The Elements of Regionalization – An Evidence-Based Approach to the Creation and Running of Trauma Systems

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1. Contributions of Authors

This thesis is a manuscript-based thesis. However, the thesis comprises much more than the text of the manuscripts listed. Manuscripts which were used in this thesis are listed below. Muck of the work has not yet been submitted for publication. The student (Abraham M Liberman) was the principle author and investigator and was responsible for design, data acquisition, analysis and conclusions for all studies. Co-authors were responsible for student supervision, mentoring, and helped with study design and the drawing of conclusions.

1. **Liberman M,** Mulder DS, Sampalis JS. The History of Trauma Care Systems – From Homer to Telemedicine; MJM Focus: Special Forum on Trauma Care. *McGill Journal of Medicine* 2004;7(2):214-222.

2. **Liberman M,** Mulder DS, Sampalis JS. The Evidence Supporting a Systematic Approach to the Care of the Injured Patient – From Prevention to Rehabilitation; MJM Focus: Special Forum on Trauma Care. *McGill Journal of Medicine* 2004;7(2):223-237.

3. **Liberman M**, Mulder DS, Lavoie A, Sampalis JS. Implementation of a Trauma Care System: Evolution Through Evaluation. *Journal of Trauma* 2004;56:1330-1335.

4. **Liberman M**, Branas CC, Mulder DS, Lavoie A, Sampalis JS. Advanced Versus Basic Life Support in the Pre-Hospital Setting – The Controversy between the "Scoop and Run" and the "Stay and Play" Approach to the Care of the Injured Patient. *International Journal of Disaster Medicine*. 2004;2:1-9.

5. **Liberman M**, Mulder DS, Jurkovich GJ, Sampalis JS. The Association between Trauma System and Trauma Center Components and Outcome in a Mature Regionalized Trauma System. *Surgery* 2005;137:647-658.

2. Abstract (English)

Regionalized trauma systems have repeatedly been shown to improve outcomes. However, until now, we did not know which elements of these systems and to what degree these elements improve outcome. Trauma systems and the components which comprise them were originally devised based on expert opinion. They have subsequently been shown to significantly improve the outcome of injured patients in many systems throughout the world over the last thirty years. Our primary objective was to bring an evidence-based approach to the creation and running of trauma systems, based on outcomes related to specific elements which make up the structure of the systems and contribute to the process of care which make up these systems.

The series of projects which comprise this thesis have attempted to dissect trauma systems into their basic components and then attribute specific outcomes to each element in order to enable the creation of evidence-based, cost-effective trauma systems for the future. To our knowledge, this is the first study to ever look at trauma systems in this way and hence creates benchmarks for future research in this area.

Evidence-based, component-oriented analysis can be successfully applied to the evaluation of trauma care systems. Results from these analyses can be used to define variables which impact positively on outcome for injured patients and to what degree. The results of this study can be used to create new systems and update current systems in

an evidence-based manner which will lead to improved outcomes and cost-efficiency in these systems.

This is the first study to evaluate the specific elements which go into building a trauma system / trauma center. These elements were created by committees based on their experience in treating trauma patients in urban hospitals and in war-time scenarios. The creation of these systems was not evidence-based and although these systems have been shown to work and improve outcomes, we now understand which elements of these systems are responsible for the improvement in outcome, to what degree these elements contribute to improve outcome, and which elements do not.

3. Abstract (French)

L'efficacité des systèmes régionalisés de traumatologie à réduire la mortalité a souvent été démontrée. Toutefois, jusqu'à maintenant, nous ignorions quelles composantes de ces systèmes et jusqu'à quel point celles-ci amélioraient les résultats. Ces systèmes et leurs composantes étaient basés sur des opinions d'experts. L'amélioration des résultats pour les traumatisés n'a été démontrée qu'après coup dans plusieurs pays au cours des trente dernières années. Notre objectif primaire était de d'appliquer une approche fondée sur les données probantes dans la création et la gestion des systèmes de trauma, à partir des résultats de santé obtenus pour des éléments spécifiques qui composent les structures de ces systèmes et contribuent aux processus de soins.

La série de projets que constitue cette thèse tente de disséquer les systèmes de trauma en leurs différentes composantes et d'attribuer ensuite des résultats à chacune d'elles de façon à permettre la création future de systèmes basés sur l'évidence et l'efficacité. À notre connaissance, il s'agit de la première étude à examiner les systèmes de trauma de cette façon et ainsi elle crée un étalon pour les prochaines études dans ce domaine.

