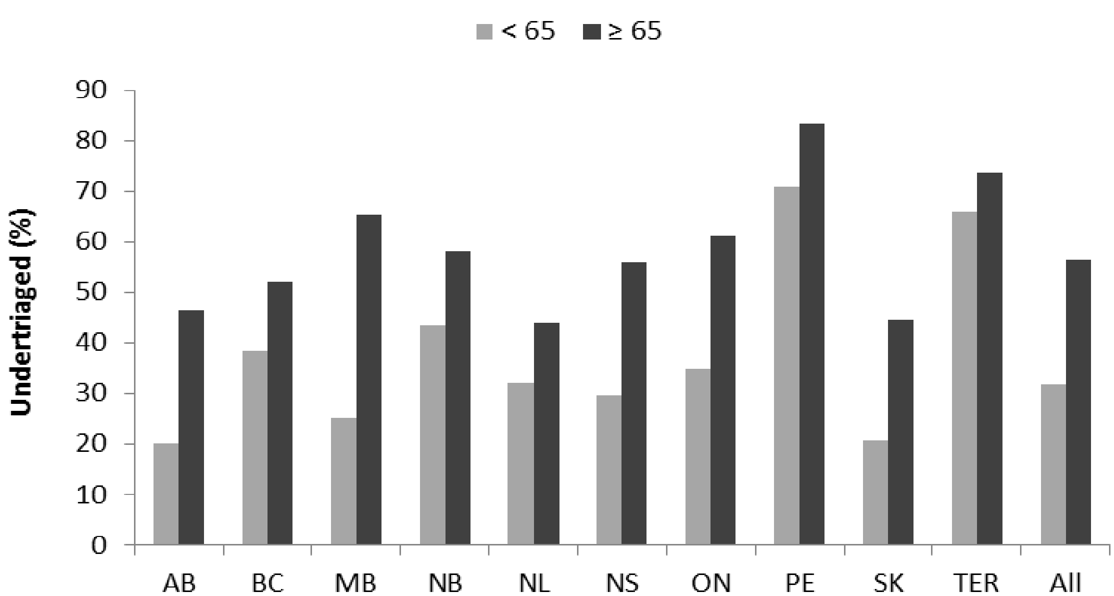


Figure 9:3 Proportion of Patients in each Province not Receiving Care in a Trauma Centre by Age



BC – British Columbia; AL – Alberta; SK- Saskatchewan; ON – Ontario; PE - Prince Edward Island; MB – Manitoba, NB – New Brunswick; NS - Nova Scotia; NL – Newfoundland and Labrador; TER - Territories

Figure 9:4 Proportion of Patients in each Province not Receiving Care in a Trauma Centre by Age and Gender

Figure 9:4A Patients < 65 years old

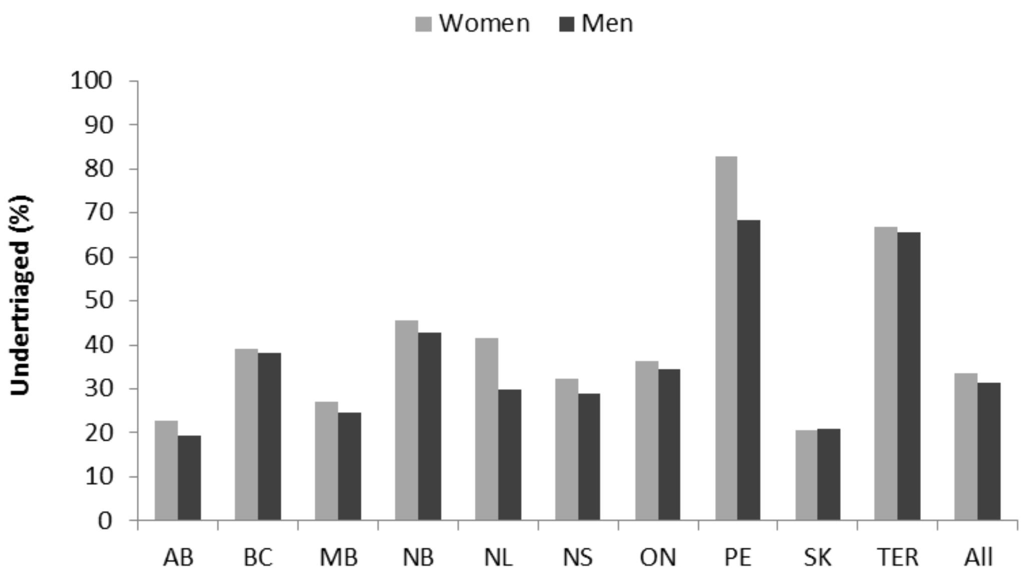


Figure 9:4B Patients ≥ 65 years old

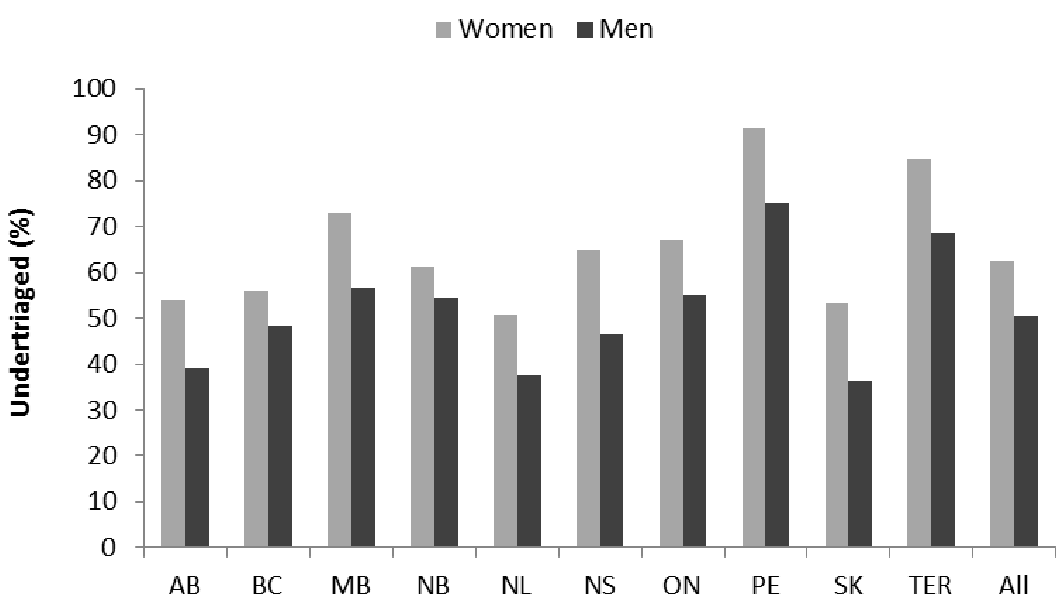


Figure 9:5 Proportion of Patients in each Region not Receiving Care in a Trauma Centre by Age

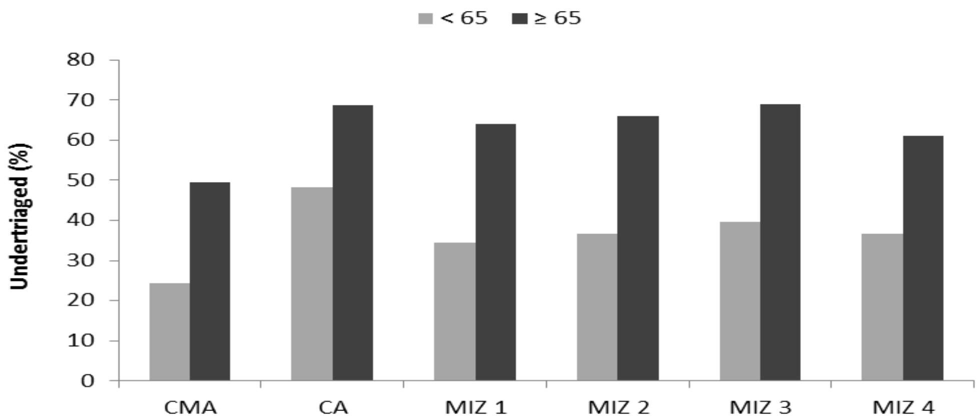


Figure 9:6 Proportion of Patients in each Region not Receiving Care in a Trauma Centre by Age and Gender

Figure 9:6A: Women

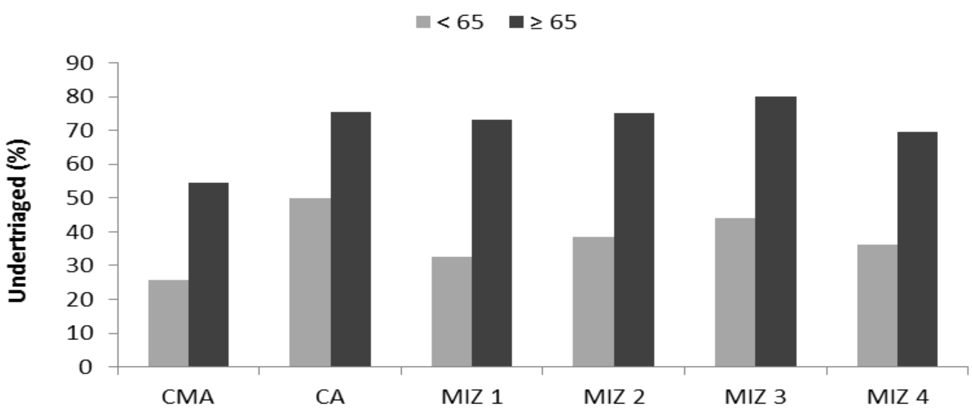
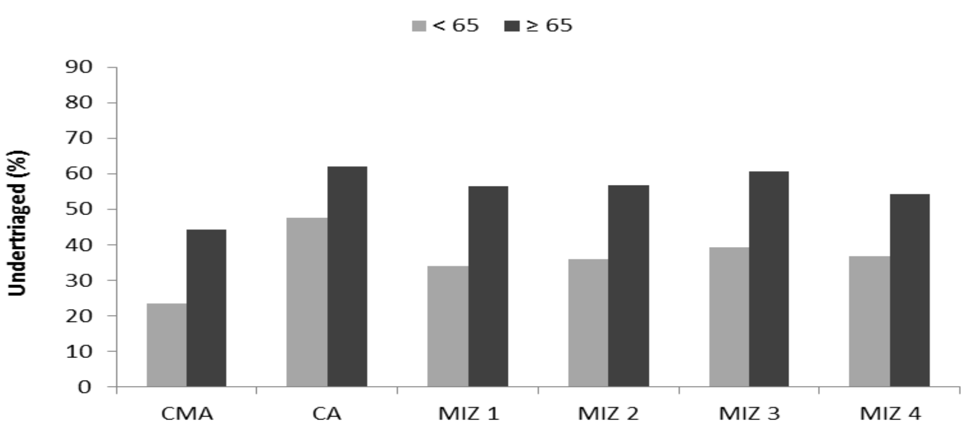


Figure 9:6B: Men



* The Territories are removed from this analysis as these areas do not include these MIZ categories. CA – census agglomeration; CMA census metropolitan area; MIZ – metropolitan influenced zone: 1- strongly influenced; 2 – moderately influenced: 3 – weakly influenced: and 4 – no influence

Table 9.5 Factors Predicting Receipt of Trauma Centre Care for Patients with Major Trauma

Characteristics	Unadjusted OR (95% CI)	Adjusted Analysis OR (95% CI)	Multi-level Model OR (95% CI)
Age			
17 – 29	Reference	Reference	Reference
30 - 49	0.71 (0.68, 0.74)	0.80 (0.76, 0.85)	0.80 (0.76, 0.85)
50 - 64	0.53 (0.50, 0.55)	0.64 (0.61, 0.68)	0.64 (0.61, 0.68)
65 - 79	0.34 (0.33, 0.36)	0.44 (0.41, 0.46)	0.44 (0.41, 0.46)
≥ 80	0.20 (0.19, 0.21)	0.27 (0.25, 0.28)	0.27 (0.25, 0.28)
Female	Reference	Reference	Reference
Male	1.75 (1.70, 1.79)	1.27 (1.22, 1.32)	1.27 (1.22, 1.32)
ISS			
16 – 24	Reference	Reference	Reference
25 – 47	2.57 (2.50, 2.64)	2.11 (2.03, 2.20)	2.11 (2.02, 2.20)
48 – 75	7.07 (6.24, 8.01)	2.48 (2.12, 2.90)	2.48 (2.10, 2.93)
Mechanism			
Fall	Reference	Reference	Reference
MVC	3.02 (2.93, 3.11)	2.29 (2.19, 2.39)	2.29 (2.19, 2.40)
Blunt	1.94 (1.84, 2.03)	1.20 (1.12, 1.28)	1.20 (1.12, 1.28)
Other	2.39 (2.28, 2.50)	1.77 (1.66, 1.89)	1.77 (1.66, 1.89)
Comorbidity			
0	0.28 (0.27, 0.29)	0.40 (0.38, 0.42)	0.40 (0.38, 0.42)
1	0.28 (0.27, 0.29)	0.39 (0.37, 0.41)	0.39 (0.37, 0.41)
2	0.35 (0.34, 0.36)	0.46 (0.44, 0.48)	0.46 (0.44, 0.48)
3	0.48 (0.46, 0.51)	0.60 (0.57, 0.64)	0.60 (0.57, 0.64)
> 3	Reference	Reference	Reference
Severe injury by body region*			
Head	2.00 (1.95, 2.05)	1.96 (1.85, 2.08)	1.96 (1.85, 2.08)
Chest	1.22 (1.20, 1.26)	1.01 (0.96, 1.06)	1.01 (0.96, 1.08)
Abdomen	2.87 (2.68, 3.09)	1.33 (1.22, 1.47)	1.33 (1.20, 1.49)
Upper	1.93 (1.79, 2.08)	1.23 (1.12, 1.37)	1.23 (1.11, 1.39)
Lower	0.66 (0.63, 0.68)	0.93 (0.89, 0.99)	0.94 (0.88, 1.00)
Weekday	Reference	Reference	Reference
Weekend	1.23 (1.20, 1.26)	1.01 (0.97, 1.04)	1.01 (0.97, 1.05)
Night	Reference	Reference	Reference
Day	0.65 (0.64, 0.67)	0.71 (0.69,0.73)	0.72 (0.69, 0.74)
April – November	Reference	Reference	Reference
December - March	0.92 (0.89, 0.94)	1.02 (0.99, 1.06)	1.02 (0.98, 1.06)
Urban	Reference	Reference	Reference
Rural	0.90 (0.87, 0.93)	1.65 (1.58, 1.73)	1.65 (1.57, 1.74)
Income			
Quintile 1 (poorest)	Reference	Reference	Reference
Quintile 2	0.90 (0.87, 0.94)	0.99 (0.95, 1.04)	0.99 (0.95, 1.04)
Quintile 3	0.87 (0.84, 0.90)	1.05 (1.00, 1.10)	1.05 (0.99, 1.10)
Quintile 4	0.86(0.82, 0.89)	0.99 (0.95, 1.05)	0.99 (0.94, 1.05)
Quintile 5 (Richest)	0.89 (0.86, 0.93)	1.02 (0.97, 1.08)	1.02 (0.97, 1.08)
Fiscal Year	1.00 (0.99, 1.00)	1.00 (1.00, 1.01)	1.0 1.00, 1.01)

