A STUDY OF PREHOSPITAL TRAUMA CARE IN ONTARIO

By

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ABSTRACT

Objectives:

1. To describe variations in major trauma between rural and urban residents of Ontario in terms of external causes, severities, prehospital care and clinical outcomes.
2. To determine whether prehospital intubation improves survival to hospital discharge among victims of major trauma.

Methods:

The study involved secondary analyses of data from the Ontario Prehospital Advanced Life Support Study (OPALS). OPALS is the largest study of prehospital emergency medical services conducted worldwide.

1. Rural-urban status of trauma patients was determined using modified Beale Codes. Differences in trauma characteristics and patient care were compared among four geographic groups (Large Metro, Medium Metro, Small Metro, Rural).
2. Patients who were intubated in the field were individually matched with non-intubated patients by patient age, injury severity score category, abbreviated head injury score category, and exact Glasgow coma scores. Cox regression was used to estimate the effect of prehospital intubation on patients' survival to hospital discharge, stratifying on patient matching.

Results:

1. Patients in the large metro and rural groups had higher injury severity scores (median=25, 24 respectively) than the other two groups (median=22). Paramedics generally spent more time in rural and large metro areas (median=37.4, 36.6 minutes respectively) than in medium and small metro (median=32.0, 30.7 minutes respectively) areas. Response times and transport times in rural groups were significantly longer than the other three groups, while scene times in the large metro group were significantly longer compared with the other geographic groups. There were no significant differences in survival rates by geographic group.
2. There were no significantly differences between the intubated and the non-intubated groups by age, sex, Glasgow coma scores, injury severity score, and systolic blood pressure category. Prehospital intubated patients experienced a 3-fold risk of mortality after adjustment for potential confounders. (HR 2.9; 95% CI 1.4 to 5.8).

Conclusions:

1. While response and transport times for major trauma were longer in rural areas, there were no significant differences in mortality in patients with different rural urban status.
2. Prehospital intubation showed a negative association with survival among major trauma patients. Further randomized trials are required to investigate this clinical issue.

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CHAPTER 1

INTRODUCTION

Trauma imposes a great burden on modern society. It is the leading cause of death for Canadians between the ages of 1 and 44 and the fourth leading cause of death for Canadians of all ages. [1] Trauma is also a leading cause of disability. Many non-fatal traumatic injuries result in impairments and disabilities such as blindness, spinal cord injury and intellectual deficit.[1]

Prehospital care is an essential part of a comprehensive trauma care system. Emergency medical systems are responsible for initial medical assessment and treatment prior to arrival at a medical facility. Provision of prehospital care to trauma patients in more rural and remote environments is an important and neglected health issue.

Rural trauma is substantially different from urban trauma in terms of causes, the persons involved, injuries sustained, and clinical outcomes. Canada's vast land mass and low population density have lead to many challenges for the provision of prehospital care to rural trauma victims. Rural areas have fewer primary care physicians and specialists, and also have limited options for hospital-based medical treatment. [2] Patients need to be transported to regional centres for specialized care.[3, 4] Sparse populations in rural areas not only influence the availability of prehospital medical services, but also the discovery of trauma in rural areas.[5] The probability of dying from a major trauma in a rural area is therefore much greater than in urban areas. [6,7]

1.1 PURPOSE OF THESIS

In this thesis, I will investigate two important questions surrounding the provision of trauma care to Ontario residents.

The first component will describe variations in major trauma between rural and urban residents of Ontario in terms of external causes, severities, emergency medical services and clinical outcomes. This study will increase our understanding of the causes and impacts of rural trauma on the health of Canadians.

The second component will focus on the association between prehospital intubation and trauma patient mortality. Prehospital procedures such as intubation by paramedics have been introduced in Ontario, but should only be maintained if they have been proven to be useful. Intubation, an invasive procedures used in advanced life support, requires considerable training of paramedic staff and is very expensive to maintain. Evidence-based medical practice suggests a need to determine whether specific interventions such as prehospital intubation are actually effective for trauma patients in real world settings.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1 TRAUMA

Trauma is defined as an injury or wound to a living body caused by the application of external force or violence. [8] The forces may arise from mechanical energy, heat, electricity, or chemicals.[9] The leading mechanisms of death due to trauma are related to motor vehicles, falls and poisoning. [10]

Trauma is the leading cause of death for Canadians between the ages of 1 and 44 and the fourth leading cause of death for Canadians of all ages. [1] In 2003 alone, 13,906 Canadians died as a result of traumatic injuries. [1] In 2003, trauma was the second leading cause of potential years of life lost (after cancer) before the age of 70.[1]

Trauma is also a major cause of disability in Canada. Between April 2002 and March 2003, 226,436 people were admitted to hospital in Canada because of traumatic injuries, excluding adverse events in medical care.[1] Many of these non-fatal injuries resulted in impairments and disabilities such as blindness, spinal cord injury and intellectual deficit due to brain injury.[1]

In terms of costs, the economic burden of unintentional and intentional injuries combined is estimated to be greater than $12.7 billion per year or 8% of the total direct and indirect costs of illness, ranking 4th after cardiovascular disease, musculoskeletal conditions and cancer.[11] Another economic study estimated that unintentional injuries alone cost Canada more than $8.7 billion annually.[12]

2.2 TRAUMA CARE SYSTEMS AND PREHOSPITAL CARE

A trauma system is an organized, coordinated system for the provision of trauma care to all injured patients in a defined geographic area.[13-15] The elements of a trauma system are: access to care, prehospital care, hospital care and rehabilitation.[7, 9] There are three types of trauma centres in Canada.[14] Tertiary trauma centres (Level I centres) play a lead role in the regional trauma system, and have the capability of providing definitive care for seriously injured patients. District trauma centres (Level II centres) are situated in a community hospital and are sufficient to treat single-system traumas or some multi-system traumas prior to referral to a tertiary centre. Primary trauma centres (Level III centres) are situated in smaller hospitals or nursing stations. All but minor injuries need to be referred to either Level I or II trauma centres.[14, 15]

Prehospital care is an essential part of a trauma care system. This multi-disciplinary approach involves activation of the system through 911, central ambulance dispatch centres, ambulance paramedic services and medical direction.[16, 17]

Most trauma victims gain access to the health care system through the Emergency Medical system. The role of the Emergency Medical system is more complex than simply transporting the trauma victim to a medical facility. Trained health care professionals such as paramedics are responsible for the initial assessment and management of the injured patient prior to arrival at a medical facility.[18, 19]

In prehospital trauma care, there are two competing strategies: “rapid transportation” versus “field stabilization”.[20] In “rapid transportation”, the victim is transported as fast as possible to a trauma centre and minimal time is spent providing prehospital care. In “field stabilization”, the stabilization of the patient prior to transport, including intubation to assist in breathing and intravenous infusion to raise blood pressure, is the essential part of prehospital care. This results in slower access times to definitive hospital care.

Basic life support is a level of care that provides noninvasive emergency care. The goal of basic life support care is to maintain breathing and circulation and to transport the patient to definitive trauma care as soon as possible. It includes the provision of basic airway management (e.g. cleaning and keeping the airway open), cardiopulmonary resuscitation, and control of external hemorrhage. Basic life support is less costly because it requires limited equipment and training.[21, 22]

Advanced life support involves the use of invasive procedures. In contrast to basic life support systems, advanced life support provides advanced therapy to the patient at the scene, rather than waiting until arrival at a hospital. Advanced life support includes more sophisticated airway management (e.g., endotracheal intubation), cardiac monitoring and defibrillation, and administration of medications. Advanced life support is very expensive to maintain and requires considerable training of paramedic staff.[23-26]

2.3 MEASUREMENT OF TRAUMA SEVERITY AND FUNCTIONAL OUTCOMES

2.3.1 Scoring of Trauma Severity

To compare the severity and clinical outcomes for trauma patients, injury severity scoring systems are widely used as standardized tools. There are two major types of injury scoring systems: anatomic and physiologic scoring systems.

2.3.1.1 Anatomical Scoring Systems

Abbreviated Injury Scale

The Abbreviated Injury Scale is an anatomical scoring system. Injuries are ranked on a scale of 1 to 6, with 1 for minor, 2 for moderate, 3 for serious, 4 for severe, 5 for critical and 6 for unsurvivable injuries. [27, 28]

Injury Severity Score

The Injury Severity Score is the main summary anatomical scoring system in current use.[31] Injuries are assigned an Abbreviated Injury Scale for each of six body regions (Head, Face, Chest, Abdomen, Extremities (including Pelvis), External). Only the highest Abbreviated Injury Scale in each body region is used. The 3 most severely injured body regions have their score squared and added together to produce the Injury Severity Score.[27, 28] Non-survivable injuries are assigned the maximum score of 75.

2.3.1.2 Physiological Scoring Systems

Glasgow Coma Score

The Glasgow Coma Score is the accepted international standard for measuring neurological state [21,23] (Appendix A). It includes three sections: eyes, verbal response and motor response. Values for Glasgow Coma Score range from 0 to 15. Major head injuries are defined as a Glasgow coma scale of <8. [27, 29]

Revised Trauma Score

The Revised Trauma Score is assessed from the physiological responses of an injured patient. The physiological parameters that make up the Revised Trauma Score are the respiratory rate, systolic blood pressure and Glasgow Coma Score. Values for the Revised Trauma Score range from 0 to 7.84, with 0 representing the deceased patient and 7.84 representing a patient with normal physiological parameters. [27, 30]

2.3.2 Functional Outcomes of Trauma

There is a need to assess outcomes other than mortality among trauma patients. Many tools are available. The Glasgow Outcome Scale and Functional Independence Measure are two of such tools.

Glasgow Outcome Scale

The Glasgow Outcome Scale is a brief descriptive outcome scale. [31] The five categories of the ordinal scale are: Dead, Vegetative state, Severely disabled (conscious but disabled and dependent for daily support), Moderately disabled (disabled but independent and can work in sheltered setting), and Good recovery (resumption of normal life despite minor deficits).

<u>Functional Independence Measure</u>

The Functional Independence Measure is an 18-item, seven level ordinal scale [32] (Appendix B). It is used to measure the disability and rehabilitation outcomes. It measures the independence of patients with scores ranging from 126 (complete independence) to 18 (total dependence). Trained staffs are required to administer the interview directly to the patients or their proxy.

2.4 DEFINITIONS OF RURAL USED IN CANADA

Part of this thesis focused upon rural trauma and its management. Canada occupies the second largest landmass in the world. Rural Canada occupies 9.5 million square kilometers, or around 98.8% of Canada's territory. [33] 31.4% of the Canadian population (almost 9 million Canadians) and about 20% of the employed Canadian workforce live in rural and remote areas of the country. [33]

The Canadian census describes "rural areas" as sparsely populated lands lying outside urban areas. Rurality is generally measured by population density and distance from one population centre to another population centre. Several different definitions of rural are used in Canada today. [33]

1) Rural area — Census and Statistics Canada:

Rural areas are defined by population size (e.g. populations living outside places of 1,000 people or more are considered rural) or population density (populations living outside places with densities of 400 or more people per square kilometer are considered rural). They are defined at the level of census sub-division. [34]

2) Rural postal codes — Canada Post[35]*:*

A zero (0) in the second position of the postal code identifies a "rural" postal code. A "rural" postal code denotes an area where there are no letter carriers; residents go to the post office or the corner postal box to pick-up their mail. Rural postal codes may contain parts of several enumeration areas, and cross boundaries of census cub-divisions.

3) Beale Code — adapted from a US classification[36, 37]*:*

The Beale rural-urban coding system was originally developed by the U.S. Department of Agriculture to identify the 'location' of counties within the rural-urban continuum. The Beale coding system originally consisted of eleven categories of rural and urban places and uses census divisions as its base geographic unit. [36, 37] The American classification system was subsequently adapted for Canadian analyses [38].

The adapted Beale coding system classifies census divisions by the size of Census Metropolitan Areas and Census Agglomerations that they encompass or in which they are included (Appendix C). [38] The census divisions are classified by whether they belong to a metropolitan area and the population of that metropolitan area. Outside the metropolitan area, they are classified on the basis of their location relative to metropolitan regions (e.g., Nonmetro-Adjacent versus Nonmetro-Nonadjacent). Therefore, the Beale coding system contains both hierarchical (size) and geographic (location) components.

2.5 RURAL HEALTH

Urban and rural communities differ in their demographic, geographic, environmental, and socioeconomic characteristics. For example, according to the Medical Expenditure Panel Survey, a set of large-scale surveys across the United States, there were more elderly people in rural (18.8%) compared with metro counties (11.9%).[39] Residents of rural counties are more likely to have incomes in the poorest category. [40] These characteristics are responsible for differences in the health issues faced by communities. For example, economic resources available to residents of a community may have a strong influence on many health issues. Poverty is clearly related to many health problems in rural populations. [41] Differences in occupation (such as manual labor compared with white-collar service work) and environmental exposures (for example, air quality or fluoridation of water) between urban and rural communities also contribute to geographic health differences. [41]

Urban and rural communities also have differences in their access to health care. The relative scarcity of health care resources in rural areas is a continuing problem that has a negative impact on health outcomes. [42] Rural areas have difficulties in recruiting and retaining physicians and tend to have a lower supply of health care providers per capita. There are fewer specialist physicians and dentists per capita in the most rural counties.