L'analyse des données probantes sur ces composantes peut être appliquée efficacement à l'évaluation des systèmes de soins en traumatologie. Les résultats de ces analyses peuvent être utilisés pour identifier les variables qui influencent positivement le

sort des blessés et jusqu'à quel point elles le font. Les résultats de cette étude peuvent être utilisés pour créer de nouveaux systèmes et améliorer ceux déjà en place à partir de données probantes qui mèneront à de meilleurs résultats et à un meilleur rapport coûts-efficacité.

Cette étude est la première à évaluer les composantes spécifiques qui constituent les systèmes de trauma et les centres de traumatologie. La création de tels systèmes n'était pas basée sur des données probantes et même si leur capacité à améliorer les résultats à été démontrée par la suite, nous comprenons maintenant quels éléments spécifiques sont responsables de ces meilleurs résultats, à quel degré ils le sont et ceux qui ne le sont pas.

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5. Introduction

Trauma is the leading cause of death for individuals under 45 years of age in the Western world and remains the fourth leading cause of death for all ages combined ([1],[2],[3],[4]). Approximately 0.9 million people worldwide die secondary to injury (8% of all deaths) ([5]). It is also a major cause of morbidity in both the short and long-term ([6]). Injury is also a leading cause of disability, potential years of life lost and a major contributor to health care costs ([7],[8],[9],[10]). In 1994, 8,687 people died following accidents in Canada ([11]). Approximately four times as many patients suffer severe disability related to accidents each year. Trauma is the leading cause of life years lost in North America. It is estimated that injury causes 36 life-years lost per death compared to 16 life-years for cancer and 12 years for heart disease and stroke combined ([12]). Injury also contributes significantly to morbidity, with 5.1 million productive life-years lost per year in the United States, or 9 productive life-years lost per 100 injured patients ([13]). Injury is also the number one cause of disability on children and young adults in the United States ([14]).

The cost of acute medical care for injured patients is in excess of $16 billion per annum ([15]). This represents the second largest source of medical expenditures in the United States. In addition to the health dollars spent on the acute care of injured patients, an additional $150 billion US are required to cover the annual cost due to death, disability, lost wages and taxes, and the acute medical care of these patients ([9]). From a health-economic perspective, the cost of trauma and its consequences makes the elucidation of evidence-based practices paramount. Trauma care systems have been shown to significantly decrease medical care costs. It is estimated that by extending trauma care systems throughout the entire United States, annual medical care payments could be lowered by $3.2 billion ([16]). If productivity costs due to premature death are taken into account, the total savings could total $10.3 billion.

Trauma care throughout Canada and the rest of North America has seen significant changes over the last 30 years. The regionalization of trauma care, which has occurred in some Canadian and American regions, has shifted the scope of trauma patient management from hospital-based care to a systems approach. A regionalized approach to trauma care (a trauma system) consists of the global care of the injured patient, from the time of injury until the end of rehabilitation ([17],[18]). The system provides a continuum of services encompassing four elements: [1] pre-hospital care, [2] in-hospital care [3] rehabilitation and [4] research. The ultimate goal of these systems being to get the injured patient to definitive care as soon as possible ([19],[20]). Trauma systems have been designed to render "optimal care" to injured patients. Eggold explains that the definition of optimal care implies two basic premises ([21]): One premise is that suboptimal trauma is possible and demonstrable and the other premise is that optimal care must result in reduced mortality and/or morbidity, "the sine qua non of medical progress". Furthermore, by pooling resources and avoiding duplication through a system of care within a region, cost effectiveness has been said to be assured ([22]), however, this is not always the case.

The care of injured patients is a continuum from the moment of injury, until the return to daily life ([23],[24]). Regionalized trauma care incorporates several different elements, which together make up the trauma "system". These systems have been repeatedly shown to decrease mortality and improve the outcome of injured patients in various regions throughout the Western world. However, the building blocks required to build and maintain a trauma system have been based largely on expert opinion ([25]). Even though trauma systems as a whole have been shown to improve outcome, we do not know which elements making up a system contribute to improved outcome and to what degree. Furthermore, we do not know if any of the elements of the system can be safely left out in the future running of these systems and in the creation of new systems, without affecting patient outcome.