Table 9:5 (continued)

	Unadjusted OR (95% CI)	Adjusted Analysis OR (95% CI)	Multi-level Model OR (95% CI)
Distance to nearest trauma centre			
0 – 10 km			
11 – 25 km	Reference	Reference	Reference
25 – 50 km	0.47 (0.45, 0.49)	0.37 (0.35, 0.39)	0.37 (0.35, 0.39)
50 – 100 km	0.32 (0.30, 0.33)	0.23 (0.21, 0.24)	0.23 (0.21, 0.24)
> 100 km	0.29 (0.28, 0.30)	0.20 (0.19, 0.21)	0.20 (0.19, 0.21)
	0.24 (0.23, 0.25)	0.11 (0.10, 0.11)	0.11 (0.10, 0.11)
Province			
Ontario	Reference	Reference	
Alberta	2.28 (2.20, 2.36)	2.64 (2.51, 2.78)	-
British Columbia	1.14 (1.10, 1.18)	1.00 (0.96, 1.04)	
Manitoba	1.44 (1.34, 1.54)	1.43 (1.32, 1.56)	
New Brunswick	0.92 (0.85, 0.99)	1.10 (0.99, 1.22)	
Newfoundland & Labrador	1.55 (1.38, 1.73)	2.26 (1.95, 2.62)	
Nova Scotia	1.29 (1.20, 1.38)	2.03 (1.85, 2.22)	
Saskatchewan	2.19 (2.05, 2.33)	3.26 (2.99, 3.55)	
Trauma centre density	-	-	
High			Reference
Low			0.74 (0.20, 2.78)
Population density	-	-	
High			Reference
Low			1.48 (0.40, 5.50)
Percent elderly			
High			Reference
Low			1.11 (0.28, 4.36)

* Defined as Abbreviated Injury Scale (AIS) score ≥ 3; Reference category is AIS < 3. Territories and Prince Edward Island excluded due to small numbers of patients

Figure 9:7 Annual Trends in Old (≥ 65 years) to Young (< 65 years) Adjusted Odds Ratio for Receiving Care in a Trauma Centre

Adjusted for gender, ISS, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre, and admission time (hour of day, time of week and month

Figure 9:8 Annual Trends in Male to Female Adjusted Odds Ratio for Receiving Care in a Trauma Centre

Figure 9:8A Patients < 65 years

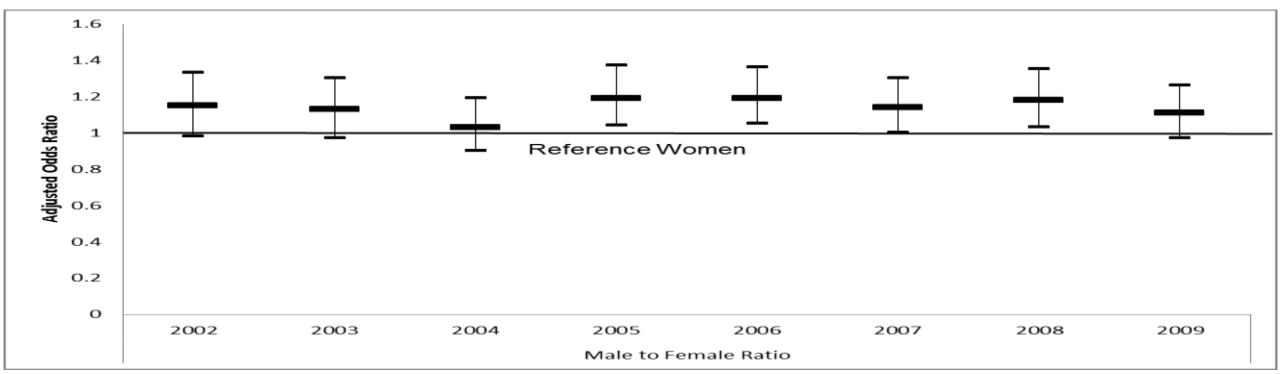
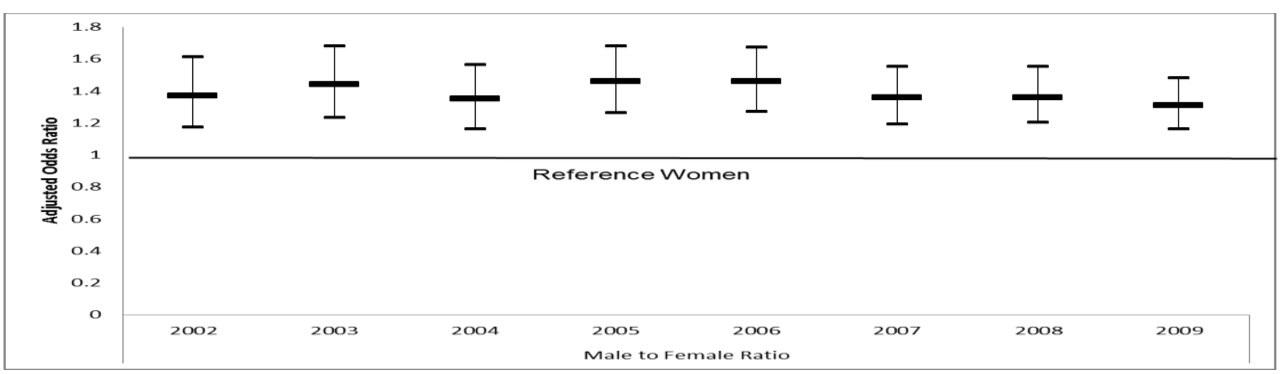


Figure 9:8B Patients ≥ 65 years



Adjusted for age, ISS, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre, and admission time (hour of day, time of week and month)

Table 9.6 Adjusted Odds Ratio for Receipt of Trauma Centre Care Stratified by Injury Severity, Mechanism of Injury and Age

	ISS 16 - 24	ISS 25 - 47	ISS 48 - 75
Age (years)*			
17 - 29	Reference	Reference	Reference
30 - 49	0.73 (0.69,0.78)	0.81 (0.74,0.89)	0.69 (0.46,1.04)
50 - 64	0.54 (0.50,0.57)	0.65 (0.59,0.72)	0.80 (0.49, 1.30)
65 - 79	0.36 (0.32,0.39)	0.46 (0.42,0.51)	0.46 (0.26, 0.80)
≥ 80	0.25 (0.23,0.27)	0.29 (0.27,0.32)	0.31 (0.14,0.69)
Gender^			
Women	Reference	Reference	Reference
Men	1.28 (1.23, 1.34)	1.20 (1.14,1.27)	1.06 (0.72,1.56)

Mechanism of Injury^		
	Fall	MVC
Age (years)**		
17 – 29	Reference	Reference
30 - 49	0.72 (0.64,0.81)	0.73 (0.69,0.79)
50 - 64	0.51 (0.44,0.57)	0.63 (0.58,0.68)
65 - 79	0.37 (0.33,0.41)	0.51 (0.47,0.56)
≥ 80	0.25 (0.22,0.27)	0.41 (0.36,0.46)
Gender^^		
Women	Reference	Reference
Men	1.34 (1.29, 1.41)	1.10 (1.04,1.17)

Age		
	< 65 Years	≥ 65 Years
Gender[γ]		
Women	Reference	Reference
Men	1.14 (1.09, 1.20)	1.38 (1.31, 1.45)

* Adjusted for sex, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre (entered as continuous) and admission time (hour of day, time of week and month)

**Adjusted for ISS (entered as continuous and cases where ISS < 15 excluded), sex, comorbidity, urban/rural location, SES, proximity to a trauma centre (entered as continuous) and admission time (hour of day, time of week and month)

^Adjusted for age, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre (entered as continuous) and admission time (hour of day, time of week and month)

^^ Adjusted for age, ISS (entered as continuous and cases where ISS < 15 excluded), comorbidity, urban/rural location, SES, proximity to a trauma centre (entered as continuous) and admission time (hour of day, time of week and month)

[γ] Adjusted for age, ISS (entered as continuous and cases where ISS < 15 excluded), comorbidity, urban/rural location, SES, proximity to a trauma centre (entered as continuous) and admission time (hour of day, time of week and month)

Table 9.7 Influence of Gender on Receipt of Trauma Centre Care (April 1, 2002 to March 31, 2010)

	Adjusted Odds Ratio (95% CI) Men Relative to Women								
	Overall			Fall			MVC		
	OR#	Lower	Upper	OR#	Lower	Upper	OR#	Lower	Upper
Alberta	1.42	1.30	1.56	1.49	1.30	1.70	1.19	1.02	1.40
British Colombia	1.19	1.11	1.27	1.27	1.15	1.40	1.11	0.98	1.24
Manitoba	1.52	1.26	1.83	1.87	1.42	2.46	0.93	0.66	1.30
New Brunswick	1.20	0.97	1.51	1.19	0.84	1.69	0.98	0.70	1.39
Newfoundland & Labrador	1.72	1.21	2.45	2.21	1.26	3.88	1.46	0.82	2.60
Nova Scotia	1.46	1.21	1.76	1.63	1.27	2.11	0.96	0.68	1.35
Ontario	1.28	1.22	1.35	1.35	1.27	1.44	1.14	1.03	1.25
Saskatchewan	1.32	1.12	1.57	1.27	0.99	1.62	0.97	0.70	1.34
Canada+	1.28	1.24	1.32	1.35	1.29	1.41	1.11	1.04	1.17

#Adjusted for age, ISS, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre, and admission time (hour of day, time of week and month)

Table 9.8 Influence of Age on Receipt of Trauma Centre Care Overall and by Mechanism of Injury (April 1, 2002- March 31, 2010)

		Adjusted Odds Ratio (95% CI) Relative to Patients < 30 years old		
		Overall*	Fall^	MVC^
Age	Alberta			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.78 (0.69, 0.89)	0.73 (0.52, 1.01)	0.74 (0.61, 0.88)
50 – 64 yrs.		0.56 (0.49, 0.65)	0.41 (0.30, 0.56)	0.66 (0.53, 0.81)
65 – 79 yrs.		0.36 (0.31, 0.42)	0.28 (0.20, 0.38)	0.46 (0.36, 0.60)
> 80 yrs.		0.19 (0.17, 0.23)	0.14 (0.10, 0.19)	0.41 (0.28, 0.60)
Age	British Columbia			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.82 (0.75, 0.91)	0.86 (0.68, 1.09)	0.78 (0.68, 0.90)
50 – 64 yrs.		0.81 (0.73, 0.90)	0.74 (0.59, 0.92)	0.76 (0.65, 0.88)
65 – 79 yrs.		0.60 (0.54, 0.67)	0.53 (0.42, 0.65)	0.55 (0.46, 0.66)
> 80 yrs.		0.51 (0.46, 0.58)	0.44 (0.35, 0.54)	0.58 (0.45, 0.74)
Age	Manitoba			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.89 (0.70, 1.14)	0.68 (0.32, 1.44)	0.86 (0.58, 1.27)
50 – 64 yrs.		0.53 (0.39, 0.70)	0.32 (0.15, 0.67)	0.58 (0.37, 0.92)
65 – 79 yrs.		0.27 (0.20, 0.36)	0.15 (0.09, 0.32)	0.43 (0.26, 0.71)
> 80 yrs.		0.10 (0.08, 0.14)	0.06 (0.03, 0.13)	0.20 (0.10, 0.40)
Age	New Brunswick			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.76 (0.56, 1.03)	1.00 (0.41, 2.44)	0.83 (0.58, 1.20)
50 – 64 yrs.		0.71 (0.51, 0.99)	1.02 (0.44, 2.37)	0.69 (0.45, 1.04)
65 – 79 yrs.		0.56 (0.39, 0.81)	0.79 (0.35, 1.81	0.40 (0.23, 0.71)
> 80 yrs.		0.31 (0.21, 0.46)	0.40 (0.18, 0.91)	0.46 (0.21,1.02)
Age	Newfoundland & Labrador			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.77 (0.45, 1.29)	0.53 (0.11, 2.59)	0.82 (0.43, 1.56)
50 – 64 yrs.		0.88 (0.52, 1.49)	0.51 (0.11, 2.37)	0.87 (0.45, 1.69)
65 – 79 yrs.		0.83 (0.47, 1.46)	0.57 (0.13, 2.61)	0.76 (0.33, 1.76)
> 80 yrs.		0.66 (0.35, 1.23)	0.48 (0.10, 2.24)	0.78 (0.18, 3.39)

Adjusted for gender, ISS, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre, and admission time (time of day and day of week).