Smaller community hospitals in rural areas may be dependent on family physicians or nurses to provide medical services. [2] In Canada, while 31% of Canadians live in rural areas, only 17% of family physicians and about 4% of specialists practice there. In Ontario, only 2.5% of specialists practice in rural communities. [2]

Rural areas, unlike large urban centres, have limited options for hospital-based medical treatment. Larger rural communities only have hospitals with basic facilities and there are no hospitals in many small rural communities. In remote locations, nursing stations as opposed to full medical facilities are available. [3, 4] Patients need to be transported to regional medical centres for specialized care. Hence, residents of rural regions often live farther from health care resources and may have to travel long distances in order to reach medical facilities. [3, 4]

2.6 RURAL TRUAMA

2.6.1 Specific Types of Trauma in Rural Populations

2.6.1.1 Motor Vehicle Crashes

Motor vehicle crashes are the most common mechanism of serious injury among both urban and rural populations. Rural residents are more likely to die from such trauma than their urban counterparts. [6, 7] Environmental and behavioural factors contribute to these crashes.

Environmental factors

Various features affect road safety, including road curvature, intersection design, signage and shoulder condition. In comparison with urban primary roads, rural roads have fewer traffic control devices, higher posted speed limits and uninterrupted segments of roadway which often lead to increased speed.[43] Design elements (e.g. two-lane highways, narrow or non-existent shoulders, and limited sight distance due to hills and curves) contribute to the risk of motor vehicle crash in rural areas.[43] There are different types of vehicles on rural roads such as slow-moving tractors or other farm machinery. These also contribute to the higher crash rates.[44]

Behavioural factors

Higher speeds are a behaviour that contributes to higher rates of rural trauma. Faster vehicle speeds in rural areas were noted in a study by Mueller et al. [45] In the United States, over 70 percent of the fatal crashes occur on roadways with speed limits of 55 miles per hours or higher in rural areas. Rural residents are less likely to wear seat belts or to use child safety seats than urban residents while driving. [47] According to Transport Canada's Surveys of Seat Belt Use in Canada, 2004-2005, an estimated 86.9% of all occupants of light-duty vehicles in rural communities use seat belts, compared with an estimated 91.1% of all occupants in urban communities. [47] Blatt et al [48] found that 59% of drivers involved in fatal crashes with alcohol involvement lived in rural and small-town clusters.

2.6.1.2 Occupational Injuries

Injuries at work comprise a substantial part of the rural injury burden. According to the National Health Interview Survey in the U.S., 42% of all injuries are work-related. [49] Farming is a particularly hazardous occupation. Although farm workers constitute only 4% of U.S. workers, 35% of deaths identified as machinery-related occur on farms. [10] A Canadian study utilizing a national farm injury registry reported an occupational injury mortality rate of $11.6/10^5$, placing agriculture as the fourth most dangerous industry in Canada. The farm work environment is characterized by a wide variety of hazards for injury, including machinery, working at heights, animals, water, poisonous gases and other chemicals, and electricity. Agricultural traumas often occur due to interaction with farm machinery. The tractor had been identified as the predominant cause of trauma, accounting for over three-quarters of the deaths. [51] In addition to tractors, other farm machinery including gravity-flow grain wagons and grain storage structures contribute significantly to agricultural trauma. [51] Trauma on farms is not limited to adult workers. Children are especially vulnerable when they are exposed to farm machinery and high buildings. [52]

2.6.2 Inadequate Prehospital Medical Services in Rural Areas

Prehospital Time

The availability, accessibility, and quality of prehospital care plays a key role in the survival of trauma patients. A variety of elements impede effective prehospital responses to trauma victims in rural areas. In cases of major trauma, especially those involving internal bleeding, nothing can replace surgery. Medical complications such as shock may occur if the patient is not managed in a timely fashion. [53] The time interval between the occurrence of trauma and definitive care is a major determinant of trauma patient outcomes. [54] Sparse populations in rural areas contribute to a lower rate of discovery of trauma in rural areas. Remoteness, difficult terrain and harsh weather are formidable barriers to perhospital care providers. Delays in discovery and extended response and transport times to hospital decrease the likelihood of surviving serious crashes.

Rural communites have longer response and transport times than urban communities. [5, 55-57] Delays in discovery or extended response times were found in 71% of prehospital deaths.[55] Zulik et al [56] reviewed 163 patients with trauma admitted to a small rural hospital in upstate New York over 2 years. Mean transport times for patients were as long as 1.6 hours (median 1.1 hours, range: 0.25 to 12 hours). Grossman et al [5] reported that response times differed significantly between urban and rural patients in the state of Washington. The mean response time was 7 minutes for urban locations compared with 13.6 minutes for rural locations. Mean transport times were also significantly longer for rural patients (17.2 vs. 8.2 minutes).

A systematic review by Carr et al [57] examined all 474 publications that reported prehospital time for trauma patients in the U.S. for a recent 30-year period. 49 articles were included in the final analysis. Average duration in minutes for urban and rural ground ambulances for the total prehospital interval was 30.9 and 43.2 minutes; the response intervals were 5.3 and 7.7 minutes; and transport intervals were 10.8 and 17.3

minutes. All urban ground ambulance time intervals (response, on-scene, and transport) were significantly shorter, on average, than those for rural ground ambulances.

2.6.3 Inexperienced Care Providers in Rural Areas

The inexperience of care providers contributes to higher mortality rates in trauma victims from rural areas. [54] Patients with major trauma taken directly to trauma centers have shorter hospital and intensive care unit stays and lower mortality than patients initially sent to other hospitals.[58] Rogers et al [59] compared the outcomes of trauma patients who were treated at two university trauma centers in 1993, one urban (San Diego) with in-house board-certified attending surgeons, and one rural (Vermont) with medical residents only. Although the patients treated in the urban centres were more severely injured than those treated at the rural centres, mortality at the two centres was not significantly different.

Rutledge et al [60] also found that counties with more board-certified surgeons per capita and with more surgeons with an AAST membership (the American Association for Surgery of Trauma Membership) or increased training in advanced trauma life support have lower per-capita trauma death rates.

2.6.4 Higher Case Fatality Rate for Rural Trauma

Trauma patients in rural areas have higher case fatality rates. According to the National Centre of Health Statistics of U.S., the age-adjusted unintentional injury death rate increases strongly as counties become less urban. [61] For males in 1996–98, the death rate was 86 percent higher in the most rural counties than in fringe counties of large metro areas in the U.S. [61] Among females the unintentional injury death rate was about 80 percent higher in most rural counties than in large metro (central and fringe) counties.[61]

Three population-based studies in the U.S. showed the same trend: Muelleman et al reviewed Nebraska death certificates over 4 years and found that the age-adjusted unintentional injury death rates were 54.2% higher in rural counties (population of less than 10 000) than in urban counties. [62] Beker et al [40] calculated population-based death rates for occupants of motor vehicles using national U.S. data. Mortality was highest in counties of low population density. For example, Esmeralda County, Nevada, with 0.2 residents per square mile, had a death rate of 558 per 100,000 populations, as compared with Manhattan, New York, with 64,000 residents per square mile and a death rate of 2.5 per 100,000. Using state Department of Transportation records of all motor vehicle collisions reported to police, Mueller et al. [44] compared the pedestrian injury and fatality rates for urban and rural areas of Washington State. Although rates of injury were higher in urban areas, the fatality rate in rural areas was higher for nearly all age groups. The relative risk was of mortality was estimated to be 2.3 (95% CI: 2.0-2.6) after controlling for potential cofounders.

2.7 PREHOSPITAL INTUBATION

2.7.1 Intubation

The most immediate life threatening complication of any trauma is loss of airway patency. Injured unconscious patients are unable to protect their airways. In such patients, the throat muscles may lose their tone so that the upper airways collapse, and air cannot easily enter into the lungs. Acute post-injury respiratory insufficiency will cause hypoxia and hypercarbia because the lungs cannot take in sufficient oxygen or expel sufficient carbon dioxide to meet the needs of the cells of the body. An additional concern is aspiration and the development of pneumonia.

Airway management has the highest priority in prehospital emergency care. [63] The first step in evaluating and treating any trauma patient is to assess airway patency and restore it to a functional level. Intubation is the "gold standard" for securing the opening of an airway. [63] Airway patency could be restored with intubation and the lower airways can be protected from aspiration.

2.7.2 Intubation in Prehospital Settings

Experience from the last several decades has shown that paramedics can safely perform many interventions that were previously performed only by physicians and nurses in the emergency department. Many of these procedures have proven beneficial for trauma victims; however, there remains significant controversy surrounding prehospital intubation for trauma patients. [64-75]

Although intubation is readily accomplished in hospital settings, the practice of medicine in the prehospital setting leads to numerous challenges not encountered in the hospital. Multiple factors like environment, experience, and skills of paramedics may compromise successful rates and clinical outcomes of prehospital intubation.

2.7.2.1 Summary of Current Studies of Prehospital Intubation

Results from previous studies have generated conflicting data about the potential benefit of prehospital intubation in the treatment of injuries, with some studies suggesting positive effects[64, 65] and others demonstrating adverse associations [69-75].

Positive effects

Two studies have showed a beneficial effect of prehospital intubation in trauma patients. Winchell et al [64] in 1997 performed a retrospective study of blunt trauma patients with scene Glasgow Coma Score ≤ 8 in San Diego County from 1991 to 1995. Field intubation significantly decreased mortality form 36% to 26% in the study group. However, multivariate analyses were not used in the study and functional outcomes were not compared. Suominen et al [65] in 2000 analyzed 59 pediatric blunt head traumas with Head Abbreviated Injury Scale ≥4 in one trauma centre in Finland; children were intubated in the field (n=24), a regional hospital (n=13), or at a trauma centre (n=22). Mortality was highest in the children intubated in the regional hospital. The authors concluded that field intubation may improve survival.

No difference in effects of prehospital intubation

Three studies did not show effect of prehospital intubation on survival. Sloane et al [66] reviewed all trauma patients who underwent prehospital rapid sequence induction intubation from 1988 to 1995 at a hospital in San Diego. After comparing results for 21 patients in a field intubation group and 54 patients in a hospital intubation group with isolated head injury (Glasgow Coma Score ≤8, Injury Severity Score ≥9, Abbreviated

Head Injury Scale ≥3 and all other Abbreviated Injury Scale ≤3), they found no differences in total hospital days, length of intensive care unit stay, or mortality in the two groups. There were no major differences in complications between the two groups.

Cooper et al [67] in 2001 published results of a retrospective study using data from the U.S. National Pediatric Trauma Registry. Ninety-nine seriously head injured patients who received Bag-valve-mask ventilation were compared with 479 comparable trauma patients who received intubation. The mortality rate was virtually identical in the two groups (both 48%). The authors concluded that prehospital intubation offered no demonstrable survival or functional advantage when compared with prehospital Bag-valve-mask ventilation in serious pediatric head injury.

The only prospective trial thus far conducted was performed by Gausche et al [68], who compared survival and neurological outcomes of pediatric patients treated with Bag-valve-mask ventilation only with those treated with Bag-valve-mask ventilation followed by intubation. Patients included trauma victims, but also other patients including those experiencing cardiopulmonary arrest and respiratory failure who required airway management. There were only 16% and 21% trauma patients in each group, respectively. Survival in the 404 patients in the Bag-valve-mask ventilation group was not significantly different from that in the intubation group. There was no difference in the rate of achieving a good neurological outcome between the two groups. The authors argued that the addition of prehospital intubation did not improve survival or neurological outcomes among pediatric trauma patients.

Negative associations between prehospital intubation and trauma outcomes

Seven studies concluded that prehospital intubation has a negative effect on the survival of trauma patients. All were retrospective studies. The following four studies used data from a single trauma centre. Murray et al [69] examined severe head injury (Glasgow Coma Score ≤8 and Abbreviated Head Injury Scale ≥3) patients; the mortality rates in the successfully intubated group, the unsuccessfully intubated group, and the nonintubated group were 81%, 77%, 43% respectively. Intubated patients had a significantly higher relative risk of mortality (RR=1.74) when compared with nonintubated patients and unsuccessfully intubated patients.

Eckstein et al [70] analyzed major trauma patients over a period of 36 months. Among the 403 patients who received Bag-valve-mask ventilation, the mortality rate was 67% while the mortality rate was 93% in the 93 patients that received intubation. After adjusting for sex, mechanism of injury and Injury Severity Score, the patients in the Bag-valve-mask ventilation group were 5.3 times more likely to survive than the patients in the intubation group (95% CI: 2.3-14.3).

Bochicchio et al [71] collected 191 consecutive trauma patients with Glasgow Coma Score≤8 and Head Abbreviated Injury Scale ≥3. 78 were intubated in the field and 113 patients were intubated immediately at admission by a anesthesiologist. There were no significant differences in age, Glasgow Coma Score, Abbreviated Head Injury Scale, or Injury Severity Score between the two groups. Patients who were intubated in the field had a significantly higher mortality and morbidity (ventilator days, hospital days, ICU days, nosocomial pneumonia rate) compared with hospital intubated patients.

Stockinger et al [72] reviewed all trauma patients seen in a trauma centre in New Orleans in a 34-month period. 316 patients received prehospital intubation and 217 had bag-valve-mask ventilation. When stratified by Injury Severity Score, Revised Trauma Score, and mechanism of injury, prehospital intubation was associated with greater or similar mortality than bag-valve-mask ventilation. Multivariate analysis was not used in this study. The intubation patients had longer prehospital times (22.0 vs. 20.1 minutes).

Three large studies using national, state, or county registries were published in recent years. DiRusso et al [73] reviewed the National Pediatric Trauma Registry of U.S. from 1994 to 2002. 1913 patients were intubated in the field, 1654 in the regional hospital, and 1876 in trauma centres. After adjusting for age, sex, race, New Injury Severity Score, Head Relative Injury Severity Score, Revised Trauma Score, Pediatric Trauma Score, heart rate, systolic blood pressure, and respiratory rate in the model, the odds ratios for field intubation, non-trauma centre intubation, and trauma centre intubation were 14.4, 5.8 and 4.8.