We will attempt to answer the question of the impact of the different elements of trauma care regionalization on the morbidity and mortality of trauma patients. To our knowledge, this is the first ever evidence-based approach to the creation and running of trauma systems based on specific elements which make-up the system. Firstly, we will examine the impact of these elements in a highly regionalized Provincial trauma care system and then we will examine them in trauma systems throughout North America which possess varying levels of regionalization. We will also look at the impact of these elements on outcome in urban compared to rural trauma care areas. Furthermore, we attempt to describe the process of regionalization in the Province of Quebec from before trauma care regionalization until today and describe the evidence-based changes which were made to an evolving system and their impact on patient outcome.

6. Review of the Literature

6.1 Epidemiology of Trauma Deaths

Trauma presents a significant burden of illness. It contributes to approximately 140,000 deaths per year in the United States ([26]). Unintentional injuries account for 4.6% of deaths and 19.6% of potential years of life lost in patients younger than 65 years of age. ([27]) Accidents account for 61% of deaths due to trauma in the United States and nearly half of these deaths are due to motor vehicle accidents ([7]). Falls, occurring mostly in the octogenarian population, account for the second most prevalent portion of unintentional deaths.

Death resulting from trauma follows a trimodal distribution ([28],[23],[29],[30],[31]). These peaks were first alluded to in a report by Beebe and DeBakey in 1952 ([32]) and by Zollinger in 1955 ([33]) and later expanded on by Trunkey. The first peak of death following injury is dubbed the "immediate deaths" and occurs within seconds of injury. It accounts for 50% of trauma-related mortality. These early deaths occur secondary to lacerations to the brain, upper spinal cord, heart, aorta and other major vessels. Virtually all of these patients die and little, if anything, can be done to save them. Cales showed that 44% of trauma deaths occurred at the scene ([34]). The only way to reduce deaths in the first peak of trauma mortality is through prevention strategies and programs, as well as tougher legislation on firearms and motor vehicle traffic laws ([35]). Injury prevention and control has more immediate health and economic benefits than the prevention and control of chronic diseases ([36]).

The second peak of mortality, the "early deaths" occurs within minutes to a few hours following injury and contributes to 30% of mortality following trauma. This period has been dubbed the "golden hour" following injury ([23]). Deaths in this period are secondary to injuries which require urgent and definitve care. These injuries are time-critical and the sooner the patient receives definitive care for these injuries, the better the prognosis. Important injuries in this category include: subdural and epidural hematomas, hemopneumothorax, liver lacerations, ruptured spleen, pelvic and long bone fractures causing significant bleeding as well as injuries to blood vessels contributing to significant blood loss. These injuries require timely definitive care, usually through surgery to repair the source of blood loss or to evacuate a compressive hematoma (cerebral hemorrhage) or an interventional procedure. If these procedures are not provided promptly and properly by the appropriate personnel and in the appropriate setting, the risk of death increases substantially.

It is for the patients in the second period of trauma deaths, that systematic trauma care is expected to make an impact. These are the major trauma patients, in need of definitive and appropriate care in a timely manner. Patients receiving rapid transport to hospital, will not have good outcomes, if they are taken to the wrong hospital. Patients taken to the right hospital, will also have poor outcomes if there is a delay in getting them there. The second peak is the focus of trauma systems and regionalized care of the injured patient.

The third peak of mortality following trauma, the "late deaths" occurs several days or week following injury. These deaths account for approximately 20% of deaths after injury. Deaths in this period are usually secondary to sepsis and multiple organ system failure. Rapid and appropriate care can reduce these injuries, however most of these deaths will occur regardless of the system of trauma care and the key to reducing them lies in research into systemic mediators of sepsis and multiple organ dysfunction. Time is less of a factor in the outcome of these patients, rather the quality of medical care and the state of medical knowledge contribute to outcome in these patients.

Recently researchers have identified a fourth peak of trauma deaths which requires further study. The fourth peak of deaths are those that occur in the first year following injury ([37]). The age characteristics of this unique group of patients show that patients over the age of 65 have a 15-fold greater chance of dying in the year following injury.

6.2 Long-Term Consequences of Injury

Improvements in trauma care realized through the implementation of integrated regional trauma care systems, technological innovations and advances in medical knowledge and surgical expertise, have resulted in significant reduction of trauma related mortality. This has led to an increase in the population prevalence of individuals who have survived an injury, and have returned to the community with various degrees of functional capacity. The point of entry of a surviving trauma victim into the health care system occurs at the time of injury, which is an acute event of sudden onset, and the exit is effectively at the time of discharge from acute or long-term care. However, there is now evidence that significant effects of injury are carried over for much longer. As a result, this patient population of trauma survivors may have continued needs for health care resources that may not be met. The consequences of such unmet needs may be increased morbidity, health care utilization, costs and mortality.