^Adjusted for gender, ISS, comorbidity, urban/rural location, SES, proximity to a trauma centre.+ Data for PEI and TER excluded

Table 9:8 (continued)

		Adjusted Odds Ratio (95% CI) Relative to Patients < 30 years old		
		Overall*	Fall^	MVC^
Age	Nova Scotia			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		1.03 (0.77, 1.39)	1.24 (0.62, 2.48)	0.94 (0.63, 1.40)
50 – 64 yrs.		0.73 (0.54, 0.99)	0.88 (0.47, 1.69)	0.59 (0.38, 0.89)
65 – 79 yrs.		0.59 (0.43, 0.81)	0.65 (0.35, 1.22)	0.64 (0.37, 1.12)
> 80 yrs.		0.33 (0.23, 0.46)	0.37 (0.20, 0.69)	0.58 (0.27, 1.27)
Age	Ontario			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.74 (0.68, 0.80)	0.65 (0.54, 0.77)	0.69 (0.61, 0.78)
50 – 64 yrs.		0.56 (0.52, 0.61)	0.47 (0.40, 0.56)	0.55 (0.48, 0.62)
65 – 79 yrs.		0.46 (0.42, 0.50)	0.38 (0.32, 0.44)	0.49 (0.42, 0.57)
> 80 yrs.		0.29 (0.26, 0.31)	0.24 (0.20, 0.28)	0.35 (0.29, 0.42)
Age	Saskatchewan			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.67 (0.53, 0.85)	0.71 (0.38, 1.34)	0.62 (0.43, 0.90)
50 – 64 yrs.		0.69 (0.53, 0.92)	0.60 (0.33, 1.11)	0.56 (0.37, 0.86)
65 – 79 yrs.		0.51 (0.38, 0.67)	0.35 (0.20, 0.63)	0.84 (0.48, 1.48)
> 80 yrs.		0.27 (0.21, 0.36)	0.20 (0.11, 0.36)	0.46 (0.23, 0.91)
Age	Canada+			
17 – 29 yrs.		Reference	Reference	Reference
30 – 49 yrs.		0.76 (0.72, 0.80)	0.72 (0.64, 0.81)	0.72 (0.67, 0.78)
50 – 64 yrs.		0.60 (0.57, 0.63)	0.51 (0.46, 0.57)	0.61 (0.56, 0.69)
65 – 79 yrs.		0.44 (0.42, 0.47)	0.37 (0.33, 0.41)	0.49 (0.45, 0.54)
> 80 yrs.		0.30 (0.28, 0.31)	0.24 (0.22, 0.27)	0.40 (0.35, 0.45)

*Adjusted for gender, ISS, mechanism of injury, comorbidity, urban/rural location, SES, proximity to a trauma centre, and admission time (time of day and day of week).

^Adjusted for gender, ISS, comorbidity, urban/rural location, SES, proximity to a trauma centre.+ Data for PEI and TER excluded

Table 9.9 Adjusted Odds Ratio for Receipt of Trauma Centre Care Stratified by Urban-Rural Location

	Adjusted Odds Ratio (95% CI) Relative to Patients < 30 years old					
	CMA	CA	Strong MIZ	Moderate MIZ	Weak MIZ	No MIZ
Age						
17 -29	Reference	Reference	Reference	Reference	Reference	Reference
30 – 49	0.74 (0.69,0.80)	0.77 (0.69,0.86)	0.72 (0.57,0.91)	0.92 (0.76,1.10)	0.82 (0.71,0.95)	0.65 (0.46,0.93)
50 – 64	0.55 (0.51,0.60)	0.72 (0.64,0.81)	0.59 (0.46,0.76)	0.79 (0.65,0.96)	0.73 (0.62,0.86)	0.67 (0.43,1.06)
65 – 79	0.41 (0.38,0.44)	0.57 (0.51,0.65)	0.45 (0.35,0.58)	0.61 (0.50,0.74)	0.53 (0.45,0.64)	0.43 (0.26,0.71)
≥ 80	0.28 (0.26,0.30)	0.35 (0.31,0.40)	0.22 (0.17,0.30)	0.27 (0.21,0.34)	0.21 (0.17,0.26)	0.37 (0.20,0.69)
	Adjusted Odds Ratio (95% CI) Men Relative to Women					
Female	Reference	Reference	Reference	Reference	Reference	Reference
Male	1.24 (1.18,1.30)	1.36 (1.26,1.47)	1.32 (1.12,1.55)	1.42 (1.25,1.62)	1.51 (1.35,1.70)	1.29 (0.94,1.78)

Table 9.10 Multivariable Hierarchical Model Examining Mortality

Characteristics	Adjusted Odds Ratio (95% CI) for Mortality		
	All	< 65 years	≥ 65 years
Age		1.02 (1.01, 1.02)	1.05 (1.05, 1.06)
< 65 years	Reference		
≥ 65 years	3.60 (3.40, 3.81)	-	-
Gender			
Men	Reference	Reference	Reference
Women	0.91 (0.87, 0.96)	1.02 (0.93, 1.11)	0.70 (0.66, 0.75)
ISS			
16 – 24	Reference	Reference	Reference
25 – 27	3.17 (3.01, 3.34)	6.68 (5.99, 7.44)	2.36 (2.22, 2.51)
48 – 75	7.27 (6.41, 8.25)	14.79 (12.54, 17.43)	4.95 (3.75, 6.54)
Mechanism			
Fall	Reference	Reference	Reference
Blunt	0.43 (0.37, 0.49)	0.47 (0.40, 0.56)	0.56 (0.44, 0.71)
MVC	0.67 (0.63, 0.72)	0.73 (0.66, 0.81)	0.87 (0.80, 0.96)
Other	0.93 (0.84, 1.02)	1.24 (1.09, 1.41)	0.88 (0.76, 1.03)
Comorbidity			
0	0.52 (0.49, 0.56)	0.58 (0.50, 0.68)	0.54 (0.50, 0.59)
1	0.71 (0.66, 0.76)	0.88 (0.77, 1.00)	0.69 (0.64, 0.76)
2	0.84 (0.78, 0.90)	1.00 (0.88, 1.12)	0.81 (0.74, 0.89)
3	0.91 (0.85, 0.99)	0.97 (0.86, 1.10)	0.93 (0.84, 1.02)
> 3	Reference	Reference	Reference
Trauma centre			
Non-trauma centre	Reference	Reference	Reference
Trauma centre	1.11 (1.00, 1.24)	2.09 (1.74, 2.50)	1.03 (0.92, 1.16)
Weekend			
Weekday	Reference	Reference	Reference
Weekend	1.01 (0.97, 1.06)	1.05 (0.97, 1.14)	1.01 (0.95, 1.08)
Day time			
Night	Reference	Reference	Reference
Day	1.06 (1.01, 1.11)	1.07 (0.99, 1.16)	1.04 (0.98, 1.11)
Rurality			
Urban	Reference	Reference	Reference
Rural	0.93 (0.87, 1.00)	0.86 (0.77, 0.96)	1.03 (0.94, 1.13)

Table 9:10 (cont'd)

Characteristics	Adjusted Odds Ratio (95% CI) for Mortality		
	All	< 65 years	≥ 65 years
Income quintile			
Quintile 1 (poorest)	Reference	Reference	Reference
Quintile 2	1.03 (0.96, 1.10)	1.08 (0.96, 1.20)	1.00 (0.92, 1.09)
Quintile 3	1.04 (0.97, 1.11)	1.09 (0.97, 1.23)	1.01 (0.92, 1.10)
Quintile 4	0.89 (0.83, 0.96)	0.96 (0.84, 1.08)	0.87 (0.79, 0.95)
Quintile 5 (richest)	0.92 (0.85, 0.99)	1.03 (0.91, 1.17)	0.86 (0.79, 0.95)
Admission Month			
April - November	Reference	Reference	Reference
December - March	1.01 (0.96, 1.06)	0.94 (0.86, 1.03)	1.04 (0.98, 1.11)
Distance to trauma centre			
0 – 11 km	Reference	Reference	Reference
11 - 25 km	0.92 (0.85, 0.99)	0.98 (0.86, 1.10)	0.93 (0.84, 1.02)
26 - 50 km	0.94 (0.86, 1.02)	1.09 (0.96, 1.25)	0.88 (0.79, 0.98)
50 - 100 km	0.93 (0.86, 1.01)	1.08 (0.95, 1.22)	0.87 (0.79, 0.96)
> 100 Km	0.87 (0.81, 0.95)	1.09 (0.97, 1.23)	0.79 (0.71, 0.88)
Hospital Type			
Teaching	Reference	Reference	Reference
Community Hospitals	0.96 (0.87, 1.07)	1.02 (0.86, 1.22)	0.95 (0.85, 1.07)
Population density			
High	Reference	Reference	Reference
Low	0.87 (0.69, 1.10)	0.79 (0.67, 0.93)	0.86 (0.65, 1.12)
Trauma centre density			
High	Reference	Reference	Reference
Low	1.01 (0.76, 1.36)	0.93 (0.69, 1.25)	0.97 (0.69, 1.36)
Proportion of population elderly			
High	Reference	Reference	Reference
Low	0.97 (0.74, 1.29)	0.97 (0.74, 1.28)	1.04 (0.75, 1.44)
Fiscal Year	0.96 (0.95, 0.98)	0.96 (0.95, 0.98)	0.98 (0.97, 0.99)

Chapter 10 General Discussion

10.1 Introduction

Trauma is a major public health concern.[177] Establishing priorities for health policy and prevention strategies to address the more than 14,000 deaths among Canadians[2] are, therefore, important objectives for the Canadian heath system. The body of work presented in this thesis responds to an identified information gap that impedes the ability to optimally meet these objectives. Specifically, this thesis presents (1) a comprehensive profile of provincial and national major trauma hospitalizations including temporal and demographics patterns; (2) patterns in injury mortality; (3) an examination of the extent of receipt of trauma centre care amongst severely injured Canadians; and (4) analyses of the factors influencing care in a trauma centre. In addition to the discussion that followed each of the previous chapters addressing these areas, this chapter provides a general summary of the main findings highlighted by this work and the relevant policy implications. Future research needs to extend and complement the findings herein are also proposed.

10.2 Major Trauma Hospitalization and the Elderly Population

The trends in injury hospitalizations demonstrated a shift towards elderly patients, with patients ≥ 65 years accounting for 41% of the major trauma patients in fiscal 2009; a 12% relative increase in the proportion over the 8 year period. The anticipated impact of an aging population has become an increasing focus of debates and research within the trauma community.[190, 228, 229] It has been suggested that by 2050, approximately

40% of trauma hospitalizations will be due to the elderly.[186] The data presented here suggest that this threshold, in particular for major trauma, has already been reached. Therefore, within the context of an aging Canadian population,[230] these findings, coupled with the observation of higher severe injury hospitalization rates amongst the elderly have important implications for Canadians and Canada's health system. Importantly, the morbidity and mortality consequences of trauma in the elderly, including decreased functional ability in the years following trauma[231] and higher short- and long-term mortality compared to younger trauma patients[189, 232]are well established. From a health system's perspective, the management of elderly trauma patients is associated with disproportionately higher resource use,[213, 214, 233] including a greater proportion of the acute care bed-days consumed by trauma patients.[214] The growing number of elderly major trauma patients, and potential increases if these trends continue, also have important clinically relevance, including the potential for a profound impact on the provision of pre-hospital, acute care and rehabilitation services. Notably, the frequency of pre-existing comorbidities and decreased physiological reserve in elderly trauma patients underscores the complexity associated with the management of this patient population.[186, 234] Further, while the current evidence-base is inconsistent, several authors have identified the importance of pre-existing conditions in explaining some of the variability in mortality between younger and older patients.[232, 234] Addressing the complexity of care required by these patients will, therefore, be of increasing importance as the population ages. This will likely require the identification and adoption of innovative approaches to the clinical assessment, acute care management and rehabilitation practices that result in improved outcomes for these patients. Unfortunately, the trauma literature is scant with respect to specific recommendations for the management of this patient population[186, 235-237] and underscores the need for further research focused on geriatric trauma. While early efforts to address this gap are encouraging[238] developing the evidence on which to base resuscitation, acute care management and rehabilitation treatment standards to optimize outcomes for this patient population will require commitment from the clinical and research trauma community, policy makers and funding organizations.

Primary and secondary prevention of injury among elderly Canadians should also be a key policy response to the evidence presented in this thesis regarding the temporal and demographic trends in major trauma hospitalization rates. Opportunities for prevention are highlighted by the almost 60% relative increase in the number of fall related injury hospitalizations amongst elderly trauma patients. It is well recognized that fall rates increases with advancing age, therefore, the absolute number of fall related injuries is expected to continue to increase as the population ages, even in the absence of attendant increases in fall risk. Several important advancements have been made in reducing falls among the elderly[239, 240] and these and other avenues must be explored in order to mitigate the consequences of this disease among the elderly.

10.3 Major Trauma Hospitalization within the Provinces

Age-standardized hospitalization rates for major trauma varied markedly across the provinces, with several provinces experiencing increases in major trauma hospitalization rates over the study period. The geographical variation in injury hospitalization rates and patterns across the provinces highlighted in this thesis underscore the value of timely local data for understanding the profile of patients with trauma and for informing injury prevention and trauma system development efforts. It also advances awareness of the need for further research and improvements in injury prevention by identifying opportunities to learn from other provinces. Importantly, among the key findings from the provincial analyses are the higher major injury hospitalization rates noted among the more westerly provinces. Delineating the factors underlying this variation will be essential to furthering injury prevention efforts across Canada.

Consistent with the pan-Canadian profile, there was an increase in the absolute numbers and age-standardized rates of major trauma hospitalization among the elderly across most provinces. Notable exceptions are the provinces of Saskatchewan, New Brunswick and Manitoba (for the latter two provinces data is available from 2003 and 2004 onward, respectively). This highlights that trauma remains a significant public health concern, particularly among the elderly, and that the aging population will continue to have a significant impact on the major trauma experience in most provinces. A national focus that includes coordinated funding for injury research, prevention and trauma system improvements is warranted.