Davis et al [74] performed a retrospective analysis using the San Diego Traumatic Brain Injury Database in 2005. 13625 moderate to severe brain injury (Abbreviated Head Injury Scale >3) patients were included. Cox regression was used to explore the impact of prehospital intubation on outcome, controlling for age, gender, mechanisms, Glasgow

Coma Score, Abbreviated Head Injury Scale, Injury Severity Score and hypotension. Prehospital intubation was associated with increased mortality (OR: 2.1, 95% CI: 1.8 to 2.5).

Wang et al [75] conducted a retrospective analysis using data form the Pennsylvania Trauma Outcome Study. Adult trauma patients with Abbreviated Head Injury Scale ≥3 were included. 1797 patients who received prehospital intubation were compared with 2301 patients who revived intubation in the Emergency Department. Using Cox regression, odds ratio estimates were adjusted for differences in age, sex, Abbreviated Head Injury Scale, Injury Severity Score, mechanism of injury, admission systolic blood pressure, mode of transport, and the use of prehospital neuromuscular blocking agents. The adjusted odds of death were higher for prehospital intubation than intubation in the emergency department (OR: 3.99, 95% CI: 3.2 to 4.9).

2.8 SUMMARY

In summary, this literature review has described the following topics related to trauma and associated prehospital care: 1) trauma; 2) trauma care systems and prehospital care; 3) measurement of trauma severity and functional outcomes; 4) definitions of rural used in Canada; 5) rural health; 6) rural trauma; and 7) prehospital intubation.

CHAPTER 3

METHODOLOGY

3.1 STUDY OBJECTIVES

This thesis has two study objectives:

1. To describe variations in major trauma between rural and urban residents of Ontario in terms of external causes, severities, prehospital medical services and clinical outcomes.

2. To determine whether prehospital administration of intubation by paramedics, a key component of advanced life support, will improve survival to hospital discharge among victims of major trauma, compared with similar patients who were not intubated.

3.2 HYPOTHESES

In the two analyses contained in this thesis, I examined the following hypotheses:

Hypothesis 1. Differences will exist between rural and urban residents of Ontario in terms of external causes, severities, prehospital medical services and outcomes of major trauma;

Hypothesis 2. The provision of intubation during prehospital care will improve survival to hospital discharge among victims of major trauma, compared with similar patients who were not intubated.

3.3 OVERVIEW OF STUDY DESIGN

3.3.1 Objective 1. Trauma in Ontario and Geographic Status

In order to address objective 1, a descriptive analysis of trauma was developed. This analysis focused on comparisons of trauma in rural and urban areas. The degree of rurality of trauma patients was determined by modified Beale Codes, a geographic coding system that is based upon population density and proximity to urban centers.[31]

3.3.2 Objective 2. Prehospital Intubation and Trauma Survival

The second thesis objective focused on the association between prehospital intubation and trauma patient mortality. Although not fully understood, prehospital intubation may have an effect on trauma patients' survival. A matched study design was employed, comparing risks for non-survival among intubated and matched non-intubated trauma cases, controlling for trauma severity, patient age, and injury mechanisms and types.

3.4 DATA SOURCES

3.4.1 OPALS

This thesis was based on analyses of data from the Ontario Prehospital Advanced Life Support Study (OPALS).[76] OPALS is the largest prehospital study yet conducted, worldwide. Eleven base hospitals in Ontario (Burlington, Cambridge, Kingston, London, Niagara, Ottawa-Carleton, Peterborough, Sarnia, Sudbury, Thunder Bay, and Windsor) and 17 communities with different population sizes throughout Ontario participated. Each community was served by its own Central Ambulance Communications Centre, which provided dispatch information. These study communities are clearly defined and separate geographic areas (usually based on municipal boundaries). The communities must have been served by ambulance services with an annual call volume of at least 1,000 dispatched code 3 (prompt) or 4 (life-threatening) calls. Community populations range in size from 12,000 (Lindsay) to 750,000 (Ottawa-Carleton). The study period was from 1994 to 2002. This original OPALS trauma study was lead by Dr. Ian Stiell of the Ottawa Hospital Research Unit and the University of Ottawa.

3.4.2 Inclusion Criteria for OPALS

OPALS included major trauma patients who (1) experienced an injury caused by any mechanism, (2) had an Injury Severity Score more than 12, (3) had been transported by land ambulance within the study communities, and (4) had been entered into the Ontario Trauma Registry Comprehensive Data Set by virtue of being treated at 1 of the 11 trauma hospitals in Ontario.

3.4.3 Exclusion Criteria for OPALS

Exclusions were trauma patients transported by air ambulance to these same trauma hospitals and trauma cases not seen in a lead trauma hospital. The following trauma patients were also excluded: (1) patients younger than 16 years; (2) patients who were "obviously dead" as defined by the Ambulance Act of Ontario (decomposition, rigor mortis, or other). Burn patients were excluded from some analyses because of their small numbers.

3.5 DATA COLLECTION

Data collection was conducted by the 11 base hospital sites and an Ottawa data collection center. Records examined for each case included the following: ambulance call reports, dispatch reports, in-hospital records, telephone interviews, and the Ontario Trauma Registry Comprehensive Data Set which contains detailed data on patients hospitalized in 11 lead trauma facilities in Ontario. The latter data includes information on demographics, pre-hospital and hospital care, patient outcomes and six-month follow-up condition of patients. Times were based on those provided by the local Central Ambulance Communication Centers and local fire departments.

3.6 KEY VARIABLES FOR STUDY

Variables considered in this analysis are summarized in Table 3-1. Geographic and demographic factors included age, sex and degree of rurality of trauma patients, the external causes, nature, type and the severity of trauma, times for trauma services and clinical outcomes of trauma.

3.6.1 Demographics of Patients

Trauma patients were classified as adult (16 to 55 years) and older adult (>55) according to their age. Patients younger than 16 years old were already excluded from the database.

Table 3-1 Variables considered in the descriptive study

Category	Description
Demographics	
Age	Years
Sex	Male or Female
Degree of Rurality	Large Metro, Middle Metro, Small Metro, Rural
External Causes of Trauma	ICD-9 E-code
	Transport Accidents, Falls, Homicides, Suicides
Nature of Trauma	ICD-9 N-code
Type of Trauma	Blunt, Penetrating, or Burn
Severity of Trauma	AIS, ISS, GCS, RTS
Time for Trauma Services	
Response Time	From call received by EMS to arrival at the scene
Scene Time	From arrival at the scene to departure
Transport Time	Departure from scene to arrival at hospitals
Total Prehospital Time	
Outcome	
Survival to Hospital Discharge	Alive or Dead
Length of stay in ICU	Days
Length of stay in lead trauma hospital	Days
Glasgow Outcome Scale at discharge	
Functional Independence Measure at discharge	

AIS: Abbreviated Injury Scale; ISS: Injury Severity Score; GCS: Glasgow Coma Score; RTS: Revised Trauma Score; ICD-9: International Classification of Diseases-version 9; ICU: Intensive Care Unit; EMS: Emergency Medical Services

3.6.2 Degree of Rurality

The degree of rurality of patients was determined using the modified Beale code system[38]. In this study, the original Beale six categories were collapsed into four categories (large metro, medium metro, small metro and rural areas) by the degree of rurality of their residence.

The four categories were defined as follows:

1) The large metro group included the "large metro" and the "large metro fringe" categories in the modified Beale code (Beale code=0 or 1), i.e., a central and most

populous census division of a census metropolitan area with a population greater than 1 million or remaining census division(s) within or partially within a census metropolitan area with a population greater than 1 million. [38]

2) The medium metro group is the same as the "medium metro" category in the modified Beale code (Beale code=2), i.e., census division(s) containing, within, or partially within a census metropolitan area with a population between 250,000 and 999,999.

3) The small metro group is the same as the "small metro" category in the modified Beale code (Beale code=3), i.e., census division(s) containing, within or partially within a census metropolitan area/census agglomeration with a population between 50,000 and 249,999.

4) The rural group included the "Nonmetro-Adjacent" and the "Nonmetro-Nonadjacent" categories in the modified Beale code (Beale code=4, 5), i.e., census divisions that share a boundary with a census metropolitan area/census agglomeration that has a population greater than 50,000 or census divisions that do not share a boundary with a census metropolitan area/census agglomeration that has a population greater than 50,000.

3.6.3 Mechanism of Trauma

The mechanism of trauma was determined by the external causes of injury (E code) in the International Classification of Diseases.[77] The International Classification of Diseases is published by the World Health Organization and is the most widely used coding system for reporting mortality and morbidity in the world. E codes classify environmental events, circumstances, and other conditions according to mechanisms leading to injury and other adverse effects.

3.6.4 Nature of Trauma (International Classification of Diseases- version 9)

The nature of trauma was described using the International Classification of Diseases (version-9) N codes. The International Statistical Classification of Diseases provides codes to classify diseases and a wide variety of signs, symptoms, and external causes of injury or disease.[77] Every health condition can be given a code up to six characters long. The different natures of trauma were analyzed according to their importance to the survial of trauma patients. Subcategories including brain injury, spinal cord injury, nerve and internal organ injury, fracture and dislocation were analyzed.

3.6.5 Types of Trauma

Counts and percentage of the three main type of trauma (blunt, penetrating and burns) were described.

3.6.6 Severity of Trauma Cases

The initial assessment (whether in the field or in a regional hospital) of respiratory rate and systolic blood pressure were described. Trauma patients were divided into two groups according whether they were in shock state (systolic blood pressure<90mmHg) or not when their systolic blood pressure was first measured. The respiratory rate is categorized into two groups: normal respiratory rate (10-29 per minutes) and abnormal respiratory rate (<10 or >29 per minutes). [63]

Injury Severity Scores measured in the lead trauma hospitals were described. The Injury Severity Scores were placed into categories according to the following intervals (13-15, 16-24, 25-40, 41-49, 50-66, and 75). The first measured (whether in the field or in a regional hospital) Glasgow Coma Scores and Revised Trauma Scores for trauma patients were analyzed. The Glasgow Coma Scores were classified into 4 groups (Fully awake: 15, Minor injury: 13-15, Moderate injury: 9-12, and Severe injury or Coma: ≤8). The Revised Trauma Scores were also divided into 4 groups (7.84; 6-7.84; 4-6; <4).

3.6.7 Prehospital Care and Timing

3.6.7.1 Prehospital Care

The number and percentage of patients who received advanced life support and successful intubation in the field were identified.

3.6.7.2 Timing

The following prehospital times were examined in this study:

1) Response Time: The time interval between when the emergency call is received by the emergency dispatch centre to the arrival of the ambulance at the scene.

2) Scene Time: The time interval from arrival of paramedics at the scene to the departure for a receiving facility.

3) Transportation Time: The times needed to transport the patient to an appropriate facility.

4) Total Prehospital Time: The sum of the above three times.

3.6.8 Patient Outcome

3.6.8.1 Survival to Hospital Discharge

Both the number and the percentage of patients who survived to hospital discharge were both measured. Lengths of stay (days) in an intensive care unit and in the lead trauma hospitals were also measured.

3.6.8.2 Functional Outcome at Discharge

Glasgow Outcome Scale and the Functional Independence Measure at discharge were described. Glasgow Outcome Scale was organized into five categories (Good recovery, Moderate disability, Severe disability, Vegetative state, and Death).

3.7 ANALYSIS FOR OBJECTIVE 1-Ontario Trauma and Geographic Status

3.7.1 Key Exposure

The key exposure under study was a geographic descriptor of the locations of residence of trauma patients. Trauma patients were classified into four groups according to the degree of rurality of their residence: large metro, medium metro, small metro and rural.

3.7.2 Key Outcomes

Survival to hospital discharge was the primary outcome of this study. Percentages of patients who survived to hospital discharge were compared among the four groups as defined by their geographic status.

Functional outcomes at discharge including the Glasgow Outcome Scale and the Functional Independence Measure were also compared among the four groups with different geographic status.

The length of stay in an intensive care unit and in the lead trauma hospitals were also compared among the four geographic groups of patients.

3.7.3 Consideration of Potential Confounders

3.7.3.1 Severity of Trauma

Patients' severities of trauma were compared among the four geographic groups using standard measures. 1) The Injury Severity Score measured in the lead trauma hospital; 2) the first measured Glasgow Coma Score; 3) the first measured Revised Trauma Score (whether in the field or in a regional hospitals); and 4) the percentage of patients who were in shock according to their first measured systolic blood pressure.

3.7.3.2 Prehospital Timing

The time interval between the occurrence of trauma and the provision of definitive care is a major determinant of trauma patient outcomes.[63] The response times, scene times, transport times and total prehospital times were compared among the four geographic groups.

3.7.3.3 Mechanisms of Trauma

Percentages of patient with different external causes of trauma as defined by the International Classification of Diseases E-Code[77] were compared among groups, defined according to geographic status.

3.7.4 Analysis

All statistical analyses were conducted using SAS version 9.1 (SAS Institute USA) and were descriptive. A sample of 2867 trauma patients was available for this analysis. Proportions, measures of central tendency (median) and variability (inter-quartile range and 95% confidence intervals) for the key descriptors were analyzed and compared among different geographic groups. ANOVA and Kruskal-Wallis nonparametric methods were used for comparison of continuous variables, followed by post-hoc multiple comparison test (such as Dunn's procedure) to identify which geographic groups were different; χ^2 analyses were used for categorical variables (proportions).

3.7.5 Data Quality

The data quality of the OPALS appeared to be good. The completeness of key variables used in the first study was high except for the functional outcomes of trauma patients (Glasgow Outcome Scale and Functional Independence Measure). The percentage with complete recording of key variables examined in this study is listed in Table 3-2.