For years, the main trauma outcome interest in both the clinical and research setting has centered on mortality. It is only in recent years, as outcomes for injured patients have significantly improved, that morbidity and quality of life have come into the spotlight. The improvements in post-injury survival seen throughout the Western world have occurred secondary to a combination of factors. Improvements in transfusion technologies, resuscitation strategies, and surgical technologies have led to improved survival following injury([38]). The second important advance has occurred secondary to the systematic approach to the care of the injured patient using systems of regionalized trauma care([39],[40],[41],[42]). The regionalized approach to systematic trauma care has been shown to not only positively impact on the survival of injured patients, but also on their quality of life([43]).

Injured patients often suffer long-term physical([44]) and psychological([45],[46]) disabilities following trauma. These deficits lead to decreased quality of life and significantly impact on both activities of daily living and patients' ability to return to work. Patients and families often suffer significant physical, emotional and financial disruptions following severe traumatic injury([47]). These disruptions occur in both the short and long-term. Quality of life is a measure of the impact of disease, treatment and level of recovery on patients' lives. It is also essential in terms of determination of the cost-benefit ratio of treatment strategies.

Following severe traumatic brain injury, many patients have severe functional disabilities. Psychological sequelae of injury are well documented and have been repeatedly shown to affect patients' psychological status, especially following head injury. However, the long-term physical consequences and impairments resulting from trauma have been less extensively studied.

At twelve months following severe head injury, in regions with advanced rehabilitation programs, only 10% of patients have been shown to be completely or partially dependent on others to provide care and unable to carry out activities of daily living([48]). These same patients, however, were suffering from marked behavioral and sensorimotor deficits. Approximately 50% of patients suffering severe traumatic brain injury were able to work without restrictions or had returned to work([48]). Butcher reports that among patients who were previously working and suffered severe lower extremity injuries, one fifth (18%) had not returned to work at 30 months post injury([49]).

Studies have shown that even minor injuries can result in significant long-term psychological impairments([50],[51],[52],[53]). Among 507 patients injured in motor vehicle collisions in Oxford, England, 76% were minor, however, 26% of patients reported psychiatrically related symptoms and 21% reported moderate or severe pain related to the accident at three years post injury([46]). Furthermore, prevalence of psychological consequence of injury and psychological consequences relating to everyday life did not improve over three years. These outcomes were unrelated to the severity of injury. The evidence also shows that post-traumatic stress disorder, anxiety and lifestyle limitation can last for prolonged periods following injury([50],[54]). Minor head injuries have also been shown to be associated with an especially high risk for prolonged general disability([55]).

The relationship between age and long-term health related quality of life following trauma is an important issue. Injured children (ages 8-15 years) have reasonable good quality of life scores at two and a half years following injury([56]). This is in stark contrast to the geriatric population, who demonstrate significant long-term residual disability in quality of life scores([57]). Furthermore, amongst elderly patients, those older than 80 years old have worse functional outcomes than those between 65 and

80 ([58]). Oreskovich showed that only 7 out of 100 consecutive trauma patients over 70 years old were independent for their activities of daily living at one year post injury, compared to 96 patients pre-trauma ([59]). Seventeen (20%) of these patients required home assistance following discharge from hospital, whereas 61 patients (72%) required full nursing home care.

Predictors of poor functional outcome following trauma include: age([60]), gender([61],[62],[63]), major in-hospital complications([64]), injury severity([60],[65]), poor social support([66]), length of stay([67]), extremity injury([68],[49]), penetrating injury([69]), assault([69]), lack of emotional support([63],[70]), post injury depression, post traumatic stress disorder([69]), and intensive care unit stay([68]). Quality of life for families of victims and the needs of families following trauma are also important long-term issues in the global care of the injured patient([71]). We found that head injuries and motor vehicle collisions were associated with worse psychosocial function, and that increasing injury severity was associated with worse physical function at one year following injury. Age and gender were not associated with differing functional outcomes.

In terms of quality of life following injury, Girotto found that complex facial fractures were associated with significantly worse QOL (as measured by SF-36) compared to matched trauma patients without facial fractures at long term (3 to 12 years) follow-up following injury([72]). Facial injuries often involve high impact and may affect patients' vision, hearing, speech and ability to eat. We did not observe poorer quality of life scores for patients with facial fractures compared to other body regions injured.