10.4 Major Trauma Mortality and Resource Use

The data in this thesis suggest that there has been some improvement in injury related mortality over the eight-year period. Importantly, the overall age-standardized mortality rate from motor vehicle related injuries has declined, with an estimated 3.3% annual decrease over the eight-year period. This suggests that there has been some progress towards the goals of existing policies, laws and intervention strategies aimed at reducing the consequences of motor vehicle injuries.[197, 198]

However, less encouraging are the data suggesting mortality differences across age, sex and provinces. Notably, while the overall burden of injury-related mortality has remained stable, mortality was highest amongst women, with elderly women experiencing an estimated 2.9% annual increase in age-standardized mortality rate. Concurrently, there was a 3.4% estimated annual increase in fall related mortality amongst elderly individuals, suggesting that an increase in fall related injuries may contribute to the increasing rates amongst elderly women. Furthermore, the 2-fold difference in age-standardized mortality rates for older men and women across the provinces suggest marked regional variability.

The data generated from this thesis similarly demonstrated a 2-fold variability in the age-standardized hospital bed-day rates across the provinces. More importantly, consistent with the mortality trends these data support an increasing trauma resource use by the elderly across all provinces. Given, the aging of the Canadian population, these results suggest that current trauma resources will be insufficient to meet the future demand for these services. Coupled with the data of increased injury hospitalizations amongst the elderly, the findings regarding mortality and hospital bed-day utilization suggest that governments at all levels, must respond appropriately to the challenges of the changing patterns of major trauma. This will necessitate investments to improve the Canadian health system's ability to not only manage the continuum of care for these patients but enhance the ability to measure and monitor the impact of the aging population on the need for trauma resources.

10.5 Undertriage of Major Trauma Patients

Despite the importance of trauma centre care for reducing mortality following severe injury, a substantial proportion of severely injured Canadians did not receive care in a trauma centre over the period examined. There were notable variations across the provinces with undertriage rates ranging from 28% in Alberta to 76% in Prince Edward Island. Moreover, this thesis has demonstrated disparities in access for women and the elderly population, with a striking gradient of decreased access with increasing age, across mechanisms of injury and injury severity.

Undertriage is a necessary aspect of a trauma system. However, while there is no threshold that defines an acceptable level of undertriage, trauma professionals agree that trauma systems should strive to minimize undertriage rates[18, 73] and some have proposed a rate of 5% as an acceptable threshold.[224] That 41% of severely injured Canadians were undertriaged, coupled with the evidence of differential access for women and older individuals, underscores opportunities for improving the delivery of trauma services across the provinces.

The development of trauma systems is predicated on the tenet of patients receiving timely access to care in the most appropriate hospital to meet their care needs.[57, 64] Recognizing and transporting severely injured patients to a trauma centre are, therefore, important goals of a trauma system,[59, 217, 241] The question therefore becomes: what within the provision of trauma services within Canadian provinces allows so many severely injured patients, in particular the elderly, to not receive care in a trauma centre? Addressing this question requires identifying where within the system undertriage is likely to occur. Of note, undertriage may result from failure in pre-hospital trauma triage processes such that severely injured patients are not transported to designated trauma centres[217, 241] or from failures in the secondary (inter-hospital) triage processes.[9, 19, 74] While the data used in this thesis do not permit a distinction between undertriage resulting from these two decision points, plausible explanation for each are offered.

10.5.1 Field Undertriage

Within the pre-hospital setting, triage protocols are intended to facilitate decisions regarding the most appropriate facility to transport injured patients.[59] These tools assist pre-hospital providers in identifying patients for whom treatment in a trauma centre would be of benefit, while mitigating the potential for sending less critically injured patients to trauma centres (overtriage). Balancing these competing interests, ensures that on the one hand patients will receive the most optimal care to meet their needs, and on the other reduces the inefficient and potentially deleterious use of trauma centre resources that results from undue patient burden from high overtriage rates.[21, 242] Variability in triage protocols across and within individual provinces may, therefore, play a role in the observed undertriage rates. Notably, several studies have documented concerns with the triage accuracy of current protocols based on anatomical and physiological derangement and mechanistic criteria for identifying older patients requiring trauma centre care[73, 241, 242] as frequently elderly patients with severe injuries do not meet the standards set.[241, 242] In response, both the American College of Surgeons Committee on Trauma (ACS-COT) and the Centers for Disease Control and Prevention in the United States, have recommended that consideration be given to the use of age ≥ 55 years as an independent criterion for trauma centre triage.[59] Recent investigations examining the implications of the inclusion of an age criterion have suggested improvements in triage accuracy for injured elderly individuals,[73] but not without unsustainable concomitant increases in overtriage rates.[242] A mandatory policy of age criterion for trauma centre triage seems, on the surface, to be an attractive solution to reducing undertriage amongst elderly Canadians; however, the impact of higher overtriage rates on patient volumes may make this impractical. Within the Canadian context, research aimed at understanding the accuracy of current triage protocols for facilitating elderly patients receiving care in a trauma centre, and for clarifying other factors (such as age) that may be used to guide field triage decisions for patients in whom other triage criteria are less clear are warranted. As an initial step, investigations that enable an understanding of the criteria used in field triage protocols currently in use in jurisdictions and provinces across the country will be informative.

Notwithstanding the potential limitation of current field triage guidelines, several studies have documented inconsistencies in pre-hospital providers' application of these criteria.[20, 217] As previous discussed, the lack of uniformity in applying field triage protocols may relate to intentional or unintentional biases on the part of providers. Notably, a key debate in the literature is the uncertainty regarding the benefit of trauma centre care for elderly patients[10] which may create a higher threshold for triaging these patients to a trauma centre. This and other influences on pre-hospital triage decisions, such as gender based biases informed by prevailing societal norms, that result in elderly patients and women not receiving care in a trauma centre deserve research attention.

10.5.2 Secondary (Hospital) Undertriage

As noted earlier, trauma system configuration, including the regionalization/concentration of specialized trauma services within dedicated hospitals, necessitates that some severely injured patients may be initially stabilized and/or resuscitated at more proximal hospitals prior to transfer to a trauma centre for definitive care. In the absence of significant investments to establish more trauma centres across the country, the geographic expanse of the country and population densities suggest that initial undertriage to non-trauma centre will continue to be a necessary aspect of delivering trauma care in the provinces. This initial undertriage is, however, not without risks. This thesis has demonstrated substantial continued undertriage, primarily amongst the elderly and female population, where 56% and 50% respectively, were not redirected to a trauma centre following initial assessment at a non-trauma centre. A finding consistent with previous work in Ontario.[19] This may reflect failure to recognize the potential mismatch between the complexity of patients' care needs and resources available at the non-trauma centres or perceptions regarding the ability of these centres to manage sicker patients. Evidence from Ontario supporting the latter explanation has demonstrated that, compared to hospitals with limited resources, initial assessment in resource rich non-trauma centre, defined in terms of availability of specialized human and physical resources, resulted in severely injured patients being less likely to be transferred to a trauma centre.[243] The findings of these authors are concerning given that 42% of all in-hospital trauma related deaths identified in this thesis occurred in non-trauma centres.

Although the database used in this thesis did not allow measurement, it is possible that some of these deaths might have been prevented if patients had received appropriate care in a trauma centre. The analyses demonstrating no mortality benefit to being appropriately triaged to a trauma centre may make this assertion questionable. However, given the limitations of the NTR-minimum dataset with respect to the inclusion of potential confounders, these results must be framed in light of the existing body of literature that has established the benefits of trauma centre care for reducing mortality following injury.[7, 11] Moreover, mortality is but one outcome following severe injury, and its use in identifying individuals most likely to benefit from trauma centre care has been questioned.[242] Other important outcomes such as quality of life, functional ability and health care resource use following discharge must be considered in evaluating the benefits of trauma centre care. Therefore, given the extant literature and the current level of undertriage in Canada, the position taken in this thesis is that further research is needed to elucidate targets for interventions aimed at achieving expeditious and safe transfer of severely injured patients from non-trauma centres to trauma centres. This might include training opportunities for providers at non-trauma centres and establishing effective resources, including hospital triage guidelines, increased use of real-time tele- and web-consultation with trauma centres, including transmission of initial diagnostic imaging, transfer protocols and effective transport systems, to ensure that severely injured patients requiring initial management in a non-trauma centre are directed appropriately to a trauma centre for definitive care.

10.6 The Consequences of Undertriage

Whereas the above discussion acknowledges the likely inevitability of initial undertriage within the Canadian geographic context, an important risk of initial undertriage that must be considered in trauma system development is the impact of inter-facility transfer on patients' and health system's outcomes. The systematic review reported in this thesis has identified that a significant proportion (over 30%) of trauma centre admissions results from indirect transfers from a non-trauma centre. The results of the review regarding the impact of inter-facility transfer on mortality following injury were equivocal, largely due to the significant heterogeneity of the reviewed studies. However, the most methodologically appropriate study for addressing the potential mortality impact of direct transfer to a trauma centre, estimated that approximately 22% of deaths occurred among patients waiting to be transferred from a non-trauma centre to a trauma centre.[18] Coupled with the review's finding of lengthy delays to definitive care, higher costs and increased complications experienced by transfer patients, the necessity of initial undertriage at local hospitals given the dictates of geography, local and provincial resources and the immediacy of the care needs of these patients should be an important part of the discussions and considerations in developing trauma systems across the country. In this regard, policy and other health system decision-makers must attend to addressing the fragmented patient transport systems that exist in Canada as well as identify opportunities to enhance emergency services resources, including for example new helipads, in order to mitigating the risks to Canadians. Further, the development of more efficient and organized pre-hospital and inter-hospital transport systems for injured patients that are supported by the necessary legislative and regulatory frameworks is a necessary first step in addressing the high undertriage rates documented in this thesis.

10.7 Opportunities for Inter-provincial Learning

Opportunities to inform system improvements at the national level are highlighted by the observed provincial variation in access to trauma centre care. Alberta has been characterized as having a "*highly effective and far reaching helicopter medical system*"[17] for the pre-hospital care and transport of injured patients. Indeed, Alberta experienced the lowest rate of undertriage (28%) amongst the provinces. Moreover, while studies are somewhat inconsistent,[60, 244] the coordinated involvement of other hospitals in the delivery of trauma services has been shown to improve patient triage to trauma centres.[244] The data from Alberta suggest that there may be some value to this approach. In this province, three referral centres (level I and II) are supported by lower level trauma hospitals (Level III) and focus has been given to "*improving communication and access"* across these networks of hospitals.[17] In contrast, the high undertriage rates experienced by Prince Edward Island and the Territories also highlight learning opportunities for the Canadian trauma system. Given the absence of a trauma centre within these areas, the instinctive reaction to these observations might be to propose new trauma centres, in an effort to ensure closer proximity to treatment. However, the data presented in this thesis, and supported by earlier studies within the Canadian setting[20] suggest that proximity to a trauma centre does not preclude undertriage of severely injured patients. Moreover, the literature suggests that a critical mass of patients is necessary for maintaining trauma clinical expertise as well as ensuring the financial viability of trauma centres.[245, 246] Given the patient volumes in these regions it may be difficult to achieve this critical mass. The results herein do, however, support the lack of access for patients in regions without a trauma centre (or within close proximity to a trauma centre) and supports the call to "*develop locally relevant solutions to confront access disparities*".[17] This will necessitate better delineation of the location of patients with poor access to trauma centre care within the provinces; an important avenue of investigation that was not afforded by the data used in this study. Furthermore, understanding and strengthening existing coordination of inter-provincial trauma services to meet the needs of patients with limited potential access to trauma services is critical.

Underlying reasons notwithstanding, the examples offered by the experiences of Alberta, Prince Edward Island and the Territories underscores the value of improving our awareness of the aspects of trauma system design within each province that promotes or impedes appropriate access to trauma centre care. For example, improving our understanding of whether, and under which circumstances, the inclusion of other acute care hospitals is beneficial in the organization of trauma system may be helpful to inform policies for trauma care delivery. Robust data to support these types of activities are, unfortunately, lacking and supports the call for a national data strategy aimed at strengthening the Canadian trauma system's capacity to share best practices, standardize processes and develop benchmarks to improve trauma care across the country.[17]

10.8 Undertriage Rates and Trauma System Capacity

The broader issue of the implications of the degree of undertriage across the province must be addressed. If future efforts focused on reducing undertriage rates are successful, this could lead to as much as a 40% increase in the volume of trauma patients seen at trauma centres. This represents an estimated additional 5000, primarily elderly patients, per annum. Coupled with the present evidence of the increasing significance of the aging population on the demographics and incidence of trauma in Canada, this suggests that Canadian trauma resources, including transport systems, health care providers and trauma centres, are likely to be overwhelmed in the absence of efforts to increase current resources or attenuate the demand for trauma services. To offset this potential demand, there is an urgent need to develop and adopt injury prevention strategies of proven success and sustainability.