Table 3-2 Percentage of Complete Records in the First Analysis

Variables	% Complete Records
Age	99.0%
Severity of trauma	
Systolic Blood Pressure	95.9%
Glasgow Coma Scale	97.5%
Revised Trauma Score	90.0%
Injury Severity Score	100%
Times associated with prehospital care	
Response time	92.0%
Scene time	90.4%
Transpose time	92.0%
Total prehospital time	88.1%
External cause of trauma	99.5%
Outcomes	
Survival to hospital discharge	100%
Glasgow outcome scale	44.7%
Functional Independence Measure	63.7%
Length of stay- ICU	100%
Length of stay-Lead hospital	96.9%

3.8 ANALYSIS FOR OBJECTIVE 2-Prehospital Intubation and Trauma Survival

3.8.1 Key exposure

The key exposure in the second analysis was successful prehospital intubation as indicated in the prehospital record.

3.8.2 Key outcome

Survival to hospital discharge was the primary outcome of the second analysis.

3.8.3 Consideration of Potential Confounders

3.8.3.1 Matched Variables

3.8.3.1.1 Age

Survival is associated with age. Older patients have less tolerance to the same level of injury than younger adult patients; age was redefined as a dichotomy (≥55 years old; <55 years old) in this study in order to facilitate patient matching.

3.8.3.1.2 Severity of Injury

Patient survival is highly correlated with the severity of injury, as measured by the Revised Trauma Score and the Injury Severity Score.

Revised Trauma Score: The Revised Trauma Score is made up of a combination of results from three categories: Glasgow Coma Score, systolic blood pressure, and Respiration rates. It is heavily weighted by the Glasgow Coma Score and systolic blood pressure. Because respiratory rates had not been recorded in many intubated patients, we could not use the Revised Trauma Score in this analysis, but we still matched patients according to the Glasgow Coma Score and used Systolic Blood Pressure as a covariate in the analysis model.

Abbreviated Injury Scale and Injury Severity Score: One limitation of the Injury Severity Score is that it limits the total number of contributing injuries to three regions. The Injury Severity Score gives equal weight to each body region (e.g. brain and limb) and considers at most one injury per body region in cases where there are multiple severe injuries in one region. It will consider a less severe injury in a second body region rather than a more severe injury in the same region in patients with injuries in several body regions. The Abbreviated Injury Scale measures the severity of injury to each of 6 body regions. We used the Abbreviated Injury Scale for Head and Neck in response to this limitation of the Injury Severity Score. Injury Severity Score was converted to ordinal ranges (13 to 24; 25 to 66; 75) and the Abbreviated Head Injury Scale was reclassified on an new scale for analysis (No injury to Moderate injury=1; Severe to Maximum injury=2; and unspecified injury=3).

3.8.3.2 Other Covariates

3.8.3.2.1 Nature of Injury

Different natures of injury (e.g. brain injury and limb fracture) have different impacts on survival. The need for intubation generally is related to brain injury as comas lead to a loss of throat muscle tone. Upper spinal cord injury is related to the intubation as C1-C4 portions of the spinal cord innervate the diaphragm which is the main mechanical source of breathing. Chest injury (e.g. fracture of multiple ribs, injury of larynx, trachea, and lung, and pneumothorax or hemothorax) is also related to breathing difficulties. Patients who had other diagnoses such as asphyxiation were excluded from the OPALS study.

3.8.3.2.2 Systolic Blood Pressure

Blood pressure was based on the first measured systolic blood pressure and was characterized into an ordinal scale (≥90mmHg=2; 40-90mmHg=1; <40mmHg=0) because systolic blood pressures were not correlated linearly with patient survival.

3.8.3.2.3 Injury Type (Blunt and Penetrating)

Patients with penetrating injuries have a higher mortality rate than blunt trauma patients; no burn patients were included in this analysis.

3.8.3.2.4 Total Prehospital Time

The time interval between system notification of trauma and presentation to definitive care is a major determinant of trauma patient outcomes.[63] This covariate was considered as a continuous variable.

3.8.4 Analysis

All statistical analyses were conducted using SAS version 9.1 (SAS Institute, USA). Patients who were intubated in the field were matched using a computer algorithm and a ratio of 1:4 with non-intubated patients by patient age (adult: <55 years and seniors: ≥55 years), Injury Severity Score category (13-24, 25-66, and 75), Abbreviated Head Injury Scale category (No injury to Moderate injury; Severe to Maximum injury; and unspecified injury), and exact Glasgow Coma Scores. Cox regression was used to estimate the effect of prehospital intubation on patients' survival to hospital discharge, stratifying on patient matching variables. Survival time was defined as the length of hospital stay, treating patients alive at hospital discharge as censored observation. Additional confounding variables (e.g. prehospital time, injury type) were controlled for in the regression model. Residual confounding by age, systolic blood pressure, nature of injury (brain injury, spinal cord injury, and chest injury), injury type (blunt and penetrating) and total prehospital time were considered by including these covariates in the analysis. Kaplan-Meier survival curves were calculated and plotted to visually compare intubated cases to non-intubated cases in their survival.

3.8.5 Data Quality

All trauma patients with missing values in key variables were excluded in this study. Missing values were assumed to be random. A bias due to missing is not anticipated.

3.9 ETHICAL CONSIDERATIONS

The thesis is a secondary analysis of the Ontario Prehospital Advanced Life Support Study. Ethical approval for this thesis analysis was obtained from the research ethics board of Queen's University (Appendix D). The original OPALS study was approved by the research ethics board at the Ottawa Hospital. OPALS has been carried out in an anonymized manner.

CHAPTER 4

RESULTS

4.1 RESULTS FROM OBJECTIVE 1- Ontario Trauma and Geographic Status

4.1.1 Descriptive Analysis

4.1.1.1 Demographic Information

There were 2867 trauma patients in the dataset (Table 4.1.1). 72.1% of them were male. The median and inter-quartile range of age were 42 years and 28-64 years, respectively. Of 2606 patients who resided in Ontario, 214 (8.2%) patients lived in Large Metro or Large Metro Fringe areas, 1439 (55.2%) lived in Middle Metro areas, 802 (30.8%) lived in Small Metro areas, and 151 (5.8%) lived in rural areas.

4.1.1.2 Prehospital Care of Trauma

Among the 2867 trauma patients in OPALS, 52.1% received advanced life support that provides advanced therapy to patients at the scene and 142 (5.0%) received intubation in the field; this procedure was successful in 102 patients (3.6%). The success rate for prehospital intubation in this analysis was 71.8%.

Table 4.1.1 Description of OPALS Trauma Cases and Emergency Medical Care

	N		
Age (y)	2864		
Median (IQR)		42	(28-64)
<55		1899	(66.3%)
>=55		965	(33.7%)
Sex	2865		
Male		2066	(72.1%)
Female		799	(27. 9%)
Beale Code	2606		
0 (Large Metro)		47	(1.8%)
1 (Large Metro Fringe)		167	(6.4%)
2 (Medium Metro)		1439	(55.2%)
3 (Small Metro)		802	(30.8%)
4 (Nonmetro-Adjacent)		126	(4.8%)
5 (Nonmetro-Nonadjacent)		25	(1%)
Advanced Life Support Provided	2867		
Yes		1494	(52.1%)
No		1373	(47.9%)
Successful Intubation in the Field	2867		
Yes		102	(3.6%)
Attempted but failed		40	(1.4%)
No		2765	(95.0%)
Time (minutes)			
Response time (from call received to arrived scene)	2609		
Median (IQR)		7.4	(5.2-10.9)
Scene time	2568		
Median (IQR)		15.9	(11.6-21.7)
Transport time (depart scene to arrive emergency)	2613		
Median (IQR)		6.7	(4.2-10.7)
Total prehospital time	2503		
Median (IQR)		32.3	(24.9-42.1)

SD: Standard Deviation; IQR: Inter-quartile Range

The median response time for the study populations was 7.4 minutes (inter-quartile range 5.2-10.9 minutes). The median scene time was 15.9 minutes (inter-quartile range 11.6-21.7 minutes). The median transport time was 6.7 minutes (inter-quartile range 4.2-10.7 minutes). The median total prehospital time was 32.3 minutes (inter-quartile range 24.9-42.1 minutes).

4.1.1.3 Mechanism of Trauma

External causes of trauma were available for 2814 patients in the OPALS trauma case series. Motor vehicle collisions were the leading cause of trauma and accounted for 48.8% of all cases. Falls ranked second and were responsible for trauma in 27.5% of patients. The third and fourth leading causes of trauma were “homicide and injury purposed inflicted by others” (8.8%) and “suicide and self-inflicted injury” (4.1%). Specific mechanisms of injury are further described in Table 4.1.2.

4.1.1.4 Nature of Trauma

Of 2867 trauma patients in OPALS, 2628 (91.7%) patients experienced blunt trauma, 169 (5.9%) patients had penetrating trauma, and 68 (2.4%) patients experienced trauma from burns. The “top five” most common traumas by nature were fractures, brain injuries, open wounds, contusions with intact skin or superficial injury and organ injuries, respectively (Table 4.1.3). 71.4% of patients had one or more fractures, 61.3% patients experienced brain injury, 41.3% patients had open wounds, 40.0% patients had superficial injury or contusion with intact skin, and 39.5% patients had organ injury. In fracture patients, 29.2% had skull fractures which typically were connected with brain injury; 30.3% patients had fractures in the ribs, sternum or trachea, which were likely to affect their breathing and lead to mechanical ventilation.

Table 4.1.2 Mechanism of Injury Leading to OPALS Trauma Cases		
	N	% Total
External Cause of Injury (ICD-9) -Total Cases	2814	
Transport Injuries	1487	(52.8%)
Motor vehicle traffic accidents	1372	(48.8%)
Motor vehicle non traffic accidents	95	(3.4%)
Railway/water/air transport accidents	20	(0.7%)
Falls	774	(27.5%)
Fall on or from stairs or steps	241	(8.6%)
Fall on or from ladders or scaffolding	98	(3.5%)
Fall from or out of building or other structure	64	(2.3%)
Fall into hole or other opening in surface	11	(0.4%)
Other fall from one level to another	73	(2.6%)
Fall on same level from slipping, tripping, or stumbling	137	(4.9%)
Fall on same level from collision, pushing, or shoving	5	(0.2%)
Other and unspecified falls	145	(5.2%)
Homicide and injury purposed inflicted by others	247	(8.8%)
Suicide and self-inflicted Injury	115	(4.1%)
Injury undetermined whether accidentally or purposely	13	(0.5%)
Accidents caused by fire and flames	61	(2.2%)
Striking by objects or persons	29	(1.0%)
Struck by falling objects	27	(1.0%)
Accidents caused by machinery	22	(0.8%)
Others	39	(1.4%)

ICD-9: International Classification of Diseases, version 9

By nature, four kinds of trauma, i.e., brain injury, spinal cord injury, organ injury, and blood vessel injury are highly related to the survival of patients. [54] The proportions of patients who had these injuries were 61.3%, 5.8%, 39.5% and 5.9%, respectively. Among cases of organ injury, pneumothorax, hemothorax and lung injuries were more common than injuries in abdominal organs.

Table 4.1.3 Nature of Injury by patients (Note: patients typically experienced multiple injuries)

Injury according to ICD-9 code	No. of patients	% of total patients (N=2867)
Brain Injury	1758	(61.3%)
Concussion	210	(7.3%)
Cerebral laceration and contusion	442	(15.4%)
Intracranial hemorrhage	1141	(39.8%)
Spinal Cord Injury	166	(5.8%)
Upper cervical cord injury (c1-c4)	52	(1.8%)
Lower cervical cord injury (c5-c7)	65	(1.3%)
Thoracic cord injury	39	(1.4%)
Lumber and Sacrum cord injury	18	(0.6%)
Nerve Injury	165	(5.8%)
Injury of cranial nerves	40	(1.4%)
Injury of spinal plexus or nerve roots or trunks	30	(1.1%)
Injury of limb nerves	38	(1.3%)
Organ injury	1133	(39.5%)
Pneumothorax/hemothorax	581	(20.3%)
Heart	74	(2.6%)
Lung	501	(17.5%)
Liver	214	(7.5%)
Spleen	240	(8.4%)
Kidney	120	(4.2%)
Blood vessel injury	170	(5.9%)
Aorta	49	(1.71%)
Vena cava	11	(0.38)
Pulmonary blood vessels	6	(0.21%)
Subcalvian arteries/veins	10	(0.35%)
Celiac and mesenteric arteries	12	(0.42%)
Portal and spleen veins	4	(0.14%)
Renal blood vessels	11	(0.38%)
Iliac blood vessels	7	(0.24%)
Carotid artery	18	(0.63%)
Upper Limb blood vessels	11	(0.83%)
Lower limb blood vessels	19	(0.66%)
Femoral artery/veins	8	(0.28%)
Fracture	2135	(71.4%)
Skull fracture	836	(29.2%)
Face bone fracture	393	(13.7%)
Vertebral column fracture	621	(21.7%)
Chest fracture (ribs, sternum, trachea)	868	(30.3%)
Limbs (pelvis)	1253	(43.7%)
Dislocation	142	(5.0%)
Shoulder	36	(1.3%)
Elbow	15	(0.5%)
Wrist/hand/finger	20	(0.7%)
Hip	0	(1.1%)
Ankle/foot	18	(0.6%)
Open wounds	1183	(41.3%)
Superficial injury or Contusion with intact skin	1147	(40.0%)
Sprains and Strains of Joints/Muscles	100	(3.5%)
Burns	94	(3.3%)
Crushing Injury	8	(0.3%)