We have performed a prospective cohort study which described the functional status measured by the Sickness Impact Profile (SIP) ([73],[74],[75]) and quality of life measured by the Medical Outcome Study Short Form-36 (SF-36)([76]) twelve months following injury of Quebec patients having sustained mild or moderate injuries. One hundred and forty-four patients fulfilled inclusion/exclusion criteria.

Significant independent adjusted associations were observed between physical function and older age (p=0.035); social functional and head or neck injuries (p= 0.004); physical role and thoracic injuries (p= 0.076); emotional role function with treatment in the ICU (p=0.077); and motor vehicle collision (p=0.071); between mental health and surgery (p=0.033); and head or neck injuries (p=0.045); between energy/fatigue and burns (p= 0.097). These results have shown that patients surviving mild or moderate injuries and treated at level I (tertiary) trauma centers experience resilient impairments in functional capacity and quality of life for as long as one year after injury. These findings would support the need for increasing continuity of care for these patients that extend beyond the acute injury phase and medical/surgical spectrum with a definite need for rehabilitation and psychological care. The proposed program of research will continue this line of investigation.

In Quebec, we have shown that quality of life is not affected by injury severity, except in terms of energy and fatigue, at one year post injury([77]). This is important in that for patients surviving mild to moderate injury, the severity of their injury does not appear to be the factor that determines their QOL at one year. Instead it appears that the body regions injured (thoracic and head injuries being the most important) are important predictors of long term QOL. Colantonio observed similar results in terms of head injury patients at five years following injury([78]). By elucidating important elements of trauma care systems, we aim to not only improve survival outcomes, but also post-injury quality of life for surviving trauma patients.

6.3 History of Regionalization of Trauma Care

6.3.1 Ancient Systems of Trauma Care

The systematic and organized care of injured patients was borne in times of war throughout history ([79]). In one of the earliest human writings, Homer in the *Iliad*, refers to the treatment of the injured patient during the Trojan war (5th century BC) ([80]). Homer reports a 77% mortality rate from injury in the war among 147 wounded soldiers. Surgical care of these injured soldiers was poor compared to the advanced techniques of today. However, the ancient Greeks recognized the importance of systems of trauma care. Injured soldiers were transported to and treated in specialized barracks called *klisiai* or transported to offshore ships for treatment of their wounds.

Hippocrates believed that the care of traumatic injuries during war was the ideal school for surgeons. The earliest documentation of a rudimentary trauma system is the description of medical care for the Roman Legions in approximately 100 AD ([18]). The Romans had organized on-site first aid and ambulances and surgeons were on-call 24-hours a day. The trauma care hospitals (*valetudinarian*) were strategically located near every important encampment and were fairly sophisticated in design and concept ([35]).

6.3.2 Napoleonic Era

Dominique-Jean Larrey (1766-1842), a Frenchman, was probably the pioneer of systematic trauma care ([81],[82]). When international war broke out in 1792, he became a field doctor in the Rhine army. While waiting in Strasbourg for action, he organized a military medical association. Once the fighting erupted, it didn't take him long to realize that an organized system was needed in order to save more soldiers. He wrote:

> *"I now discovered the trouble it took us to move our bandaging stations – our military hospitals. According to the rules, they were supposed to stay about five kilometers from the army. The wounded were left on the field until the battle was over, or gathered at some convenient spot to which the ambulance rushed. But the roads were so choked with wagons, and such delays arose, that most of the victims died before the ambulance arrived. This gave me the idea of building an ambulance that was adequate to help the wounded during the actual battle."*

Following a battle at Limburg in which the conditions were awful and casualties high, Larrey wrote to the General with a proposal, he later wrote of this proposal:

> *"My suggestion was accepted and I received orders to construct a cart which I called the flying ambulance. My first plan was to transport the wounded on a horse-litter, but experience soon made me give it up. The*

next effort was to make a cart with good suspension, combining speed with safety and comfort."