10.9 Limitations

The limitations of this thesis, including the recognized limitations of administrative data,[227] have been described in detail in the individual chapters; however, a few are worth further discussion. First, in attempting to create episodes of trauma care for individual patients, it is plausible that patients could have been misclassified in terms of whether a specific admission was included or excluded from the eligible cohort. The potential impact of this misclassification on the results and interpretation of the results was investigated by performing analyses that excluded patients with multiple admissions. The findings of similar magnitudes of undertriage and disparities in access to trauma centre care by age and gender suggest that the results are robust to these potential misclassifications. Second, the data does not include information on patients dying in the emergency department or at the scene (i.e. prior to hospital transport). Evidence from within the Canadian setting suggest that this may range from 50% - 72%.[53, 54] Higher pre-hospital deaths in some provinces may, therefore, explain some of the area level variation in trauma hospitalization rates, mortality rates and access to trauma centre care. Temporal trends are similarly affected by time-dependent changes in the rates of pre-hospital deaths. The relative lack of health administrative and clinical information on pre-hospital patient care, coupled with the large proportion of deaths occurring in that context dictate a much greater focus on both descriptive and interventional research in the future. Having an accessible inter-provincial data repository populated for out of hospital deaths, including trauma-related deaths would advance this goal. Third, it is recognized that the evaluation of the extent of patients' injury might be different across hospitals, in particular between trauma centres and non-trauma centres. Such differences in coding practices may impact the ISS scores that were generated in trauma centres and non-trauma centres. Under coding of the extent of injury at non-trauma centre would generate a lower than expected ISS score for patients. For this thesis, the ISS was important for both identifying patients requiring trauma centre care (defined here as ISS > 15) and as an important covariate in adjusted outcomes analyses. In the former case this would suggest that the observed undertriage rates reflect a more conservative estimate of the undertriage rates experienced over the interval examined. In the latter case, reduced comparability of the ISS scores across trauma and non-trauma centres would influence the results of the adjusted analyses. For example, this residual confounding would bias the trauma centre/non trauma centre mortality comparison towards the null. The extent to which under coding occurred in non-trauma centre is unknown; however, the consistent proportions of severely injured patients that are managed in non-trauma centres argue against this being a significant threat to the results or interpretation presented in this thesis. Finally, the change to the ICD-10 coding in the NTR for 2009 necessitated imputation of AIS values for the affected diagnoses. The strategy employed to generate these values, median imputation, may result in biased estimates of the ISS calculated. Potential impact of such a bias would include affecting the number of patients deemed eligible for the study as well as the adjusted analyses performed using ISS. However, the sensitivity analyses performed to assess the potential impact of this imputation suggest that any resulting bias would be minimal. As such, extending the data available for the analyses of trends was thought to outweigh the minimal risk of a bias posed by imputing the ISS.

10.10 Conclusion

This thesis has confirmed that the care of elderly patients is increasingly important to trauma systems in Canada. Importantly, these individuals account for a growing number of hospital admissions for major trauma across the country. Further exacerbating this issue is the evidence that despite declining case fatality rates, there remains a significant mortality burden among the elderly population. Coupled with the less than optimal access to trauma centre care experienced by these patients, the findings of this thesis suggest that there are important opportunities for improving outcomes in this population. This would include a focus on injury prevention, efforts to reduce pre-hospital and in-hospital mortality, and the development of strategies to improve access to trauma centre care for elderly patients. A climate of interprovincial learning and cooperation will be important to achieving these aims. It is hoped that the data generated here will assist the Canadian trauma community in framing clinical and policy priorities that attend to the increasing major trauma hospitalization and mortality rates and disparate access to trauma centre care experienced by the elderly.

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Appendices

Appendix A: Search Strategy for Systematic Review

Search Number	Search	Results
1	emergency service, hospital/ or trauma centers/ or Emergency Medical Services/ or (Trauma adj2 cent:).ti,ab.	57725
2	Rural Health Services/ or Hospitals, Rural/ or (Hospitals/ and (Rural Health/ or Rural Population/)) or Regional Medical Programs/	12407
3	Hospitals, Urban/ or (Hospitals/ and (Urban Health/ or Urban Population/))	4731
4	exp Intensive Care Units/ or critical care/ or intensive care/	64340
5	1 or 2 or 3 or 4	134488
6	exp Accidents/ or exp "Wounds and Injuries"/	612285
7	"transportation of patients"/ or ambulances/ or air ambulances/ or triage/	16362
8	resuscitation/ or cardiopulmonary resuscitation/ or advanced cardiac life support/	26077
9	hospitalization/ or "length of stay"/ or patient transfer/	91926
10	trauma severity indices/ or abbreviated injury scale/ or glasgow coma scale/ or glasgow outcome scale/ or injury severity score/	14945
11	exp "Outcome and Process Assessment (Health Care)"/	424118
12	7 or 8 or 9 or 10 or 11	548178
13	1 or 2 or 3	72924
14	6 and 12 and 13	6366
15	cohort studies/ or longitudinal studies/ or follow-up studies/ or prospective studies/ or retrospective studies/	936091
16	treatment outcome/ or treatment failure/ or morbidity/ or incidence/ or prevalence/ or mortality/ or cause of death/ or fatal outcome/ or hospital mortality/ or infant mortality/ or maternal mortality/ or survival rate/ or survival analysis/	815082
17	16 or 15	1485692
18	14 and 17	3639

Appendix B: Data Abstraction Form Used in the Systematic Review

Reviewer Name:

Study Details

1. First author's name (last name, initials):

2. Publication title:

3. Year of publication:

4. Type of study (check one)

☐ Prospective cohort study
☐ Retrospective cohort study
☐ Case control study
☐ Cross sectional study
☐ Before and after trial
☐ Interrupted time series
☐ Other: Please Specify: _______________

5. Data collection method

☐ Retrospective

☐ Prospective

☐ Not reported

6. Specify the dates during which data was collected for this study:

7. Study Setting (check all that apply)

☐ Canada

☐ United States

☐ Canada

☐ UK

☐ Other: Please Specify:_______________

8. Was the comparison of duration of prehospital time and its effects on health outcomes for trauma patients the primary intent of the study?

   ☐ YES

   ☐ NO (GO TO QUESTION 11)

9. Were the comparison groups dichotomized on the basis of time?

   ☐ YES

   ☐ NO

10. What aspects of prehospital time did the study report? *Please check all that apply.*

☐ Discovery time (time from injury to 911 call to dispatch)

☐ Dispatch time (time from call received by dispatch to time EMS team notified/time to alarm)

☐ Response time (time from EMS team notified to arrival on scene)

☐ Time on scene (time from arrival at scene to patient departure)

☐ Transport time (time from scene to patient arrival at hospital)

☐ Total prehospital time (time from call received by dispatch to patient arrival at hospital)

☐ Other: Please Specify: _______________

11. Was the comparison of transfer status and its effects on health outcomes for trauma patients the primary intent of the study?

   ☐ YES

   ☐ NO (GO TO QUESTION 15)

12. What best describes the sending (referring) hospital(s)? (check all that apply)

☐ Non-designated hospital

☐ Level III or Level IV trauma centre

☐ Uncertain

☐ Other: Please Specify: _______________

13. What best describes the receiving hospital(s)? (check all that apply)

☐ Level I trauma centre

☐ Level II trauma centre

☐ Uncertain

☐ Other: Please Specify: _______________

14. Was the duration of the stay at the initial hospital reported?

☐ YES

☐ NO

15. What was the study setting? (check all that apply)

☐ Urban/Suburban

☐ Rural

☐ Uncertain

☐ Other: Please Specify: _____________________________

16. From which source(s) was the exposure (transfer status or duration of prehospital transport) information obtained? *(Check all that apply)*

☐ Patient charts

☐ Administrative database Specify:

☐ Uncertain

☐ Other (please state): _________________

17. From which source(s) was the outcome measurement information obtained? *(Check all that apply)*

☐ Patient charts

☐ Administrative database Specify:

☐ Uncertain

☐ Other (please state):

Patient Demographics

18. What was the patient population in the study? (check all that apply)

☐ Paediatric (< 18 years)

☐ Adult

19. Please specify how patients were selected for the study? (check all that apply)

☐ All trauma patients admitted to the emergency department of the trauma centre

☐ All trauma patients admitted to the trauma unit

☐ All trauma patients admitted from another hospital

☐ All trauma patients admitted from the scene

☐ All trauma patients admitted from within a specified geographical area

☐ All trauma patients from within a specified geographical area

☐ Random sample of trauma patients

☐ Uncertain

☐ Other: Please Specify: ____________________________

20. Was the comparison of patients admitted to trauma centre restricted to a subset of patients presenting with a specific trauma diagnosis?

☐ YES. Specify disease or condition restricted to:________________________

☐ NO

21. Did the analyses include subgroup analyses?

☐ YES

☐ NO (GO TO QUESTION 23)

22. What subgroup analyses were conducted? (check all that apply)

☐ Traumatic brain injury
☐ Shock
☐ Penetrating trauma
☐ Blunt
☐ Uncertain
☐ Other: Please Specify:

23. Describe the groups being compared in the study. Please check all that apply.

	Group			
	1	2	3	4
a) Patients receiving advanced life support (ALS)	☐	☐	☐	☐
b) Patients receiving basic life support (BLS)	☐	☐	☐	☐
c) Patients transported by land ambulance	☐	☐	☐	☐
d) Patients transported by air ambulance (helicopter)	☐	☐	☐	☐
e) Patients transported from scene	☐	☐	☐	☐
f) Physician included in transport team	☐	☐	☐	☐
g) Patients transported from lower level hospital **to** a **level I** trauma centre	☐	☐	☐	☐
h) Patients transported from lower level hospital **to** a **level II** trauma centre	☐	☐	☐	☐
i) Other Please Specify:	☐	☐	☐	☐

Outcome Assessment

24. Which outcomes were assessed? *Please check all that apply.*

☐ Mortality
☐ Length of stay
☐ Costs
☐ Complications
☐ Other: Please Specify: ____________________________

25. Please complete this section for **mortality** outcomes.

Measurement of mortality *Eg. In-hospital, in-ICU, mortality at 30 days)* Specify:	Which Pt. Est	Pt Est. Value	P value	CI	Have values been adjusted for *any* potential confounders?
Comparison 1 *(Group ______________ vs. Reference, group ___ _________)*					☐ YES **Specify:** ☐ Age ☐ Gender ☐ ISS ☐ Shock ☐ Comorbidity ☐ Insurance status ☐ Mechanism of injury ☐ Other Please specify: ☐ NO
Comparison 2 *(Group ______________ vs. Reference, group ___ _________)*					☐ YES **Specify:** ☐ Age ☐ Gender ☐ ISS ☐ Shock ☐ Comorbidity ☐ Insurance status ☐ Mechanism of injury ☐ Other Please specify: ☐ NO

26. Please record the number of patients in each group that experienced the outcome specified in question 25.
Eg. If the measurement is mortality, record as your outcome: patients who died.

Specify the outcome ______________________

N patients in group 1 with outcome _______________

N patients in group 2 with outcome _______________

Please complete this section for other outcomes assessed (copy table as needed).

Specify outcome examined (e.g. ICU-LOS, hospital LOS, cost) Specify: ____________ _______	Which Pt. Est	Pt Est. Value	P value	CI	Have values been adjusted for *any* potential confounders?
Comparison 1 *(Group ____________ vs. Reference, group ___________)*					☐ YES **Specify:** ☐ Age ☐ Gender ☐ ISS ☐ Shock ☐ Comorbidity ☐ Insurance status ☐ Mechanism of injury ☐ Other Please specify: ☐ NO
Comparison 2 *(Group ____________ vs. Reference, group ___________)*					☐ YES **Specify:** ☐ Age ☐ Gender ☐ ISS ☐ Shock ☐ Comorbidity ☐ Insurance status ☐ Mechanism of injury ☐ Other Please specify: ☐ NO

Appendix C: Quality of Studies Included in the Systematic Review

Study	Comparability of Groups	Ascertainment of Exposure	Ascertainment of Outcome	Follow-up	Control of Confounding	Potential for Bias
Odetola et al. (2010)	Poor	Good	Good	Good	Good	Medium
Moen et al.(2008)	Adequate	Good	Adequate	Good	Adequate	Medium
Rivara et a.(2008)	Adequate	Good	Good	Good	Good	Medium
de Jongh et al (2008)	Adequate	Good	Good	Good	Good	Medium
Spain et al.(2007)	Poor	Good	Good	Poor	Poor	High
Sethi et al.(2007)	Poor	Good	Good	Good	Adequate	Medium
London et al. (2006)	Adequate	Good	Good	Good	Poor	Medium
Hartl et al.(2006)	Unclear	Good	Good	Good	Adequate	High
Harrington et al. (2005)	Poor	Good	Good	Good	Poor	High
Lubin et al.(2005)	Adequate	Good	Good	Good	Poor	Medium
Larson et al.(2004)	Poor	Good	Good	Good	Poor	High
Sollid et al.(2003)	Poor	Good	Good	Good	Poor	High
Nathens et al.(2003)	Adequate	Good	Good	Good	Good	Medium
Sethi et al.(2002)	Poor	Good	Good	Good	Poor	High
Osterwalder et al. (2002)	Good	Good	Good	Good	Poor	Medium
Cummings et al. (2000)	Poor	Good	Good	Good	Poor	High
Rogers et al.(1999)	Poor	Good	Good	Good	Adequate	Medium
Falcone et al.(1998)	Poor	Good	Good	Good	Poor	High
Young et al. (1998)	Unclear	Good	Good	Good	Poor	High
Kam et al.(1998)	Unclear	Good	Good	Good	Poor	High
Sampalis et al.(1997)	Poor	Good	Good	Good	Good	Medium
Timberlake (1996)	Poor	Good	Good	Good	Poor	High
Johnson et al. (1996)	Adequate	Adequate	Unclear	Good	Poor	High
Obremskey et al.(1994)	Unclear	Good	Good	Good	Adequate	Medium
Schwartz et al. (1989)	Adequate	Good	Good	Good	Unclear	Medium
Poon et al. (1991)	Poor	Adequate	Adequate	Good	Poor	High
Stone et al. (1986)	Adequate	Unclear	Unclear	Good	Poor	High

Appendix D: List of Trauma Centre

Province	Institution Name	Level
AB	University of Alberta Hospital	Level 1
AB	Foothills Medical Centre	Level 1
AB	Royal Alexandra Hospital	Level 2
BC	Vancouver General Hospital	Level 1
BC	Royal Inland Hospital	Level 2
BC	Kelowna General Hospital	Level 2
BC	Royal Columbian Hospital	Level 2
BC	Victoria General Hospital	Level 2
MB	Health Sciences Centre Winnipeg	Level 1
NB	St. John Regional Hospital	Level 1
NB	Moncton Hospital	Level 2
NL	St. John's General Hospital	Level 1
NS	Queen Elizabeth II Health Sciences	Level 1
ON	London Health Science Centre	Level 1
ON	St. Michael's Hospital	Level 1
ON	The Ottawa Hospital (Civic)	Level 1
ON	Hote Dieu Grace Hospital	Level 1
ON	Hamilton Health Sciences	Level 1
ON	Sunnybrook Health Sciences	Level 1
ON	Sudbury Regional	Level 2
ON	Thunderbay Regional Health Sciences	Level 2
ON	Kingston General Hospital	Level 2
SK	Saskatoon Heath Region (Royal University Hospital)	Level 1
SK	Regina Qu'Appelle Health Region (Regina General)	Level 2