ICD-9: International Classification of Diseases, version 9

Table 4.1.4 Trauma Characteristics of OPALS Trauma Cases			
	N		
Injury Type	2865		
Blunt		2628	(91.7%)
Penetrating		169	(5.9%)
Burn		68	(2.4%)
Systolic blood pressure-1st measurement	2737		
≥90mmHg		2459	(89.8%)
<90mmHg (Shock)		278	(10.2%)
Respiratory rate-1st measurement	2628		
Normal (10-29/min)		2301	(87.6%)
Abnormal (<10 or >29/min)		327	(12.4%)
Glasgow Coma Scale-1st measurement (0-15)	2790		
Fully Awake (=15)		1261	(45.2%)
Minor (≥13)		579	(20.8%)
Moderate (9 to 12)		265	(9.5%)
Severe (≤8) (Coma)		685	(24.6%)
Revised Trauma Score-1st measurement (0-7.84)	2568		
7.84		1480	(57.6%)
≥6		506	(19.7%)
4-6		384	(14.9%)
<4		198	(7.7%)
Injury Severity Score in Lead Hospital (0-75)	2867		
Median (Inter-quartile Range)		22	(17-29)
13-15		330	(11.5%)
16-24		1181	(41.2%)
25-40		1066	(37.2%)
41-49		155	(5.4%)
50-66		85	(3.0%)
75 (Unsurvivable)		50	(1.7%)

4.1.1.5 Severity of Trauma

There were 278 (10.2%) patients in shock when their blood pressure was first measured in the field or in their primary hospital (Table 4.1.4). The respiratory rates of 327 (12.4%) patients were abnormal (faster than 29 per minutes or slower than 10 per minute [65]). The neurological states of patients were analyzed by Glasgow Coma Score in 2790 patients: 1261 (45.2%) patients were fully awake; 579 (20.8%) patients had minor affected neurological status, 265 (9.5%) patients were classified as moderate affected neurological status and 685 (24.6%) of patients had severe brain injury or coma. The Revised Trauma Scores were available for analyses in 2568 patients: 1480 (57.6%) patients had a full score (7.84). Injury Severity Scores were measured in the lead hospitals in all patients. Only patients with Injury Severity Score more than 12 were included in the dataset. The median score was 22 and the inter-quartile range was 17-29; 50 (1.7%) patients experienced injuries that were immediately classified as non-survivable.

4.1.1.6 Outcomes of Trauma

2335 (81.4%) patients in the full study were discharged alive (Table 4.1.5). The median days that trauma patients were admitted to a lead trauma hospital was 11 days (inter-quartile range 5 to 23 days). 1803 (62.9%) patients were admitted to an Intensive Care Unit. The median number of days that patients stayed in an Intensive Care Unit was 4 days (inter-quartile range 2 to 10 days).

There were many missing values in the Glasgow Outcome Scale and Functional Independence Measure at discharge. Among 1227 patients with Glasgow Outcome Scale assessed at discharge, 505 (41.2%) were classified as good recovery, 124 (10.1%) were classified as moderate disability, 222 (18.1%) were classified as severe disability, and 376 (30.6%) were classified as dead or in a vegetative state.

Table 4.1.5 Outcome of Injury Event for OPALS Trauma Cases			
Outcome	N		
Survival to hospital discharge	2867		
Alive		2335	(81.4%)
Dead		532	(18.6%)
Glasgow Outcome Scale at discharge	1227		
Good recovery		505	(41.2%)
Moderate disability		124	(10.1%)
Severe disability		222	(18.1%)
Vegetative state		23	(1.9%)
Death		353	(28.8%)
FIM at discharge (18-126)	1752		
Median (IQR)		103	(81-116)
Length of stay-lead hospital (days)	2759		
Median (IQR)		11	(5-23)
Length of stay-ICU (days)	1803		
Median (IQR)		4	(2-10)

IQR: Inter-quartile Range; FIM: Functional Independence Measure

In 1752 patients with a Functional Independence Measure recorded at discharge, the median score was 103 and the inter-quartile range was 81-116. Functional Independence Measure scores range from18 to126 representing scores from total functional dependence (Functional Independence Measure=18) to completely functional independence (Functional Independence Measure=126).

4.1.2 Comparison by Degree of Urban-Rural Status

A total of 2606 patients who lived in Ontario were available for comparison by rural-urban status. While there was little variation in the distribution of patients by gender across the geographic categories, ages of patients in the four geographic groups were significantly different. Patients in large metro and rural areas were significantly younger than patients in the other two groups. (Table 4.1.6; Figure 4.1.1)

A similar pattern was also observed for other variables. For external causes of trauma, the proportion of patients whose traumas were caused by transport injuries in the large metro group and the rural group were significantly higher than that of the other two groups. The proportion of patients whose trauma was due to falls was significantly higher in the medium and small metro groups. Similarly, the proportion of patients whose trauma was caused by homicide and by suicide was higher in the medium and small metro groups compared with the other two groups, although differences were not statistically significant (Table 4.1.7)

Table 4.1.6 General & Clinical Characteristics of OPALS Trauma Cases by Degree of Urban-Rural Status

	Large Metro (Beale code=0,1)		Medium Metro (Beale code=2)		Small Metro (Beale code=3)		Non-Metro (Beale code=4,5)		p
Age (y) (N=2604)									
Median (IQR)	36.0 (23-51)		43.0 (29-65)		44.0 (28-65)		38.0 (25-57)		<0.001
<55	168	78.5%	932	64.8%	510	63.7%	112	74.2%	<0.001
>=55	46	21.5%	507	35.2%	290	36.3%	39	25.8%	
Sex									
Male	151	70.6%	1042	72.5%	593	73.9%	101	66.9%	0.306
Female	63	29.4%	396	27.5%	209	26.1%	50	33.1%	
Systolic blood pressure (N=2499)									
>=90mmHg	181	86.6%	1275	91.8%	658	86.9%	126	87.5%	0.001
<90mmHg (Shock)	28	13.4%	114	8.2%	99	13.1%	18	12.5%	
Glasgow Coma Scale (N=2541)									
Median (IQR)	14 (8-15)		14 (10-15)		14 (8-15)		15 (12-15)		0.048
Minor/Moderate (>8)	154	74.8%	1083	77.5%	571	72.7%	118	78.1%	0.073
Severe (<=8) (Coma)	52	25.2%	315	22.5%	215	27.3%	33	21.9%	
Revised Trauma Score (N=2346)									
Median (IQR)	7.84 (6.4-7.84)		7.84 (6.9-7.84)		7.84 (6.0-7.84)		7.84 (7.11-7.84)		0.002
7.84-4	174	93.0%	1196	94.0%	662	88.5%	132	95.0%	<0.001
<4	13	7.0%	76	6.0%	86	11.5%	7	5.0%	
Injury Severity Score (N=2606)									
Median (IQR)	25 (17-30)		22 (17-29)		22 (17-26)		24 (17-29)		0.017
13-24	103	48.1%	753	52.3%	428	53.4%	78	51.7%	0.240
>=25	110	51.4%	667	46.4%	360	44.9%	68	45.0%	
75	1	0.5%	19	1.3%	14	1.7%	5	3.3%	

ANOVA and Kruskal-Wallis nonparametric test for continuous variables; chisq test for proportions.
IQR: Inter-quartile Range

Table 4.1.7 External Causes of Injury for OPALS Trauma Cases by Degree of Urban-Rural Status

	Large Metro (Beale code=0,1)		Medium Metro (Beale code=2)		Small Metro (Beale code=3)		Non-Metro (Beale code=4,5)		p
External Cause of Injury (N=2592)									
Transport injuries	139	65.3%	739	51.6%	384	48.2%	104	69.3%	<0.001
Falls	41	19.2%	395	27.6%	253	31.7%	26	17.3%	<0.001
Homicide and injury purpose inflicted by others	11	5.2%	122	8.5%	82	10.3%	10	6.7%	0.082
Suicide and self-inflicted Injury	6	2.8%	69	4.8%	30	3.8%	2	1.3%	0.117
Others	16	7.5%	107	7.5%	48	6.0%	8	5.3%	0.492

Table 4.1.8 Times associated with Emergency Medical Care for OPALS Trauma Cases by Degree of Urban-Rural Status					
Time (minutes)	Large Metro (Beale code=0,1)	Medium Metro (Beale code=2)	Small Metro (Beale code=3)	Non-Metro (Beale code=4,5)	p
Response time (N=2398)					
Median (IQR)	8.4 (5.7-11.8)	7.8 (5.6-11.0)	6.5 (4.7-9.4)	10.0 (6.1-14.7)	<0.001
Scene time (N=2355)					
Median (IQR)	18.6 (13.5-26.0)	15.5 (11.1-20.9)	15.9 (12.0-22.2)	16.4 (11.9-23.0)	<0.001
Transport time (N=2398)					
Median (IQR)	7.1 (4.8-10.6)	6.8 (4.2-10.4)	6.4 (3.6-10.2)	9.0 (4.8-14.2)	0.0003
Total prehospital time (N=2296)					
Median (IQR)	36.6 (29.9-45.6)	32.0 (25.0-41.5)	30.7 (24.1-41.1)	37.4 (27.3-50.6)	<0.001

SD: Standard Deviation; IQR: Inter-quartile Range

Table 4.1.9 Injury Outcome for OPALS Trauma Cases by Degree of Urban-Rural Status	Large Metro (Beale code=0,1)		Medium Metro (Beale code=2)		Small Metro (Beale code=3)		Non-Metro (Beale code=4,5)		p
Outcome									
Survival to hospital discharge (N=2606)									
Alive	172	80.4%	1169	81.2%	652	81.3%	133	88.1%	0.203
Dead	42	19.6%	270	18.8%	150	18.7%	18	11.9%	
Glasgow Outcome Scale at discharge (N=1165)									
Good Recovery	28	35.9%	203	37.5%	227	46.9%	24	39.4%	0.007
Moderate/Severe Disability	17	21.8%	152	28.0%	139	28.7%	22	39.8%	
Vegetative state/Death	33	42.3%	187	34.5%	118	24.4%	15	24.6%	
Functional Independence Measure at discharge (N=1660)									
Median (IQR)	103 (80-115)		104 (80-117)		104 (84-117)		103 (75-115)		0.861
Length of stay-ICU (days) (N=2606)									
Median (IQR)	2 (0-8)		1 (0-6)		2 (0-6)		1 (0-5)		0.103
Length of stay-lead hospital (days) (N=2524)									
Median (IQR)	11 (4-19)		10 (5-24)		11 (5-24)		11 (5-22)		0.393

IQR: Inter-quartile Range

Figure 4.1.1 General Characteristics of OPALS Trauma Cases by Degree of Urban-Rural Status