Previously, wounded soldiers were left on the battlefield until the fighting ended for the day. Larrey's ambulance could evacuate these soldiers soon after injury. The ambulance carried a doctor, quarter-master, noncommissioned officer, twenty-four infantrymen, and a drummer-boy who carried the bandage kit. He replaced the saddles' pistol holders with courier bags full of instruments and bandages. Larrey's "flying ambulance" was a big success. In April of 1793, Larrey was sent back to Paris with orders to arrange flying ambulances for the whole army. For his skill and efforts, Napoleon made him a Baron and the French Army's Surgeon General. Napoleon said of him; "*he is the most virtuous man I have ever known.*"

Military hospitals were designed to concentrate the injured soldiers in one area and operate on them as soon as possible following injury. Larrey realized the importance of the time to definitive care on outcome and arranged to establish his military hospitals as close to the battlefields as possible. Larrey, not only organized to have the wounded evacuated from the battlefield and brought promptly to treatment centers, but was also a pioneer in expanding the role of the military surgeon to encompass all aspects of patient care ([83]). He was the first to realize the importance of the surgeon in organizing all aspects of the care of the injured patient – the first "trauma system". He worked to improve sanitation, procurement of food and supplies for the sick and wounded, training of medical personnel as well as the rapid evacuation of the wounded from the battlefield.

6.3.3 Civil War

The American Civil War was another important step in systematic care of the injured patient. The large number of casualties, primarily due to the advances made in firearms, forced the creation of an extensive infrastructure in order to support the surgeons on the battlefield and care for the injured ([79]). A major advance in the systematic approach to trauma care came after the war, when the Union published 'The Medical and Surgical History of the War of the Rebellion', in a six volume set ([84]). This national publication reported the epidemiology of injuries and mortalities which occurred during the rebellion. It also explained the techniques and system elements that were employed throughout the war.

During the war, hospitals were strategically located near creeks in order to provide water which was vital to the care of the injured soldiers. When numerous regimental hospitals were involved in a single battle, they banded together to form a single brigade hospital. The subsequent level of treatment center was the division hospital and the last line, the general hospital ([79]). The Union soon recognized the deficiencies in their system of care. The small regimental hospitals were inadequate to care for the wounded. When the regiment displaced, these hospitals could not move with the regiment and transfer all the injured soldiers. This forced the establishment of independent hospitals that could receive the injured soldiers after the regiment relocated. These new hospitals were called "general hospitals", were permanent, and were able to accept the injured from the front line hospitals following displacement of the regiment ([79]).

6.3.4 World War I

Mechanical advances were responsible for improvements in trauma care in World War I. These advances allowed for field ambulances to become motor driven, instead of horse-driven as they had been in previous conflicts. Timely evacuation of wounded soldiers occurred through "*echelons of treatment facilities*" ([85]). Each echelon, with a greater treatment capacity was established as a standard protocol. The first tier was the evacuation of injured soldiers from the frontlines by corpsmen and stretcher bearers. Initial treatments of the wounded men were administered at battle aid stations near the battlefront. At these stations, the injured were administered narcotics, external hemorrhage was controlled and fractures were splinted. Seriously wounded men were then evacuated to clearing stations where surgeons performed emergency surgery which consisted mostly of the debridement of wounds. Soldiers that survived were then transported to evacuation hospitals located at safe distances from the battlefields. Definitive care was delivered at these centers and patients convalesced with the ultimate goal being to return them to the front lines. This system of escalating echelons of trauma care became the foundation for modern day civilian trauma systems. Due to the huge numbers of casualties seen in some areas, the concept of triage was born. Injured patients were sorted based both on priority and salvageability.

6.3.5 World War II

Emergency medical services in Britain were instituted under the direction of the Minister of Health for both civilian and British Forces in 1940 ([86]). The British government realized that there would be mass civilian casualties during the war and therefore the War Office and the Minister of Health agreed to pool resources in order to create a system of trauma care that made no distinction between military and civilian casualties. At the outbreak of war it was estimated that approximately 300,000 hospital beds would be needed to treat casualties and therefore civilian hospitals and civilian physicians and allied health professionals were selected and enrolled into the British Emergency Medical Service. Furthermore, there were specific detailed guidelines established for the organization of trauma centers, their location and corridors for pre-hospital transport and triage as well as mobile surgical teams which could be displaced close to the areas of casualties. Trauma centers were classified based on resources for the first time in history (Adapted from – Bailey H; *Surgery of Modern Warfare*, 1942, Vol. II p.917([86])):

- Class 1A – Hospitals of over 50 beds in which full surgical facilities are available.
- Class 1B – Smaller hospitals in which there are good surgical facilities.
- Class 2 – Hospitals suitable for the treatment of convalescent surgical and chronic medical cases. In certain cases some of these hospitals were upgraded.