Appendix E: Enabled and Disabled and New ICD-10 Codes – Effective Fiscal 2009

Enabled ICD-10-CA Codes for 2009 and Description		Disabled ICD-10-CA Codes for 2009 and Description	
S06.0	Concussion	S06.000	Concussion without loss of consciousness without open intracranial wound
S06.1	Traumatic cerebral oedema	S06.001	Concussion without loss of consciousness with open intracranial wound
S06.25	Diffuse brain injury without open intracranial wound	S06.010	Concussion with brief loss of consciousness without open intracranial wound
S06.26	Diffuse brain injury with open intracranial wound	S06.011	Concussion with brief loss of consciousness with open intracranial wound
S06.35	Focal brain injury without open intracranial wound	S06.020	Concussion with moderate loss of consciousness without open intracranial wound
S06.36	Focal brain injury with open intracranial wound	S06.021	Concussion with moderate loss of consciousness with open intracranial wound
S06.4	Epidural haemorrhage	S06.030	Concussion with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound
S06.5	Traumatic subdural haemorrhage	S06.031	Concussion with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound
S06.6	Traumatic subarachnoid haemorrhage	S06.040	Concussion with prolonged loss of consciousness without return to pres-existing level of consciousness without open intracranial wound
S06.85	Other intracranial injuries without open intracranial wound	S06.041	Concussion with prolonged loss of consciousness without return to pres-existing level of consciousness with open intracranial wound
S06.86	Other intracranial injuries with open intracranial wound	S06.090	Concussion with loss of consciousness of unspecified duration without open intracranial wound
S06.9	Intracranial injury, unspecified	S06.091	Concussion with loss of consciousness of unspecified duration with open intracranial wound
S43.402	Sprain and strain of shoulder joint, NOS	S06.100	Traumatic cerebral oedema without loss of consciousness without open intracranial wound
S62.410	Multiple fractures of shaft of other metacarpal bones, closed	S06.101	Traumatic cerebral oedema without loss of consciousness with open intracranial wound
S62.411	Multiple fractures of shaft of other metacarpal bones, open	S06.110	Traumatic cerebral oedema with brief loss of consciousness without open intracranial wound
S62.420	Multiple fractures of head of other metacarpal bones, closed	S06.111	Traumatic cerebral oedema with brief loss of consciousness with open intracranial wound
S62.421	Multiple fractures of head of other metacarpal bones, open	S06.120	Traumatic cerebral oedema with moderate loss of consciousness without open intracranial wound
S62.470	Multiple fractures of multiple sites of other metacarpal bones, closed	S06.121	Traumatic cerebral oedema with moderate loss of consciousness with open intracranial wound
S62.471	Multiple fractures of multiple sites of other metacarpal bones, open	S06.130	Traumatic cerebral oedema with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound
S62.490	Multiple fractures unspecified site of other metacarpal bones, closed	S06.131	Traumatic cerebral oedema with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound
S62.491	Multiple fractures unspecified site of other metacarpal bones, open	S06.140	Traumatic cerebral oedema with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound
		S06.141	Traumatic cerebral oedema with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound
		S06.190	Traumatic cerebral oedema with loss of consciousness of unspecified duration without open intracranial wound
		S06.191	Traumatic cerebral oedema with loss of consciousness of unspecified duration with open intracranial wound

Disabled ICD-10-CA Codes for 2009 and Description		Disabled ICD-10-CA Codes for 2009 and Description	
S06.200	Diffuse brain injury without loss of consciousness without open intracranial wound	S06.400	Epidural haemorrhage without loss of consciousness without open intracranial wound
S06.201	Diffuse brain injury without loss of consciousness with open intracranial wound	S06.401	Epidural haemorrhage without loss of consciousness with open intracranial wound
S06.210	Diffuse brain injury with brief loss of consciousness without open intracranial wound	S06.410	Epidural haemorrhage with brief loss of consciousness without open intracranial wound
S06.211	Diffuse brain injury with brief loss of consciousness with open intracranial wound	S06.411	Epidural haemorrhage with brief loss of consciousness with open intracranial wound
S06.220	Diffuse brain injury with moderate loss of consciousness without open intracranial wound	S06.420	Epidural haemorrhage with moderate loss of consciousness without open intracranial wound
S06.221	Diffuse brain injury with moderate loss of consciousness with open intracranial wound	S06.421	Epidural haemorrhage with moderate loss of consciousness with open intracranial wound
S06.230	Diffuse brain injury with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound	S06.430	Epidural haemorrhage with prolonged loss of consciousness without open intracranial wound
S06.231	Diffuse brain injury with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound	S06.431	Epidural haemorrhage with prolonged loss of consciousness with open intracranial wound
S06.240	Diffuse brain injury with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound	S06.440	Epidural haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound
S06.241	Diffuse brain injury with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound	S06.441	Epidural haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound
S06.290	Diffuse brain injury with loss of consciousness of unspecified duration without open intracranial wound	S06.490	Epidural haemorrhage with loss of consciousness of unspecified duration without open intracranial wound
S06.291	Diffuse brain injury with loss of consciousness of unspecified duration with open intracranial wound	S06.491	Epidural haemorrhage with loss of consciousness of unspecified duration with open intracranial wound
S06.300	Focal brain injury without loss of consciousness, without open intracranial wound	S06.500	Traumatic subdural haemorrhage without loss of consciousness without open intracranial wound
S06.301	Focal brain injury without loss of consciousness, with open intracranial wound	S06.501	Traumatic subdural haemorrhage without loss of consciousness with open intracranial wound
S06.310	Focal brain injury with brief loss of consciousness without open intracranial wound	S06.510	Traumatic subdural haemorrhage with brief loss of consciousness without open intracranial wound
S06.311	Focal brain injury with brief loss of consciousness with open intracranial wound	S06.511	Traumatic subdural haemorrhage with brief loss of consciousness with open intracranial wound
S06.320	Focal brain injury with moderate loss of consciousness without open intracranial wound	S06.520	Traumatic subdural haemorrhage with moderate loss of consciousness without open intracranial wound
S06.321	Focal brain injury with moderate loss of consciousness with open intracranial wound	S06.521	Traumatic subdural haemorrhage with moderate loss of consciousness with open intracranial wound
S06.330	Focal brain injury with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound	S06.530	Traumatic subdural haemorrhage with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound
S06.331	Focal brain injury with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound	S06.531	Traumatic subdural haemorrhage with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound
S06.340	Focal brain injury with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound	S06.540	Traumatic subdural haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound

Disabled ICD-10-CA Codes for 2009 and Description		Disabled ICD-10-CA Codes for 2009 and Description	
S06.341	Focal brain injury with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound	S06.541	Traumatic subdural haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound
S06.390	Focal brain injury with loss of consciousness of unspecified duration without open intracranial wound	S06.590	Traumatic subdural haemorrhage with loss of consciousness of unspecified duration without open intracranial wound
S06.391	Focal brain injury with loss of consciousness of unspecified duration with open intracranial wound	S06.591	Traumatic subdural haemorrhage with loss of consciousness of unspecified duration with open intracranial wound
S06.600	Traumatic subarachnoid haemorrhage without loss of consciousness without open intracranial wound	S06.900	Intracranial injury, unspecified without loss of consciousness without open intracranial wound
S06.601	Traumatic subarachnoid haemorrhage without loss of consciousness with open intracranial wound	S06.901	Intracranial injury, unspecified without loss of consciousness with open intracranial wound
S06.610	Traumatic subarachnoid haemorrhage with brief loss of consciousness without intracranial wound	S06.910	Intracranial injury, unspecified with brief loss of consciousness without open intracranial wound
S06.611	Traumatic subarachnoid haemorrhage with brief loss of consciousness with intracranial wound	S06.911	Intracranial injury, unspecified with brief loss of consciousness with open intracranial wound
S06.620	Traumatic subarachnoid haemorrhage with moderate loss of consciousness without open intracranial wound	S06.920	Intracranial injury, unspecified with moderate loss of consciousness without open intracranial wound
S06.621	Traumatic subarachnoid haemorrhage with moderate loss of consciousness with open intracranial wound	S06.921	Intracranial injury, unspecified with moderate loss of consciousness with open intracranial wound
S06.630	Traumatic subarachnoid haemorrhage with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound	S06.930	Intracranial injury, unspecified with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound
S06.631	Traumatic subarachnoid haemorrhage with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound	S06.931	Intracranial injury, unspecified with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound
S06.640	Traumatic subarachnoid haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound	S06.940	Intracranial injury, unspecified with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound
S06.641	Traumatic subarachnoid haemorrhage with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound	S06.941	Intracranial injury, unspecified with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound
S06.690	Traumatic subarachnoid haemorrhage with loss of consciousness of unspecified duration without open intracranial wound	S06.990	Intracranial injury, unspecified with loss of consciousness of unspecified duration without open intracranial wound
S06.691	Traumatic subarachnoid haemorrhage with loss of consciousness of unspecified duration with open intracranial wound	S06.991	Intracranial injury, unspecified without loss of consciousness with open intracranial wound
S06.800	Other intracranial injuries without loss of consciousness without open intracranial wound	S43.71	Sprain and strain of other and unspecified parts of shoulder girdle, infraspinatus (muscle) (tendon)
S06.801	Other intracranial injuries without loss of consciousness with open intracranial wound	S43.72	Sprain and strain of other and unspecified parts of shoulder girdle, subscapularis (muscle)
S06.810	Other intracranial injuries with brief loss of consciousness without open intracranial wound	S43.73	Sprain and strain of other and unspecified parts of shoulder girdle, supraspinatus (muscle)
S06.811	Other intracranial injuries with brief loss of consciousness with open intracranial wound		
S06.820	Other intracranial injuries with moderate loss of consciousness without open intracranial wound		
S06.821	Other intracranial injuries with moderate loss of consciousness with open intracranial wound		
S06.830	Other intracranial injuries with prolonged loss of consciousness with return to pre-existing level of consciousness without open intracranial wound		

Disabled ICD-10-CA Codes for 2009 and Description		Disabled ICD-10-CA Codes for 2009 and Description
S06.831	Other intracranial injuries with prolonged loss of consciousness with return to pre-existing level of consciousness with open intracranial wound	
S06.840	Other intracranial injuries with prolonged loss of consciousness without return to pre-existing level of consciousness without open intracranial wound	
S06.841	Other intracranial injuries with prolonged loss of consciousness without return to pre-existing level of consciousness with open intracranial wound	
S06.890	Other intracranial injuries with loss of consciousness of unspecified duration without open intracranial wound	
S06.891	Other intracranial injuries with loss of consciousness of unspecified duration with open intracranial wound	

Appendix F: Results of the Analysis Using the ICD-10 Crosswalk and 2009-Adjusted ICD-10 Crosswalk