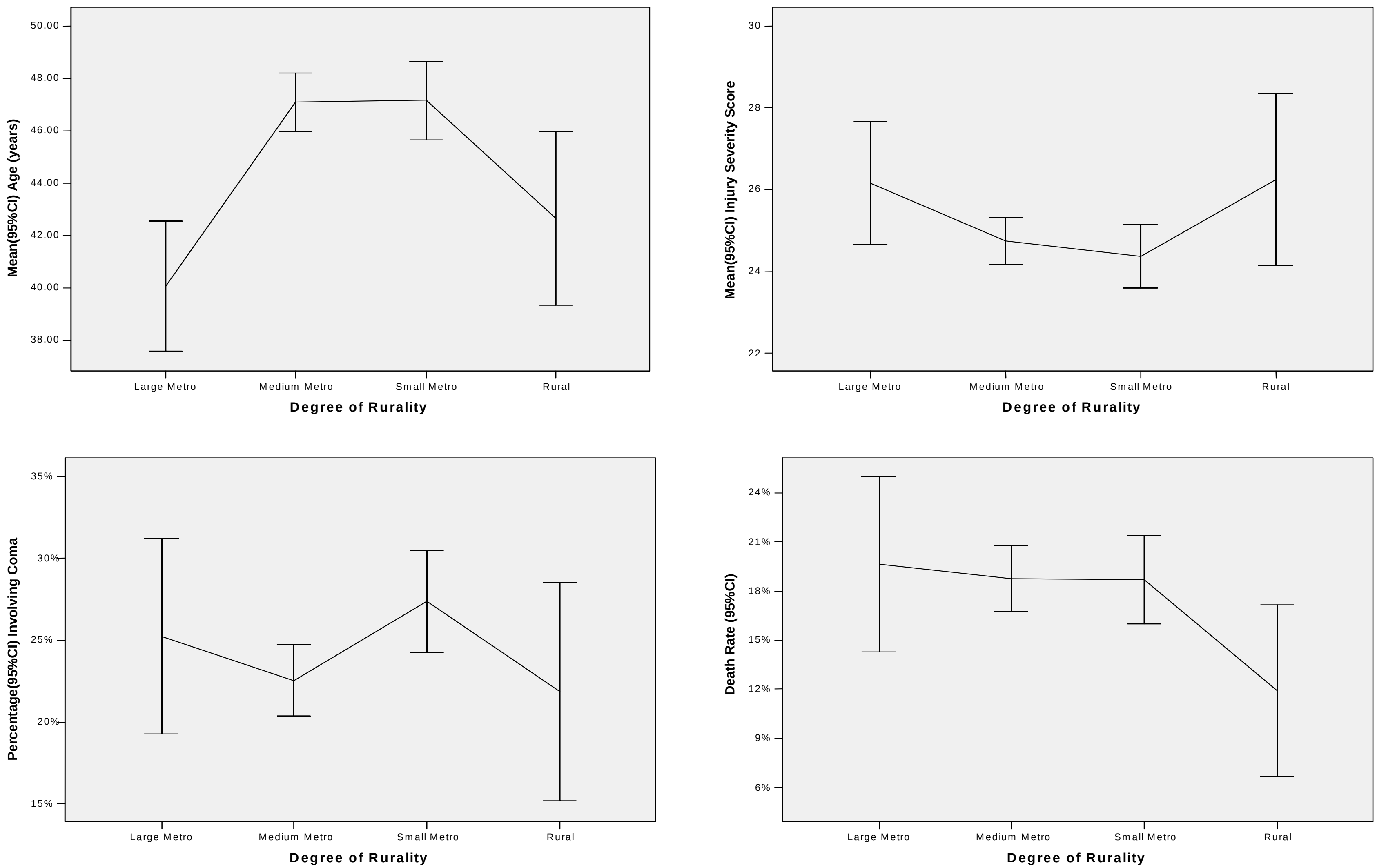
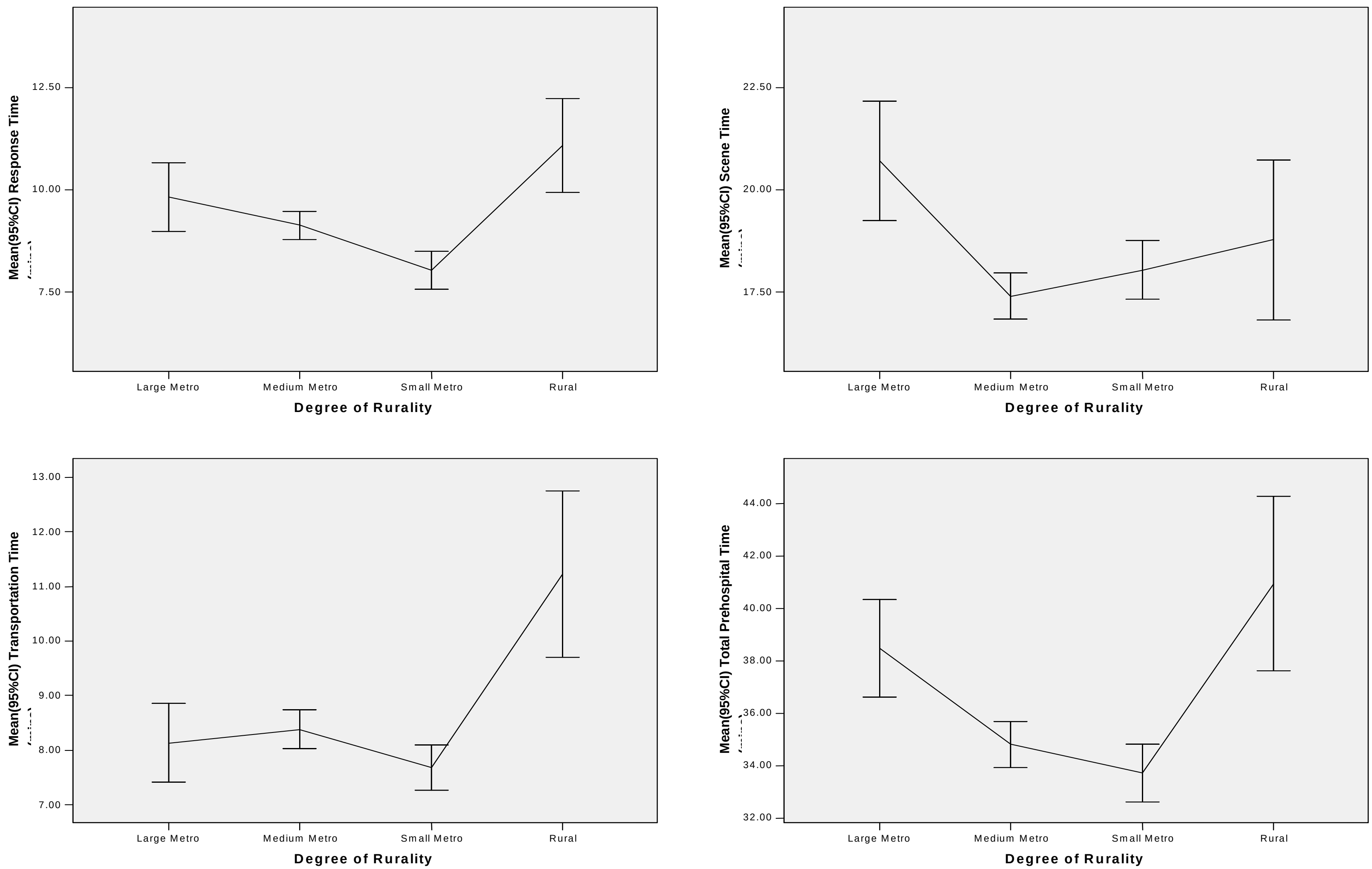


Figure 4.1.2 Times associated with Emergency Medical Care for OPALS Trauma Cases by Degree of Urban-Rural Status



For the severity of trauma, severity scores were not normally distributed. Nearly half of patients received the maximum value of the Glasgow Coma Score (15, fully awake) and more than half of patients received the maximum value of the Revised Trauma Score (7.84) in each of the four groups. There were no differences in the medians of these two scores by geographic status. With respect to the Injury Severity Scores, patients in large metro and rural groups had larger median scores (indicating higher severity) than the other two groups (p=0.017).

For the comparison of times associated with emergency prehospital care, the general trend was that paramedics spent more time in the field in rural and large metro areas than in medium and small metro areas. The response times in the rural group were significantly longer than the times for the large and medium metro groups; the latter were significantly longer than the times spent in the small metro areas. The scene times in the large metro area were significantly longer than the times in other three groups. The transport times in the rural group were significantly longer than the times in the other three groups. The total prehospital times in the large metro and rural groups were significantly longer than the times in the medium and small urban groups. (Table 4.1.8; Figure 4.1.2)

There were no significant differences in survival rates at discharge among patients in the four geographic groups, although the mortality rate in rural areas appeared lower than in the other three groups. Also, there were no significant differences among patients in the four geographic groups in terms of the length of stay in a lead trauma hospital or special care unit. For functional outcomes after trauma, there were no differences in the Functional Independence Measure in the four geographic groups at discharge. The comparison of proportions among different levels of Glasgow Outcome Scale showed significantly higher proportions of good recovery and lower proportions of death or vegetative state among patients in the small metro group than that in the other groups. (Table 4.1.9; Figure 4.1.1)

4.2 RESULTS FROM OBJECTIVE 2-Prehospital Intubation and Trauma Survival

There were 102 patients who were successfully intubated in the field. The median age of the 102 patients included in this analysis was 44 years (inter-quartile range 27-64). Male patients constituted 69% of the intubated patients. 82 patients (80.4%) had brain injury; 41 patients (40.2%) had chest injury; 6 patients (5.9%) had upper spinal cord injury. The intubated patients on average experienced more severe injuries than the other patients in OPALS. The median Injury Severity Score was 27 (inter-quartile range 25-43). The median Glasgow Coma Score was 3 (inter-quartile range 3-4). 77 patients (88.5%) had a Glasgow Coma Score ≤8 (indicating coma). Among all trauma patients, the median Injury Severity Score was 22 (inter-quartile range 17-29), the median Glasgow Coma Score was 15 (inter-quartile range 9-15), and only 24.6% patients had a Glasgow Coma Score ≤8.

We excluded patients with incomplete data for key variables and patients who experienced trauma other than brain, chest or upper spinal cord injury (e.g. asphyxiation, drowning, burn). Only 87 patients who were successfully intubated in the field therefore met the inclusion criteria for analysis. These 87 patients were matched with patients who were not intubated in the field in a ratio of 1:4 by age category (adult: <55 years and seniors: ≥55 years), Injury Severity Score category (13-24, 25-66, and 75), Abbreviated Head Injury Scale category (No injury to Moderate injury; Severe to Maximum injury; and unspecified injury), and Glasgow Coma Score. There were 414 patients included in this analysis (87 intubated patients and 327 matched non-intubated patients).

Table 4.2.1 Characteristics of Patients

Variables	Patients Intubated	Not intubated	p-value
Age (y)			
Median (IQR)	44 (27-64)	38 (27-61)	0.4
<55	57 (65.5%)	221(67.6%)	0.72
≥55	30 (34.5%)	106(32.4%)	
Sex			
Male	60 (69.0%)	247 (75.5%)	0.21
Female	27 (31.0%)	80 (24.5%)	
Injury Type			
Blunt	77 (88.5%)	311 (95.1%)	0.02
Penetrating	10 (10.5%)	16 (4.9%)	
SBP-1st measurement			
≥90mmHg	53 (60.9%)	236 (72.2%)	0.07
40-90mmHg	16 (18.4%)	52 (15.9%)	
<40mmHg	18 (20.7%)	39 (11.9%)	
GCS-1st measurement (0-15)			
Median (IQR)	3 (3-4)	3 (3-4)	0.77
Minor or Fully Awake (≥13)	1 (1.2%)	4 (1.2%)	0.99
Moderate (9 to 12)	9 (10.3%)	34 (10.4%)	
Severe (≤8) (Coma)	77 (88.5%)	289 (88.3%)	
ISS in Lead Hospital (0-75)			
Median (IQR)	27 (25-43)	29 (25-38)	0.79
13-24	19 (21.8%)	69 (21.1%)	0.82
25-66	60 (69.0%)	234 (71.6%)	
75	8 (9.2%)	24 (7.3%)	
Prehospital time (minutes)			
Median (IQR)	36.0 (27.5-42.6)	25.5 (19.4-34.0)	<0.001

SD: Standard Deviation; IQR: Interquartile Range
ISS: Injury Severity Score; GCS: Glasgow Coma Score; SBP: Systolic Blood Pressure;

There were no significantly differences between the intubated and not intubated groups by age, sex, and injury severity (Glasgow Coma Score and Injury Severity Score). The proportion of patients in each category of systolic blood pressure (≥90mmHg; 40-90mmHg; <40mmHg) in the two groups was close to being significantly different (p=0.07). The intubated patient group had a similar percentage of penetrating injury (P=0.21) but longer total prehospital times (p<0.001). Further characteristics of patients in this study are listed in Table 4.2.2.

The adjusted hazard ratios for mortality in hospital associated with key variables are listed in Table 4.2.3. When adjusted for the matched variables only, the hazard ratio of mortality was 3.5 (95% CI: 1.5-6.9) for prehospital intubation. Elevated hazard ratios were also found for penetrating injury, 0-40mmHg blood pressure, 40-90mmHg pressure, and brain injury. Total prehospital time and age did not appear to have a significant effect on mortality (HR 1.0 per minute).

Prehospital intubated patients had a nearly 3-fold hazard of mortality after adjusting for all potential confounders. (HR 2.9; 95% CI 1.4 to 5.8). The hazard ratios of mortality adjusting for all variables are shown in Table 4.2.2. Total prehospital time failed to have a significant impact on mortality (HR 0.99; 95% CI 0.97 to 1.02) in this analysis. Results of stratified analyses of hazard ratios by brain injury and shock are shown in table 4.2.3 and table 4.2.4. Survival curves for intubated and not intubated groups of patients by the log-rank survival test are shown in the figure 4.2.1. This analysis also suggest that intubation was associated with an increased hazard of mortality.

Table 4.2.2 Adjusted Hazard Ratios for Mortality in Hospital				
Variables	No. of Patients		HR adjusted for matched variables* only (95% CI)	HR adjusted for all variables# (95% CI)
	Survived	Died		
Age (y)			1.0 (1.0-1.1)	1.0 (1.0-1.1)
Prehospital Time			1.0 (0.99-1.02)	0.99 (0.97-1.02)
Prehospital Intubation				
Not intubated	181	146	1.0	1.0
Intubated	29	58	3.5 (1.5-6.9)	2.9 (1.4- 5.8)
Brain Injury				
No	21	32	1.0	1.0
Yes	189	172	5.0 (1.2-20.2)	9.1 (1.9- 50.2)
Injury Type				
Blunt	205	183	1.0	1.0
Penetrating	5	21	4.9 (1.5-16.6)	6.0 (1.5- 23.4)
Systolic blood pressure-1st measurement				
≥90mmHg	174	115	1.0	1.0
40-90mmHg	27	41	1.7 (0.8-3.5)	2.7 (1.2- 6.0)
<40mmHg	9	48	6.5 (14.8-2.5)	7.0 (2.9- 16.6)

*age category, Injury Severity Score category, Abbreviated Head Injury Scale category, Glasgow coma score

matched variables + age, systolic blood pressure category, total prehospital time, type and nature of injury