- Class 3 – Infectious Disease hospitals, which were kept available for their peace-time use.
- Special Hospitals – Many well-equipped special hospitals were classified between 1 and 2. In some cases they were reserved for peace-time use (e.g.: maternity, children's and mental facilities)

In World War II, the immobile medical units which were used in WWI by the United States could not keep up with the fast pace of movement of troops. This need gave birth to the "*AUX units*" which were composed of special surgical teams which traveled to the front lines in order to treat wounded soldiers. Furthermore, the advent of air travel allowed for the evacuation of wounded patients by plane during the WWII conflict, which had not been previously used in war time situations.

The passage of patients through the echelons of care established in WWI became quicker and more efficient ([85]). Time lag to definitive treatment was shown to have a negative impact on survival in thoracic and abdominal wounds, as well as in extremity fractures ([32],[87]). Trueta recognized and wrote that: "*surgical aid to casualties in the frontline is impeded by many factors and has to be adapted to varying conditions, but the main basis of success is to have the wounded patient on the operating table at the earliest possible moment*" ([87]). In WWI, the time from injury to definitive care ranged between 12 and 18 hours. This was decreased by 50% in WWII ([79],[23]). The improvements in time to definitive care as well as the advances in antisepsis, shock resuscitation, transfusion and surgical technique contributed to significantly improved survival rates for injured patients. The many civilian physicians, surgeons and anesthesiologists who were drafted into service in WWII observed the benefits of the systematic approach to trauma care and brought back high expectations to their civilian communities in North America ([85]).

6.3.6 Korean War

The AUX units of WWII were the root of the MASH units (Mobile Army Surgical Hospital units) used in the Korean conflict. The MASH unit was a mobile surgical hospital comprising 60 beds which operated to the rear of the combat area, however just out of range of artillery fire. Injured soldiers no longer had to endure multiple transportations before receiving definitive care, instead they arrived at definitive care centers often within the "golden hour" of trauma care ([38]). The introduction of air ambulances and helicopters were also a major advance in the timely care of the wounded in Korea. The Korean War was the first time in military history that the helicopter was used extensively to evacuate casualties from the forward battle fields to supporting medical facilities ([88]). These transport mechanisms reduced the time from injury to definitive care to between 2 and 4 hours and mortality was only 2.4% ([79],[35]).

6.3.7 Vietnam

The Vietnam War saw the treatment of 250,000 casualties ([89]). In Vietnam, due to the mountainous terrain and the consequent difficulty in evacuating injured soldiers, the helicopter was utilized extensively as a part of the pre-hospital arsenal ([90],[91]). The first helicopters used for evacuation of injured soldiers had two pods on the outside of the aircraft on either side for evacuation of injured soldiers from the front lines to the awaiting MASH units. The classic pattern of casualty evacuation from previous conflicts was revised in Vietnam. The battalion and regimental aid stations, which had formerly been the first line of surgical care by a physician, were being systematically overflown by the medical evacuation helicopters in Vietnam and landing in an area where definitive care could be rendered. This was either a unit from a medical battalion, a mobile surgical hospital, a field hospital, an evacuation hospital, or a hospital ship awaiting offshore. These helicopters further decreased time to definitive surgical care to between one and one and a half hours ([90]).

Pre-hospital time for patients treated at the U.S. Navy Hospital in Da Nang were reported to be only 80 minutes ([92]). In WWII, it often took four to six months from the time of injury to get an injured soldier back to the United States by hospital ship. Due to improvements in transportation as well as the newly orchestrated evacuation and treatment system, soldiers injured on the battlefields in Vietnam would often arrive at the Naval Hospital, Great Lakes Illinois within 72 to 96 hours from the time of injury ([93]). The significant advances in both the systematic care of the injured patient, as well as the improvements in surgical, transfusion related and antimicrobial technology resulted in decreases in mortality for patients reaching medical facilities from 8% in WWI to 4.5%

in WWII to 2.5% in Korea and to less than 2% in Vietnam ([94,95,96]). Average times to definitive care were: 10 hours in WWII, 5 hours in Korea and 1 hour in Vietnam ([95]). The advancements in medical and surgical treatments, the advent of widely available helicopter and airplane evacuation and the decreased time from injury to definitive care allowed the US medical forces to save 98% of casualties in Vietnam, compared to 94-96% in WWII ([93]).