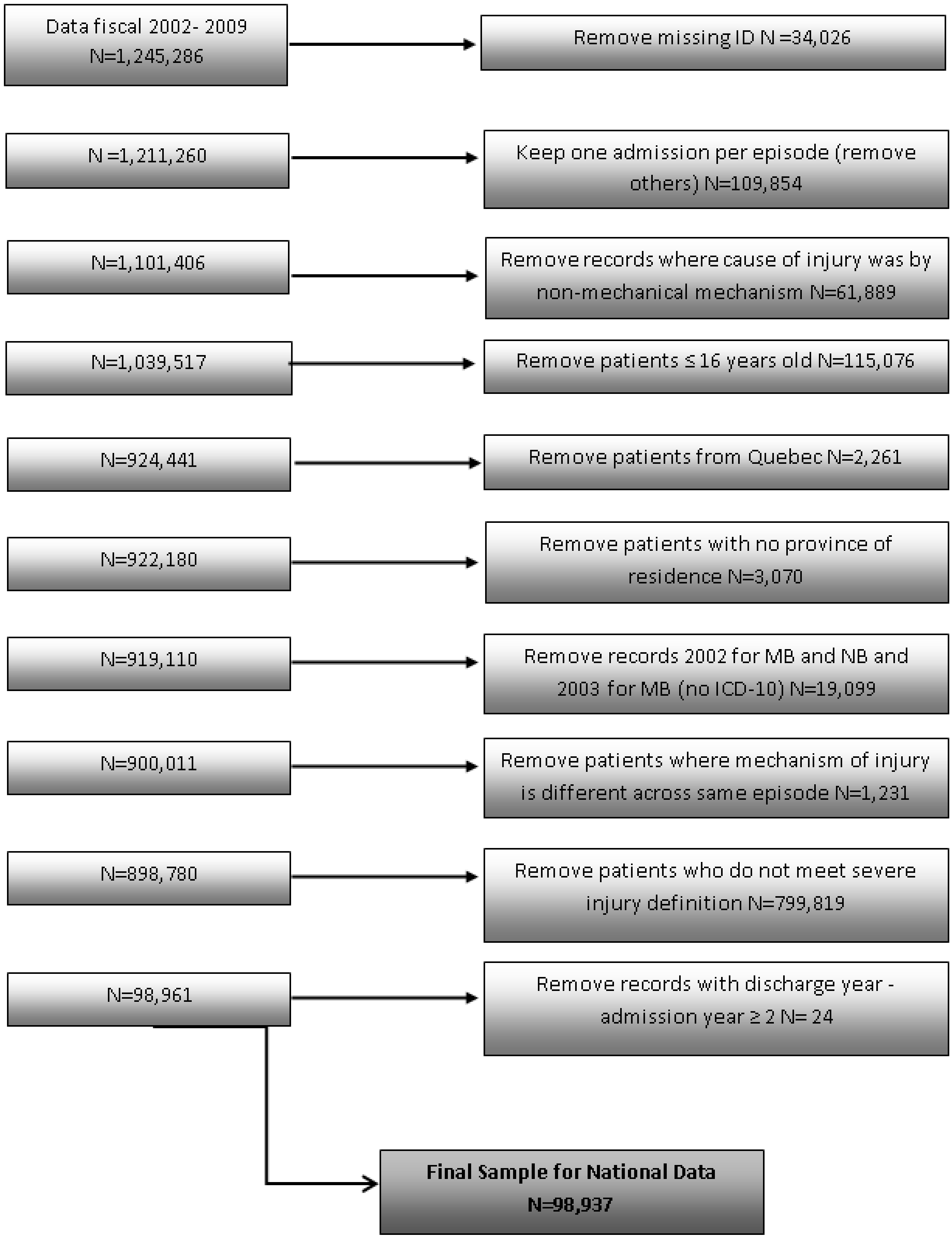
	2004	2005	2006	2007	2008	2009
Of the total records with ICD-10 in S and T range, the number of records with the old version of codes	11,023 (7.9)	10,972 (7.9)	11,474 (8.2)	11, 643 (8.2%)	11, 664 (8.1%)	_
Of the total the records with ICD-10 in S and T range, the, number of records with new version of codes	_	_	_	_	_	12, 348 (8.6
Proportion of all records where the difference in ISS (i.e. using old version and new version of code*) is zero	99.4	99.3	99.4	99.4%	99.5%	-
Mean(SD) and median difference in ISS_{old} (AIS based on old version of codes) and ISS_{2009} (AIS imputed based on median value) for all records*	Mean:0.02 (0.87) Median: 0 Min: -12 Max: 21	Mean:0.01 (0.89) Median: 0 Min: -12 Max: 21	Mean:0.01 (0.85) Median: 0 Min: -16 Max:21	Mean: -0.009(0.80) Median: 0 Min: -16 Max: 22	Mean: -0.0002(0.81) Median: 0 Min: -25 Max: 21	-
Number of patients defined as eligible using ISS_{old}	11,693 (10.3)	12,065 (10.6)	13,206 (11.5)	13, 653 (11.7)	13, 615 (11.6)	9,458 (8.1)
Number of patients defined as eligible using ISS_{2009}	11,703 (10.3)	12, 102 (10.7)	13, 257 (11.5)	13, 679 (11.7)	13, 722 (11.7)	14, 325 (12.3
Number of records assigned differently (i.e. eligible using ISS_{old} not equal eligible using ISS_{2009})	196 (0.17)	177 (0.16)	163 (0.14)	166 (0.14)	185 (0.16)	4867 (4.2)[#]
Number of patients for whom ISS_{2009} overestimates the "true" ISS causing these patients to be eligible	103	107	107	96	146	NA
Number of patients for whom ISS_{2009} underestimates the "true" ISS causing these patients to be ineligible	93	70	56	70	39	0
Mean(SD) and median difference between ISS_{old} and ISS_{2009} for patients where "true" ISS is overestimated	Mean: -10.9 (2.1) Median: -12 Min: -12 Max: -6	Mean: -11.3 (3.5) Median: -12 Min: -12 Max: -7	Mean: -11 (2.1) Median: -12 Min: -16 Max: -6	Mean: -10.8 (2.2) Median: -12 Min: -12 Max: -3	Mean: -11.5 (3.5) Median: -12 Min: -25 Max: -6	NA
Mean(SD) and median difference between ISS_{old} and ISS_{2009} for patients where "true" ISS is underestimated	Mean: 15.2 (3.8) Median: 16 Min: 7 Max: 21	Mean: 14.3 (3.7) Median: 12 Min: 5 Max: 21	Mean: 15.8 (3.8) Median: 16 Min: 5 Max: 21	Mean: 14.6 (4.1) Median: 16 Min: 5 Max: 21	Mean: 16 (4.8) Median: 16 Min: 5 Max: 21	NA
Percent of eligible patients (as defined by ISS_{old}) in 2002 to 2008 with old version of the new codes	44.6%	45.7%	46.1%	47.5%	47.9%	NA

* refers to the AIS (hence ISS) values assigned based on the affected codes. Note for comparison – for 2004 to 2008 the old version of the ICD-10 codes that were changed in 2009 were recoded to match the newer vision of the codes. AIS values based on median values were assigned to these codes. % - represent percent for the year. # - due to the fact that the new codes that came into effect in 2009 would not have received an AIS value using the crosswalk. 2004 starting year for this detail review as data for all provinces were available from this year forward

Appendix G: Proportion of Patients Undertriaged Using ICD-10 Crosswalk and 2009-Adjusted ICD-10 Crosswalk

FISCAL YEAR	Age	Percent undertriage - original crosswalk	percent undertriage - '2009' crosswalk	Difference
2002	17-29	27.59	27.25	0.34
2003	17-29	26.76	26.63	0.13
2004	17-29	26.75	26.65	0.10
2005	17-29	24.48	24.20	0.29
2006	17-29	24.49	24.33	0.16
2007	17-29	23.67	23.58	0.10
2008	17-29	24.33	24.25	0.09
2009	17-29	24.04	24.04	0.00
2002	30-49	35.41	35.34	0.07
2003	30-49	33.35	33.12	0.22
2004	30-49	32.53	32.39	0.14
2005	30-49	32.07	31.85	0.21
2006	30-49	31.06	30.88	0.18
2007	30-49	30.89	30.63	0.26
2008	30-49	31.82	31.63	0.18
2009	30-49	30.75	30.75	0.00
2002	50-64	38.11	38.32	-0.21
2003	50-64	40.27	40.08	0.19
2004	50-64	39.35	39.20	0.15
2005	50-64	39.75	39.64	0.11
2006	50-64	37.69	37.60	0.09
2007	50-64	38.96	38.85	0.11
2008	50-64	39.09	39.15	-0.06
2009	50-64	38.42	38.42	0.00
2002	65-79	49.42	49.50	-0.08
2003	65-79	49.59	49.31	0.28
2004	65-79	48.96	48.97	0.00
2005	65-79	47.67	47.67	0.00
2006	65-79	48.20	48.37	-0.18
2007	65-79	47.95	47.93	0.02
2008	65-79	51.61	51.73	-0.12
2009	65-79	51.54	51.54	0.00
2002	>=80	64.82	64.91	-0.09
2003	>=80	63.97	63.90	0.07
2004	>=80	62.89	62.87	0.03
2005	>=80	62.87	62.86	0.01
2006	>=80	63.41	63.50	-0.09
2007	>=80	60.88	60.98	-0.10
2008	>=80	63.78	63.94	-0.16
2009	>=80	62.58	62.58	0.00
2002	Less 65 yrs	33.55	33.46	0.09
2003	Less 65 yrs	32.95	32.77	0.18
2004	Less 65 yrs	32.48	32.34	0.14
2005	Less 65 yrs	31.72	31.52	0.20
2006	Less 65 yrs	30.79	30.63	0.16
2007	Less 65 yrs	30.90	30.73	0.17
2008	Less 65 yrs	31.66	31.58	0.08
2009	Less 65 yrs	31.16	31.16	0.00
2002	65+ yrs	56.90	57.00	-0.10
2003	65+ yrs	56.64	56.46	0.18
2004	65+ yrs	56.16	56.13	0.02
2005	65+ yrs	55.43	55.44	-0.01
2006	65+ yrs	56.04	56.16	-0.11
2007	65+ yrs	54.68	54.73	-0.05
2008	65+ yrs	58.18	58.32	-0.14
2009	65+ yrs	57.53	57.53	0.00

Appendix H: Patient Flow Chart



Appendix I: Description of Undertriage Patients by Province

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Alberta - April 1, 2002 and March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	51.4	78.6
≥ 65 yrs.	48.6	21.4
Age (%)		
17 -29 yrs.	14.7	30.3
30 – 49 yrs.	20.8	30.3
50 – 64 yrs.	16.0	18.0
65 – 79 yrs.	18.6	12.1
> 80 yrs.	30.0	9.3
Age (mean, SD)	60.39 (23.62)	45.66 (21.15)
Gender (%)		
Male	58.6	74.1
Female	41.4	25.9
ISS* (%)		
16 – 24	75.2	49.7
25 – 47	24.0	46.4
47 – 75	0.78	3.9
ISS (Mean, SD)	19.9 (6.7)	24.8 (9.4)
Mechanism		
Fall	55.2	30.7
MVC	27.5	47.0
Blunt	8.4	10.0
Other	9.0	12.3
Comorbidities		
0	26.2	14.3
1	27.8	16.9
2	18.3	15.7
3	11.4	13.4
> 3	16.2	39.8
Area		
Urban	19.1	15.3
Rural	76.6	79.5
Missing	4.3	5.3
Classification Area		
CMA	35.1	65.9
CA	23.5	7.6
Strong MIZ	5.4	3.1
Moderate MIZ	10.6	6.6
Weak	21.9	13.3
No MIZ	2.2	1.2
Missing	1.3	2.4
Income		
1 (Poorest)	24.0	26.3
2	22.0	19.8
3	19.3	18.1
4	14.3	14.8
5	12.6	13.5
Missing	7.8	7.5
Admission Time (Night)	51.76	66.70
Admission Day (Weekend)	38.07	43.81
Admission Season		
Winter	30.02	27.93
Proximity to Trauma Centre		
0 -10 kms	18.4	41.5
11- 25 kms	12.9	19.0
26 – 50 kms	4.8	6.8
50 – 100 kms	10.5	9.1
100+ kms	52.4	41.5
Missing	0.87	1.9
Proximity (Mean, SD)	134.7 (131.3)	62.54 (100.4)

* Patients with ISS missing or less than 15 excluded. MIZ – Metropolitan Influenced Zone