Table 4.2.3 Adjusted Hazard Ratios for Mortality in Hospital by Brain Injury

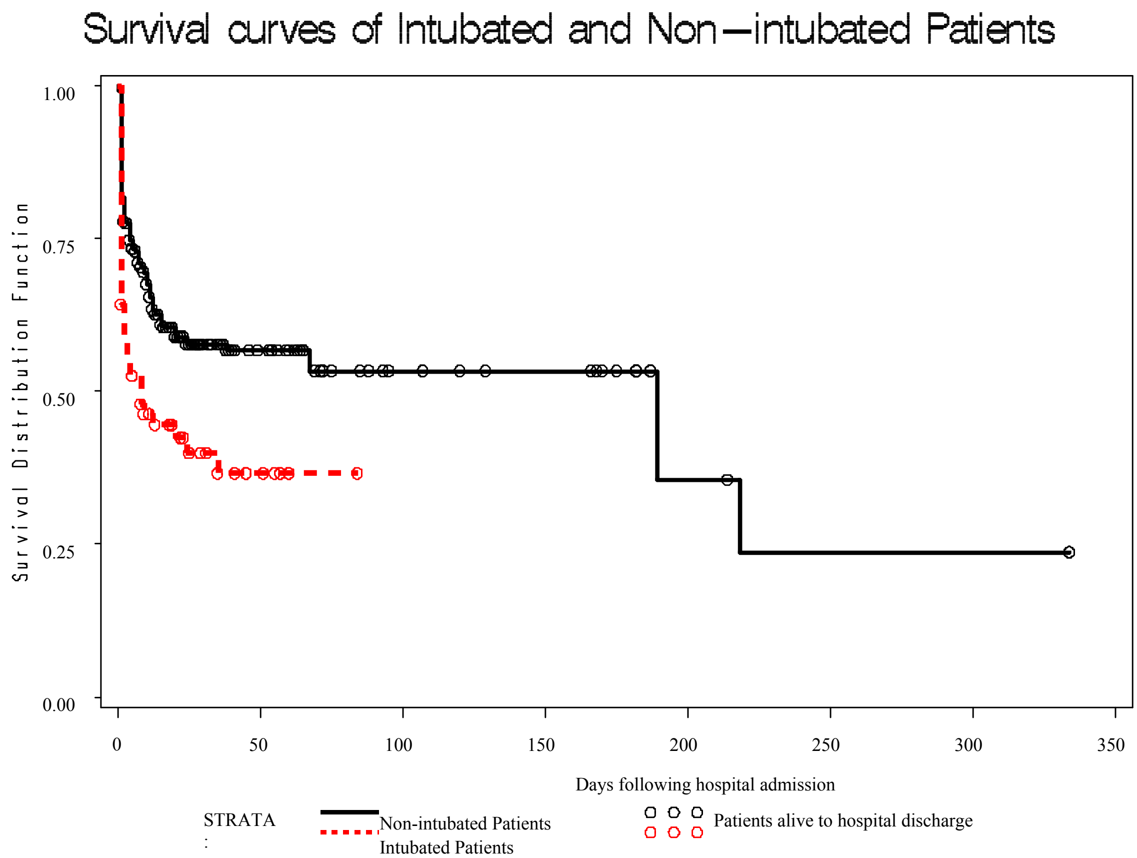
	HR adjusted for matched variables only (95% CI)	HR adjusted for all other variables (95% CI)
Brain Injured		
Not Intubated	1.0	1.0
Intubated	3.1 (3.1-6.0)	3.0 (1.4-6.4)
Not Brain Injured		
Not Intubated	1.0	1.0
Intubated	*	*

* HR would not maximize

Table 4.2.4 Adjusted Hazard Ratios for Mortality in Hospital by Shock

	HR adjusted for matched variables only (95% CI)	HR adjusted for all variables (95% CI)
Shock		
Not Intubated	1.0	1.0
Intubated	3.5 (0.9-14.4)	4.5 (1.0-20.9)
No Shock		
Not Intubated	1.0	1.0
Intubated	2.1 (1.0-4.5)	1.8 (0.8-4.2)

Fig 4.2.1 Survival Curves of Intubated and Non-intubated Patients



CHAPTER 5

DISCUSSION

5.1 OBJECTIVE 1-Ontario Trauma and Geographic Status

5.1.1 Restatement of Objective and Hypothesis

The objective of this study was to describe variations in major trauma between rural and urban residents of Ontario in terms of external causes, severities, prehospital treatments and clinical outcomes. Our hypothesis was that differences would exist between rural and urban residents of Ontario in terms of external causes, severities, prehospital medical services and outcomes of major trauma. In addition, prehospital care plays a very important role in the outcomes of trauma, and effects of geography on this care are important to understand.

5.1.2 Summary of Results

In terms of mechanisms of injury, transport injury was the leading cause of trauma in all four geographic groups. Falls, injuries purposely afflicted by others, and suicide were also important mechanisms. Proportions of transport injury victims in the large metro group and the rural group were significantly higher than that of the other two groups, while fall injuries were lower in the former two groups. With respect to trauma severity, there were no differences in the median Revised Trauma Score among groups. Patients in the large metro and rural groups had higher Injury Severity Scores than the other two groups. With respect to times associated with emergency prehospital care, as expected, response times and transport times in rural groups were significantly longer than the other three groups, while scene times in the large metro group were significantly longer. There were no significant differences in mortality among patients with different rural-urban status.

5.1.3 Interpretation of Results

5.1.3.1 External Causes of Trauma

External causes of trauma varied between rural and urban populations. Urban and rural communities differ in both environmental characteristics and associated behavioural norms. Injuries associated with falls from high buildings and exposures to illicit drugs, for example, are especially common in large metro areas, whereas farm machinery traumas are especially common in rural areas.

Transport injuries were the most frequent cause of major trauma in our study, overwhelming all other causes. Motor vehicle crashes were responsible for the largest component of these transport injuries. 48.8% of trauma patients in our study were injured by motor vehicle crashes, which account for 92% of the total transport injury patients. Proportions of transport injuries victims were highest in the rural groups, and significantly higher than that of the medium and small metro groups. Poor road conditions, harsh weather, fewer traffic control devices, mixed types of vehicles, more alcohol involvement, less seat belt use and speed all contribute to the elevated rate of transport injuries in rural areas.[42-47]

Falls, the second leading cause of injury, were reported less frequently in rural areas than in the small and medium metro groups in our study. Injuries purposely afflicted by others and suicide were the third and the fourth leading causes of injury in our study. Rates in the rural group are slightly lower than rates in other groups, although there were no significant differences among the four groups. Similar trends have been found by other researchers. In a report from Baker et al, [10] suicide rates were much higher in metropolitan areas than other areas. This may be attributable to the availability of different methods for suicide, or to different social conditions that are risk factors for suicide. Similarly, the rate of homicide is substantially higher among people in central cities than among people living elsewhere. In New Hampshire and North Dakota, the homicide rate was less than 2 per 100 000 population, whereas the rate was 28/100 000 in Washington D.C, which is entirely urban and a central part of a metropolitan area.[10]

5.1.3.2 Severity of Trauma

In trauma, mortality rates are highly related to the severity of injury experienced by individual patients. Shock, a hypovolemic state, would considerably decrease the possibility of survival chances in trauma patients, if not treated in a timely fashion. Proportions of these patients were not different in the four geographic groups in our case series. With respect to severity of trauma, our findings showed no clinically meaningful differences in the medians of these trauma scores among the four geographic groups. More than half of the patients in the rural group had a maximum Glasgow Coma Score (15), while the medians of Glasgow Coma Score in other three groups were all 14, suggesting only a modest decline in function in one of three key responses (Eye, Verbal and Motor) from the fully awake status. To illustrate, a one-point difference is the difference in the state when one can open eyes spontaneously to the state where one opens their eyes only in response to voice. This is a relatively minor neurological injury and would not affect the survival of trauma patients heavily. More than half of trauma patients in the four geographic groups had full Revised Trauma Scores, which means a normal Glasgow Coma Score (neurological state), a normal blood pressure, and a normal respiratory rate. With respect to Injury Severity Scores, patients in large metro and rural groups reported slightly larger median scores than the other two geographic groups. (Median= 25, 24 vs. 22, 22, respectively). These were considered to be minor differences.

5.1.3.3 Prehospital Time

The time interval between the occurrence of trauma and the receipt of definitive care in a trauma centre is considered to play an important role in survival. To achieve even small reductions in response times means additional vehicles and personnel to an Emergency Medical Service system, which may be very costly.

Response time is defined as the time interval from the call received by dispatchers to the paramedics' arrival at the scene. Adequate training of dispatchers and paramedics and the quality of the communication system are key elements to reduce these response times. In our study, the response time in the rural geographic group was significantly longer than times for large and medium metro groups; the latter was significantly longer than times spent in small metro areas. Longer distances from the emergency service centre to the trauma site obviously explain the increased response times observed in rural areas.

Scene time is the time interval from arrival of paramedics to the trauma scene to their departure for a receiving facility. The amount of “on scene time” is dependent on possible extrication time and the number of paramedics and trauma patients on the scene. The number of stabilizing treatments attempted in the field will also increase the scene time. In our study, the scene time in the large metro area was significantly longer than scene times observed in the other three geographic groups. This may be because more emergency treatments were provided in urban populations.

Transport time is the time needed to transport the patient from the scene to an appropriate facility. The transport time is largely controlled by distance from the site to the medical facility, the speed of ambulances and road conditions. In our study, the transport time in the rural geographic group was significantly longer than times observed in the other three groups. This is attributable to the remoteness of locations of the rural trauma sites. Many trauma patients require types of medical care not available in a local or regional hospital located in rural areas; this will increase transport times if patients are transported to a trauma centre.

The sum of the above three times is the total prehospital time. In our study, the total prehospital times in the large metro and rural geographic groups were significantly longer than times spent in the medium and small urban groups. Increased rural times are likely attributable to distances from care, where the increased urban times are more likely attributable to time spent in the field.

5.1.3.4 Mortality from Trauma

Contrary to our hypothesis and other population-based research [45, 59, 78], our study did not find a higher mortality rate among rural residents. In other studies, a comparison of trauma patients in the U.S. on the basis of place of residence showed that unintentional injury death rates are highest in rural areas. [45, 59, 78] Mortality for the most rural areas was more than 50% greater than that for central cities (69% vs. 39%).

One possible reason for our finding is that OPALS included only patients transported by land ambulance. Trauma patients transported by air ambulance and patients who were "obviously dead" (as defined) were excluded from our dataset. Many injured patients were likely to have died at the scene, and this could be higher in rural areas. A population based study performed by Cooper et al [78] reported that 9 of the 11.6 per 100 000 children who died in New York State in 1989 as a result of trauma were never admitted to the hospital. Mueller et al [45] compared the pedestrian injury and fatality rates for urban and rural areas of Washington State from 1981 to 1983 using state Department of Transportation records. They found that although there were no significantly differences between the proportions of patients who died after receipt of emergency medical care in rural areas and in urban areas (68% and 75% respectively), 48% of the rural cases died prior to admission, compared to only 32% of urban fatalities. Rogers et al [59] also reported that 40.5% of trauma patients died at the scene of injury in an urban system, compared with 72% of patients in a rural environment. The higher proportion of scene deaths in rural environments is likely attributable to delayed discovery and long response times.

5.2 OBJECTIVE 2-Prehospital Intubation and Trauma Survival

5.2.1 Restatement of Objective and Hypothesis

The objective of this study was to determine whether prehospital intubation by paramedics, a key component of advanced life support, would improve survival to hospital discharge among major trauma patients, compared with similar patients who were not intubated. Intubation is a complex procedure. Although it is readily performed in hospital settings, multiple factors like environment, experience, and skills of paramedics may compromise rates and timeliness of prehospital intubation. Results from previous studies have generated conflicting data about the potential benefit of prehospital intubation in the treatment of injuries. Our basic hypothesis was that provision of intubation during prehospital care would improve survival to hospital discharge among victims of major trauma, compared with similar patients who were not intubated.

5.2.2 Summary of Results

87 patients who were intubated successfully in the field and 327 patients who were not intubated were individually matched on age category, Injury Severity Score and Head & Neck Abbreviated Injury Scale category, and exact Glasgow Coma Scores.

No significant differences existed between the intubated and non-intubated groups by age, sex, Glasgow Coma Scores, Injury Severity Score, and systolic blood pressure category. This suggested that the matching was effective at achieving balance on prognostic factors. Prehospital intubated patients had nearly 3 times the relative hazard of mortality after adjustment for all potential confounders (HR 2.9; 95% CI 1.4 to 5.8).

Hazard ratios of mortality were also higher for penetrating injuries, 0-40mmHg blood pressure, 40-90mmHg pressure, and diagnosis of brain injury. Total prehospital time failed to have a meaningful impact on mortality in this analysis.

5.2.3 Interpretation of Results

Our results showed that provision of prehospital intubation in the field had a negative association with rates of survival among major trauma patients in Ontario. The main question remains: is this due to a bias among patients or a detrimental effect of this procedure?

5.2.3.1 Bias

Selection bias may have occurred in this study, as prehospital intubation for more severely injured patients is likely. Clearly, patients with severe trauma may be easier to intubate or more apt to be seen as a candidate for intubation. To allow easier intubation without the help of drugs in the field, a patient must be unconscious, and a higher likelihood of death might be expected in such a group. Clinical experiences shows that patients who can be intubated without the use of drugs have a poor prognosis. [79, 80] Lockey and colleagues [79] performed a retrospective analysis of a helicopter-based emergency medical service in London, U.K.. Only one in 486 trauma patients who was intubated without drugs survived. Christensen et al [80] investigated 172 severely injured patients and prehospital intubation done in 74(43%) patients. Mortality rates were 42% and 92% respectively in the groups defined according to receipt or not of anesthetic.

The trauma scores provided were estimated by paramedics in complicated field environments and have limitations. Although we individually matched the severity scores (Injury Severity Score and Glasgow Coma Score) of intubated and non-intubated trauma patients and there were no important differences between scores of the two groups, there is still the possibility that patients in the intubated group were more severely injured than their matched patients in the comparison group.

Although our study minimized the risk of bias by using statistical techniques (Cox regression) to control for differences in confounders like systolic blood pressure and injury type, it is open to question whether even these regression models would be able to adjust for prognostic factors that affect patient outcomes.

Information available in the database was somewhat limited. For example, some important preexisting medical conditions (e.g. coronary heart disease, diabetes, hematologic disorders) and in-hospital complications (e.g. nosocomial infection, postoperative complications) could affect the survival of patients, but were also not available to be controlled for in the analysis.

5.2.3.2 Detrimental Effect of Prehospital Intubation

Prehospital intubation may have potential deleterious effects for trauma patients. Potential harms of prehospital intubation on survival may include increased total prehospital time, complications of intubation, hyperventilation, and hemodynamic effects of positive pressure ventilation in hypovolemic patients. [53, 82-94]

5.2.3.2.1 Increased Prehospital Time from Prolonged Attempts in the Field

Field stabilization may lead to longer prehospital times among trauma patients. Critically injured patients require blood transfusion and operative interventions that are not available in the field. Any action that delays the trauma patients' delivery is ultimately detrimental to survival. It is widely believed that the victim's chances of survival are greatest if he or she receives definitive care in the operating room within the first hour. This appears to be true in cases of internal bleeding. [52, 53]

5.2.3.2.2 Complications of Intubation

Complications of intubation may contribute to poor mortality outcomes observed among intubated patients. Complications include mechanical injury, esophageal intubation, aspiration, barotraumas, incorrect tube size, and tube dislodgment. Intubation in field, especially multiple attempts, may cause mechanical injury to the airway. Jaeger et al [85] reported a case of tracheal injury caused by multiple attempts at intubation of the trachea. In a case series of 1953 patients, Wang et al [82] reported that intubation errors occurred in 444 patients, including tube misplacement or dislodgement in 61 (3.1%) patients, multiple intubation attempts in 62 (3.2%), and failed intubation in 359 (18.5%). In a prospective observational study, Katz et al [83] studied 108 intubated patients; 25% of patients were found to have improperly placed endotracheal tubes, and 67% of them were found to be in the esophagous. In the other 33% of patients, the tips of the tube were found to be in the hypopharynx, above the vocal cords. In a study by Jemmett et al [84], 13 of the 109 (12%) studied patients were found to have misplaced endotracheal tubes.

5.2.3.2.3 Environmental considerations in field settings

Intubation is a complex procedure and it is more difficult when attempted in prehospital settings. Complication rates can be higher in the field. Ehrlich et al[85] examined intubation attempts in 2,907 patients less than 19 years old. Two-thirds of the field cases had complications compared with 29% at the transferring hospitals, and only 4% at the trauma center.

An experienced anesthesiologist or an emergency physician is typically available only in hospital settings. Paramedics may have more limited training and clinical experience than emergency physicians. Burton et al [86] demonstrated that paramedics used intubation skills uncommonly in Maine. Less than one-third of paramedics used this skill for any given calendar year and even worse, less than 1% of paramedics intubated children annually.

Unlike the intensive care unit where ventilatory parameters such as inspiratory time, tidal volume, respiratory rates and pressure have been well considered, these important parameters that could affect survival are rarely controlled for in prehospital settings.

5.2.3.2.4 Hyperventilation and Hypoxia

After successful prehospital intubation, paramedics commonly perform ventilation manually (without the assistance of portable ventilators). Paramedics can inadvertently provide high rates of ventilation, even when educated about proper rates.

Hyperventilation is also more pronounced in community hospital settings with less experience handling traumatic brain injury. Gervais et al [87] found that manual ventilation during transport without controlling minute volume lead to hypocarbia. Hurst et al [88] also reported that members of health care team tended to ventilate patients at a more rapid rate and with a lower tidal volume during manual ventilation than on ventilatory support. Tobias et al [89] also found unintentional hyperventilation occurred in intrahospital transport of children using manual ventilation. Unintentional hyperventilation may be deleterious in certain conditions.

Hyperventilation may benefit brain injury patients since it can cause rapid reduction of intracranial pressure. [90] However, respiratory alkalosis caused by hyperventilation can lead to cerebral vasoconstriction and increase haemoglobin's affinity for oxygen. An increase in cerebral vascular resistance caused by vasoconstriction will result in a decrease in the cerebral blood flow. The haemoglobin's increased affinity for oxygen will hamper the release of oxygen in tissue. Because of its high rate of oxygen consumption and limited reserves, the brain requires a constant supply of oxygen. The brain is more sensitive to hypoxia when it is already made vulnerable from a primary injury such as head trauma or global ischemia from hemorrhagic shock. Aggravation of brain ischemia caused by a forced hyperventilation may compromise patient outcomes, especially in patients with severe head injury and hemorrhagic shock.

Studies had found that oxygen desaturation is associated with prehosptial intubation and hyperventilation. Dunford et al [91] reported that 57% of trauma patients experienced desaturation during prehospital rapid sequence intubation. 84% of these events occurred in those who had normal initial oxygen saturation with basic airway skills. The median duration of desaturation was 160 seconds, and the median decrease in oxygen saturation was 22%. In addition, 19% of patients experienced marked bradycardia (pulse rate <50 beats/min) during desaturation events. Fortune et al [92] showed a 30.7% decrease in cerebral blood flow, jugular venous desaturations, and decreased brain tissue oxygen levels associated with hyperventilation.

5.2.3.2.5 Positive Pressure Ventilation

Traditionally, paramedics have been trained to provide intermittent positive pressure ventilation after intubation to protect the airway and deliver more oxygen. In contrast to spontaneous ventilation, which decreases intrathoracic pressure and enhances venous return into the right atrium, positive pressure ventilation increases intrathoracic pressure, which diminishes the cardiac preload. Studies have found that positive pressure ventilation may increase pulmonary vascular resistance and it may lead to direct external compression of the heart.[93] The negative hemodynamic effect of intermittent positive pressure ventilation can be significant in trauma patients with severe circulatory compromise.

5.3 STRENGTHS AND LIMITATIONS

5.3.1 Strengths of the Study

5.3.1.1 Objective 1- Ontario Trauma and Geographic Status

The first strength of this study is its high level of generalizability. The analysis used the data from the Ontario Prehospital Advanced Life Support Study. OPALS is the largest prehospital study in the world. We expect that the results could be generalized to the whole of Ontario.

Second, in some settings volunteers act as paramedics in rural communities; they are often inexperienced and not well trained. This will confound the association between the trauma care services and patients' outcomes. In the province of Ontario, all paramedics have undergone classroom teaching and practical training through a 10-month community college program. These paramedics were not volunteers and received standard additional advanced life support training in this study. The skills and training of the paramedics are therefore less likely to confound the association.

Another strength of this study was our efforts to define geographic status using a standard classification system.

5.3.1.2 Objective 2- Prehospital Intubation and Trauma Survival

A strength of the second component of this study is that we matched subjects by critical parameters including age and severity of injuries which are highly correlated with survival.

Second, we used multivariate methods to account for other potential confounders. Many covariables such as nature and type of injury may confound the association under study. We adjusted for these confounders in our Cox model.

5.3.2 Limitations of the Study

5.3.2.1 Objective 1- Ontario Trauma and Geographic Status

An important limitation of our study is that the trauma records for individual cases in some communities were incomplete. Trauma patients transported by air ambulance to these same trauma hospitals were also not included. Also, some trauma cases may go directly to an emergency department by private vehicle instead of through emergency medical services systems, and would have been missed.

The most important limitation of this study is that some patients who died in the field were not included. Many deaths occur at crash scenes, which will substantially underestimate the mortality rate and the severity of the trauma. Second, rural patients are more likely to die at the scene than their urban counterparts. This will confound the comparison among the four geographic groups.

Another important limitation is that information about notification and/or discovery times (the time interval from the time of injury and the time the call was received) were not available. Although emergency medical service response times, scene times and transport times were short, prolonged discovery times are problematic in rural communities. This will lead to greater underestimation of the total prehospital time in the rural areas. There were missing values in trauma scores measured in the field; in these cases we used the first available measure from the hospital system which may not best represent the truth. There were also many missing values in the functional outcome measurement. Only 42.8% (1227 of 2867) cases had a reported Glasgow Outcome Scale and only 61.1% (1752/2867) cases had the functional independence measure at discharge.

Finally, rural-urban status was determined by the residence of patients instead of the location of trauma. 52.8% of trauma cases in this study were transport injuries. Although most motor vehicle injuries occur close to a person's place of residence, major injuries could occur elsewhere. Many transport accidents happened on highways or places with a different geographic status than the residence of trauma victims. This will lead to misclassification of the geographic exposure status of patients.

5.3.2.2 Objective 2- Prehospital Intubation and Trauma Survival

A limitation of this study is that it has a relative small number of intubation patients that were heterogeneous in nature. Only 102 patients were intubated successfully in the field. The three main natures of injuries documented in these cases were brain, chest and upper spinal cord injury. Others injuries included asphyxiation, drowning and burns. It is difficult to examine the effect of the prehospital intubation on each subset of patients. The association between different natures of trauma and the outcomes may be different, and one association may mask or confound others.

Another limitation with this analysis was that some important variables which could affect the survival of patients were not available for study. These variables included comorbidity of trauma patients (e.g. coronary heart disease, diabetes, hematologic disorders) and in-hospital conditions (e.g. nosocomial infection, postoperative complications).

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH

5.4.1 Objective 1- Ontario Trauma and Geographic Status

Our study was a secondary analysis of existing data from OPALS. The limited patient numbers in rural groups weakened our results in the comparison of trauma by urban-rural geographic status.. A national study could be done to examine trauma characteristics and associated emergency care for rural residents.

5.4.2 Objective 2- Prehospital Intubation and Trauma Survival

Intubation is considered to be the definitive approach to airway control for most critically ill and injured patients. Intubation has potential risks, especially in complicated prehospital settings. The inexperience of paramedics could also contribute to complications for this procedure. Many resources have been invested in the equipment and training for implementing and maintaining this skill. It remains unknown whether simple airway maneuvers are sufficient for trauma patients. The subset of trauma patients who may best benefiet from prehospital intubation also requries identification. These questions are best answered by randomized trials.

CHAPTER 6

CONCLUSION

6.1 Objective 1-Ontario Trauma and Geographic Status

The health needs of rural Canadians are often different from those of urban Canadians. Provision of prehospital care to trauma patients in rural environments is a neglected health issue. This thesis involved a descriptive study of major trauma and related prehospital care in Ontario with a comparison among patients in four different geographic groups. Study findings showed that transport injuries were the leading causes of trauma in all four groups. Falls, homicide, and suicide attempts were the next leading causes of trauma respectively. The proportion of transport injuries victims in the large metro group and the rural group were significantly higher than that of the other two groups. The geographic pattern was reverse among fall victims. There was no significant difference in the severity of trauma among patients in four groups. With respect to times associated with emergency prehospital care, response times and transport times in rural groups were significantly longer than the other three groups; scene times in the large metro group were significantly longer. There were no significant differences in mortality in patients in the four different geographic groups. Our findings provided basic information that increased understanding of the causes and impacts of rural trauma.

6.2 Objective 2-Prehospital Intubation and Trauma Survival

In our study, prehospital intubation showed a negative association with survival among major trauma patients. This association may be due to inherent differences between the intubated and non-intubated groups although we matched on some key parameters and adjusted for others in the statistical model. The association may also be caused by the complications and the detrimental effect of this procedure, especially in complicated field environments. Prehospital services should not be maintained where they have been proven not to be beneficial. It is necessary to determine which interventions or treatments (like prehospital intubation) are actually effective in real world settings. The provision of intubation in the field for victims of major trauma may not be effective.

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Appendix A

Glasgow Coma Score

	Score
Eyes Response:	
Spontaneously	4
To speech	3
To pain	2
Never	1
Best Verbal Response:	
Orientated	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
Silent	1
Best Motor Response:	
Obeys commands	6
Localises pain	5
Flexion withdrawal	4
Decerebrate flexion	3
Decerebrate extension	2
No response	1

Appendix B

Functional Independence Measure (FIM™) Instrument

	ADMISSION	DISCHARGE	FOLLOW-UP
Self-Care			
A. Eating			
B. Grooming			
C. Bathing			
D. Dressing - Upper Body			
E. Dressing - Lower Body			
F. Toileting			
Sphincter Control			
G. Bladder Management			
H. Bowel Management			
Transfers			
I. Bed, Chair, Wheelchair			
J. Toilet			
K. Tub, Shower			
Locomotion			
L. Walk/Wheelchair			
M. Stairs			
Motor Subtotal Score			
Communication			
N. Comprehension			
O. Expression			
Social Cognition			
P. Social Interaction			
Q. Problem Solving			
R. Memory			
Cognitive Subtotal Score			
TOTAL FIM Score			

<table>
<tr><td rowspan="2">L
E
V
E
L
S</td><td>Independent
7 Complete Independence (Timely, Safely)
6 Modified Independence (Device)</td><td>NO HELPER</td></tr>
<tr><td>Modified Dependence
5 Supervision (Subject = 100%+)
4 Minimal Assist (Subject = 75%+)
3 Moderate Assist (Subject = 50%+)

Complete Dependence
2 Maximal Assist (Subject = 25%+)
1 Total Assist (Subject = less than 25%)</td><td>HELPER</td></tr>
<tr><td colspan="3">Note: Leave no blanks. Enter 1 if patient is not testable due to risk.</td></tr>
</table>

Appendix C

Description of Beale coding system

Code	Name	Description
0	Large Metro	Central and most populous census division of a CMA with a population greater than 1 million
1	Large Metro Fringe	Remaining census division(s) within or partially within a CMA with a population greater than 1 million
2	Medium Metro	Census division(s) containing, within, or partially within a CMA with a population between 250,000 and 999,999
3	Small Metro	Census division(s) containing, within or partially within a CMA/CA with a population between 50,000 and 249,999
4	Nonmetro-Adjacent	Census divisions that share a boundary with a CMA/CA and the CMA/CA has to have a population greater than 50,000
5	Nonmetro-Nonadjacent	Census divisions that *do not* share a boundary with a CMA/CA that has a population greater than 50,000

Note: Because CMA and CA boundaries are different than census division boundaries, census divisions may: (1) contain entire CMA/CAs; (2) be found completely within CMA/CA boundaries; or (3) be only partially within the territory of a CMA or CA. In all cases, the census division is classified using the Beale code that is associated with the size of that CMA/CA.