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: British Columbia- April 1, 2002 and March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	55.9	68.8
≥ 65 yrs.	44.1	31.2
Age (%)		
17 -29 yrs.	15.3	23.3
30 – 49 yrs.	22.8	26.7
50 – 64 yrs.	17.9	18.6
65 – 79 yrs.	20.3	16.0
> 80 yrs.	23.8	15.2
Age (Mean, SD)	58.0 (22.9)	51.2 (22.7)
Gender (%)		
Male	63.9	70.6
Female	36.1	29.4
ISS (%)		
16 – 24	67.19	46.77
25 – 47	30.62	49.53
47 – 75	0.97	3.32
Missing	1.22	0.38
ISS (Mean, SD)	20.9 (6.9)	24.6 (8.9)
Mechanism		
Fall	51.53	38.96
MVC	30.68	42.02
Blunt	10.14	9.14
Other	9.87	9.87
Comorbidities		
0	21.66	15.93
1	26.58	18.03
2	20.32	16.29
3	12.54	13.29
> 3	18.90	36.47
Area		
Urban	77.51	82.15
Rural	19.54	13.77
Missing	2.94	4.08
Classification Area		
CMA	45.82	62.53
CA	29.87	22.41
Strong MIZ	2.17	1.44
Moderate MIZ	7.94	4.92
Weak	11.13	5.22
No MIZ	1.58	0.69
Missing	1.50	2.79
Income		
1 (Poorest)	24.04	23.87
2	19.38	19.86
3	17.32	18.59
4	17.20	16.23
5	15.85	15.47
Missing	6.21	5.98
Admission Time(Night)	54.73	61.52
Admission Day (Weekend)	39.75	41.55
Admission Season (Winter)	30.19	29.85
Proximity to Trauma Centre		
0 -10 kms	23.50	55.22
11- 25 kms	16.21	15.10
26 – 50 kms	14.78	8.09
50 – 100 kms	15.38	8.81
100+ kms	29.57	10.57
Missing	0.56	2.22
Proximity (Mean, SD)	115.9 (175.1)	44.3 (103.0)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Manitoba - April 1, 2004 and March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	45.59	82.37
≥ 65 yrs.	54.41	17.63
Age (%)		
17 -29 yrs.	14.21	31.80
30 – 49 yrs.	17.31	33.40
50 – 64 yrs.	14.07	17.17
65 – 79 yrs.	19.66	11.59
> 80 yrs.	34.75	6.04
Age (Mean, SD)	62.7 (24.0)	43.4 (20.0)
Gender (%)		
Male	57.31	75.55
Female	42.69	24.45
ISS (%)		
16 – 24	69.49	51.81
25 – 47	27.61	45.48
47 – 75	0.74	2.59
Missing	2.15	0.12
ISS (Mean, SD)	20.0 (6.6)	24.1 (8.9)
Mechanism		
Fall	60.27	25.88
MVC	19.33	43.26
Blunt	9.02	11.38
Other	11.38	19.47
Comorbidities		
0	28.48	16.47
1	27.34	19.39
2	19.87	17.01
3	9.36	13.52
> 3	14.95	33.61
Area		
Urban	62.76	68.20
Rural	34.75	28.88
Missing	2.49	2.92
Classification Area		
CMA	37.71	59.98
CA	10.44	3.94
Strong MIZ	2.49	4.40
Moderate MIZ	12.39	9.16
Weak	26.94	12.86
No MIZ	8.62	7.44
Missing	1.41	2.22
Income		
1 (Poorest)	28.69	37.76
2	25.19	20.54
3	15.82	13.15
4	15.49	11.50
5	11.04	10.72
Missing	3.77	6.33
Admission Time Night ()	44.78	65.86
Admission Day Weekend	36.84	49.88
Admission Season Winter	29.29	28.23
Proximity to Trauma Centre		
0 -10 kms	32.05	50.12
11- 25 kms	4.85	24.86
26 – 50 kms	4.11	8.22
50 – 100 kms	11.72	5.67
100+ kms	46.26	9.53
Missing	1.01	1.60
Proximity (Mean, SD)	155.6 (184.6)	92.2 (160.3)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: New Brunswick April 1, 2003 and March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	55.79	69.72
≥ 65 yrs.	44.21	30.28
Age (%)		
17 -29 yrs.	16.01	23.51
30 – 49 yrs.	21.06	25.82
50 – 64 yrs.	181.73	20.39
65 – 79 yrs.	19.66	16.29
> 80 yrs.	24.55	13.99
Age (Mean, SD)	58.3 (23.3)	51.00 (22.5)
Gender (%)		
Male	61.31	69.94
Female	38.69	30.06
ISS (%)		
16 – 24	70.01	47.40
25 – 47	26.65	48.74
47 – 75	1.71	3.13
Missing	1.63	0.74
ISS (Mean, SD)	21.3 (8.2)	24.4 (9.0)
Mechanism		
Fall	49.03	41.07
MVC	39.70	45.31
Blunt	6.37	8.11
Other	4.90	5.51
Comorbidities		
0	19.19	15.63
1	22.14	19.35
2	18.88	16.15
3	13.05	13.99
> 3	26.73	34.90
Area		
Urban	41.96	51.86
Rural	52.84	39.81
Missing	5.21	8.33
Classification Area		
CMA	0.70	27.68
CA	34.03	30.88
Strong MIZ	8.16	6.10
Moderate MIZ	26.96	17.41
Weak	25.49	11.76
No MIZ	3.89	2.08
Missing	0.78	4.09
Income		
1 (Poorest)	23.78	21.43
2	19.11	20.01
3	18.96	17.19
4	17.17	17.78
5	15.62	15.70
Missing	5.36	7.89
Admission Time Night ()	49.49	62.05
Admission Day Weekend	40.33	45.16
Admission Season Winter	31.16	26.71
Proximity to Trauma Centre		
0 -10 kms	4.90	32.96
11- 25 kms	2.10	19.12
26 – 50 kms	5.59	12.65
50 – 100 kms	25.56	11.01
100+ kms	61.15	20.31
Missing	0.70	3.94
Proximity (Mean, SD)	147.0 (85.2)	59.2 (69.1)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Newfoundland & Labrador April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	58.80	70.22
≥ 65 yrs.	41.20	29.78
Age (%)		
17 -29 yrs.	13.25	22.74
30 – 49 yrs.	22.36	24.50
50 – 64 yrs.	23.19	22.98
65 – 79 yrs.	20.50	18.76
> 80 yrs.	20.70	11.02
Age (Mean, SD)	58.0 (21.4)	50.9 (21.3)
Gender (%)		
Male	61.49	75.03
Female	38.51	34.97
ISS (%)		
16 – 24	79.71	47.01
25 – 47	17.18	49.47
47 – 75	1.45	2.34
Missing	1.66	1.17
ISS (Mean, SD)	20.0 (8.3)	24.1 (8.3)
Mechanism		
Fall	51.35	42.79
MVC	40.99	42.56
Blunt	4.14	9.50
Other	3.52	5.16
Comorbidities		
0	28.57	18.41
1	29.40	20.63
2	18.63	16.76
3	12.01	13.13
> 3	11.39	31.07
Area		
Urban	48.45	56.86
Rural	47.41	32.71
Missing	4.14	10.43
Classification Area		
CMA	4.35	48.42
CA	24.02	6.80
Strong MIZ	2.90	3.05
Moderate MIZ	30.43	20.28
Weak	29.19	12.19
No MIZ	7.25	2.46
Missing	1.86	6.80
Income		
1 (Poorest)	27.74	19.81
2	16.36	14.65
3	15.53	18.05
4	13.66	18.29
5	18.22	17.12
Missing	8.49	12.08
Admission Time Night ()	52.80	66.35
Admission Day Weekend	36.44	47.25
Admission Season Winter	37.06	28.60
Proximity to Trauma Centre		
0 -10 kms	2.69	34.47
11- 25 kms	2.28	13.13
26 – 50 kms	3.73	9.96
50 – 100 kms	2.69	8.91
100+ kms	86.75	26.85
Missing	1.86	6.68
Proximity (Mean, SD)	333.0 (203.7)	108.3 (181.2)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Nova Scotia- April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	43.12	69.60
≥ 65 yrs.	56.88	30.40
Age (%)		
17 -29 yrs.	10.94	24.75
30 – 49 yrs.	14.64	25.44
50 – 64 yrs.	17.54	19.40
65 – 79 yrs.	22.32	17.04
> 80 yrs.	34.57	13.36
Age (Mean, SD)	64.9 (22.3)	50.4 (22.4)
Gender (%)		
Male	56.23	73.13
Female	43.77	26.87
ISS (%)		
16 – 24	72.83	51.96
25 – 47	23.55	44.84
47 – 75	1.01	2.80
Missing	2.61	0.39
ISS (Mean, SD)	19.9 (6.9)	23.7 (8.5)
Mechanism		
Fall	66.59	41.21
MVC	23.77	41.26
Blunt	4.86	10.02
Other	4.78	7.51
Comorbidities		
0	23.26	20.33
1	26.30	21.41
2	19.78	14.78
3	13.33	11.94
> 3	17.32	31.53
Area		
Urban	47.17	54.47
Rural	48.55	38.06
Missing	4.28	7.47
Classification Area		
CMA	12.03	47.69
CA	33.84	15.03
Strong MIZ	1.67	4.22
Moderate MIZ	14.86	10.27
Weak	34.86	17.78
No MIZ	0.22	0.25
Missing	2.54	4.76
Income		
1 (Poorest)	18.26	20.78
2	23.04	19.94
3	19.93	18.86
4	18.62	15.77
5	15.87	17.58
Missing	4.28	7.07
Admission Time Night ()	46.67	67.29
Admission Day Weekend	38.12	47.15
Admission Season Winter	31.38	31.78
Proximity to Trauma Centre		
0 -10 kms	8.26	30.16
11- 25 kms	2.03	13.21
26 – 50 kms	1.67	5.80
50 – 100 kms	33.19	24.17
100+ kms	53.04	22.45
Missing	1.81	4.22
Proximity (Mean, SD)	151.9 (107.2)	72.9 (87.2)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Ontario April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	41.05	67.33
≥ 65 yrs.	58.95	32.67
Age (%)		
17 -29 yrs.	9.20	23.15
30 – 49 yrs.	15.28	25.37
50 – 64 yrs.	16.57	18.82
65 – 79 yrs.	24.89	18.74
> 80 yrs.	34.05	13.93
Age (Mean, SD)	65.3 (21.4)	51.4 (22.4)
Gender (%)		
Male	57.02	70.09
Female	42.98	29.91
ISS (%)		
16 – 24	65.69	41.81
25 – 47	32.00	54.25
47 – 75	0.45	3.46
Missing	1.86	0.47
ISS (Mean, SD)	20.2 (5.9)	25.3 (8.9)
Mechanism		
Fall	67.89	39.41
MVC	19.06	43.29
Blunt	6.29	7.46
Other	6.77	9.84
Comorbidities		
0	23.90	14.73
1	26.98	15.60
2	20.36	15.49
3	12.04	12.97
> 3	16.71	41.21
Area		
Urban	81.57	77.69
Rural	15.45	18.07
Missing	2.98	4.24
Classification Area		
CMA	61.55	69.44
CA	20.31	11.41
Strong MIZ	6.81	6.99
Moderate MIZ	5.84	5.60
Weak	3.49	3.11
No MIZ	0.35	0.62
Missing	1.65	2.84
Income		
1 (Poorest)	20.47	21.79
2	20.62	19.28
3	18.87	18.33
4	17.37	16.28
5	17.44	17.38
Missing	5.22	6.95
Admission Time Night ()	57.00	65.24
Admission Day Weekend	37.96	42.75
Admission Season Winter	31.59	29.45
Proximity to Trauma Centre		
0 -10 kms	19.22	39.15
11- 25 kms	18.28	16.75
26 – 50 kms	21.74	16.28
50 – 100 kms	23.80	16.13
100+ kms	15.56	9.08
Missing	1.40	2.61
Proximity (Mean, SD)	54.9 (60.5)	38.0 (55.9)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Prince Edward Island- April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	56.48	72.73
≥ 65 yrs.	43.52	27.27
Age (%)		
17 -29 yrs.	19.02	38.18
30 – 49 yrs.	19.60	15.45
50 – 64 yrs.	17.87	19.09
65 – 79 yrs.	21.33	17.27
> 80 yrs.	22.19	10.00
Age (Mean, SD)	57.2 (23.8)	46.2 (23.3)
Gender (%)		
Male	63.11	84.55
Female	36.89	15.45
ISS (%)		
16 – 24	69.74	35.45
25 – 47	27.38	60.00
47 – 75	1.44 (n=5)	3.64 (n=4)
Missing	1.44	0.91 (n=1)
ISS (Mean, SD)	21.0 (7.7)	26.0 (9.0)
Mechanism		
Fall	48.99	38.18
MVC	39.19	50.00
Blunt	6.92	6.36
Other	4.90	5.45
Comorbidities		
0	23.63	27.27
1	26.80	20.00
2	17.87	13.64
3	13.54	13.64
> 3	18.16	25.45
Area		
Urban	49.57	44.55
Rural	48.70	48.18
Missing	1.73	1.73
Classification Area		
CMA	-	
CA	48.41	43.64
Strong MIZ	17.87	19.09
Moderate MIZ	18.44	10.00
Weak	12.68	20.00
No MIZ	1.44	1.82 (n=2)
Missing	1.15	5.45
Income		
1 (Poorest)	27.09	20.91
2	14.70	13.64
3	22.48	21.82
4	18.73	20.91
5	12.10	14.55
Missing	4.90	8.18
Admission Time Night ()	46.97	53.64
Admission Day Weekend	35.45	48.18
Admission Season Winter	30.84	24.55
Proximity to Trauma Centre		
0 -10 kms	-	-
11- 25 kms	-	-
26 – 50 kms	-	-
50 – 100 kms	32.56	28.18
100+ kms	66.57	66.36
Missing	0.86	5.45
Proximity (Mean, SD)	120.4 (28.2)	121.5 (28.9)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Saskatchewan- April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	48.52	74.39
≥ 65 yrs.	51.48	25.61
Age (%)		
17 -29 yrs.	16.41	30.00
30 – 49 yrs.	19.91	27.84
50 – 64 yrs.	12.20	16.55
65 – 79 yrs.	18.59	14.35
> 80 yrs.	32.89	11.26
Age (Mean, SD)	60.7 (24.8)	47.1 (22.4)
Gender (%)		
Male	59.46	72.98
Female	40.54	27.02
ISS (%)		
16 – 24	80.22	46.87
25 – 47	17.53	50.49
47 – 75	0.53	2.46
Missing	1.71	0.19
ISS (Mean, SD)	18.9 (5.9)	24.3 (8.5)
Mechanism		
Fall	55.77	32.09
MVC	21.09	42.88
Blunt	11.07	11.66
Other	12.06	13.38
Comorbidities		
0	34.87	16.07
1	31.31	17.95
2	17.60	15.91
3	8.64	12.71
> 3	7.58	37.35
Area		
Urban	60.51	65.85
Rural	37.31	32.36
Missing	2.18	1.80
Classification Area		
CMA	22.87	47.16
CA	20.63	10.71
Strong MIZ	2.24	2.51
Moderate MIZ	12.79	9.38
Weak	27.88	18.93
No MIZ	12.06	9.83
Missing	1.52	1.48
Income		
1 (Poorest)	22.81	27.44
2	20.83	18.85
3	13.71	14.94
4	13.05	12.95
5	11.67	11.92
Missing	17.93	13.90
Admission Time Night ()	49.90	64.34
Admission Day Weekend	39.29	44.54
Admission Season Winter	29.80	28.26
Proximity to Trauma Centre		
0 -10 kms	21.95	43.27
11- 25 kms	0.66	2.14
26 – 50 kms	0.99	2.70
50 – 100 kms	12.39	9.23
100+ kms	62.56	41.34
Missing	1.45	1.32
Proximity (Mean, SD)	142.0 (127.1)	96.7 (119.8)

Characteristics of Patients Receiving Care in a Trauma Centre Compared with Patients not Receiving Care in a Trauma Centre: Territories- April 1, 2002 to March 31, 2010

Characteristics	Non-Trauma Centre	Trauma Centre
Age (%)		
< 65 yrs.	84.75	88.95
≥ 65 yrs.	15.25	11.05
Age (%)		
17 -29 yrs.	27.91	38.95
30 – 49 yrs.	35.92	34.21
50 – 64 yrs.	20.93	15.79
65 – 79 yrs.	10.59	10.00
> 80 yrs.	4.65	1.05
Age (Mean, SD)	43.3 (18.5)	39.4 (16.9)
Gender (%)		
Male	74.94	78.42
Female	25.06	21.58
ISS (%)		
16 – 24	67.44	40.53
25 – 47	29.46	57.89
47 – 75	1.81	1.58 (n=3)
Missing	1.29	-
ISS (Mean, SD)	21.4 (7.7)	25.2 (8.7)
Mechanism		
Fall	26.36	16.32
MVC	37.47	45.26
Blunt	17.57	19.47
Other	18.60	18.95
Comorbidities		
0	22.74	17.37
1	26.36	15.79
2	18.35	14.21
3	12.92	8.95
> 3	19.64	43.68
Area		
Urban	48.58	39.47
Rural	45.74	50.53
Missing	5.68	10.00
Classification Area		
CMA	-	-
CA		
Strong MIZ		
Moderate MIZ		
Weak		
No MIZ		
Missing		
Income		
1 (Poorest)	17.83	24.21
2	20.41	20.53
3	15.50	13.68
4	13.18	17.89
5	12.92	10.53
Missing	20.16	13.16
Admission Time Night ()	64.08	56.84
Admission Day Weekend	43.15	47.37
Admission Season Winter	26.10	27.89
Proximity to Trauma Centre		
0 -10 kms		
11- 25 kms		
26 – 50 kms		
50 – 100 kms		
100+ kms	97.42	93.68
Missing	2.58	6.32
Proximity (Mean, SD)	1431.9 (437.9)	1491.7 (471.2)