6.3.8 Civilian Trauma Care Systems

The civilian interest and the move towards the regionalization of trauma care in the United States was secondary to the U.S. military experience with organized trauma care ([97,87]). The care of the injured patient evolved and improved significantly in World War II and was further developed during the subsequent Korean and Vietnam wars. It was the Korean and Vietnam conflicts that provided the basis for civilian regionalized emergency medical and trauma systems ([95]). Civilian trauma providers learned about well-trained paramedical personnel providing care in the field, effective pre-hospital, in-hospital and pre- to in-hospital communications, rapid emergency evacuation and transport systems (helicopter evacuations), and specialized "trauma surgeons" working out of specially designed "trauma centers" or MASH units. These advances in the care of the injured patient contributed to a 97.5% survival rate for patients in Vietnam who reached treatment facility alive.

In the early 1960s more Americans were killed annually on the nation's highways than were killed during the entire Vietnam conflict ([98]). In the United States, until the late nineteen-sixties and early nineteen-seventies, trauma care mostly occurred in the city and county hospitals or at the hospital nearest to the scene of the accident ([99]). The hospitals receiving trauma patients were ill-equipped and staffed to handle injured patients and pre-hospital care consisted of poorly trained personnel with little equipment ([100]). During peak hours and at night these emergency rooms were often staffed with the most junior or unprepared physicians or poorly trained "moonlighters". In the ambulance, there was often only a driver with little emergency training and the patient would be transferred unattended in the back of the ambulance to the nearest hospital. Radios were rarely available in ambulances, and when present they were mainly used to monitor police transmissions in order to try and pick up accident calls and arrive early on-scene. Rockwood recalls that in some cities throughout the US, animals received better emergency care than citizens. They had radio dispatched vehicles and well-trained personnel available for emergency calls for pets. Trauma mortality was often due to late, inadequate or unrecognized surgical emergencies ([101],[102],[103]).

In the early 1960s, a slew of studies were published demonstrating excess mortality following trauma in non-regionalized areas. In 1961, Van Wagoner studies 606 non-combat military deaths and concluded that one sixth (103 cases) of these were from injuries from which recovery could normally be expected and another one sixth from injuries which received inadequate care (96 cases) ([104]). This was the first published report attempting to assess preventable deaths among injured patients occurring in a non-regionalized system of care. This paper opened the eyes of healthcare providers to the poor and inadequate care that injured patients were receiving and began a movement towards establishing an effective system to prevent these needless deaths.

Following the study by Van Wagoner, Frey was able to show that out of 159 patients dying as a result of trauma in Michigan, which lacked a regionalized trauma system, 28 received inappropriate care ([105]). Gertner demonstrated that one third of deaths involving abdominal trauma following motor vehicle collisions in Baltimore, a non-regionalized area, were preventable ([106]) and Moylan showed that quality of care in hospitals treating trauma patients in five hospitals in Wisconsin was unacceptable in 16% of seriously injured patients ([107]). These preventable death studies and other reports showing excess mortality in various areas throughout North America have been vital in the move toward regionalization in respective regions ([108]).

The realization by the US government of the toll that trauma was taking on society and particularly young society in terms of morbidity and mortality as well as the "*ineffective nonsystems*"([94]) of trauma care led the National Academy of Sciences to dub injury the "*neglected disease of modern society*" ([109]) in the sentinel report prepared by the Committee on Shock and Trauma of the National Research Council. This report was titled: "*Accidental Death and Disability: The Neglected Disease of Modern Society*" and nicknamed the "*white paper*". Many important and revolutionary recommendations were made which shaped trauma systems as we know them today, including: pre-hospital radio communication systems, categorization of hospitals, the development of trauma registries, implementation of hospital trauma committees, calls for research into clinical areas of trauma care and in the areas of shock and resuscitation, and injury prevention strategies. Following this vital paper, many were convinced that injury was indeed a neglected disease and that it would continue to negatively impact on society if change was not brought about. By the early 1970s, many influential members of medical society believed that lessons learned on the battlefields in Korea and Vietnam in terms of triage, rapid transport of trauma patients to definitive care centers, and standardization of pre-hospital and in-hospital care could be applied effectively to civilian trauma patients ([110]).

The "White Paper" published by the National Academy of Sciences / National Research Council (NAS/NRC) Committees on Shock and Trauma in 1966; "*Accidental Death and Disability: The Neglected Disease of Modern Society*" ([109]) formed the basis for modern EMS systems and trauma care advances. It is considered by most to be the inaugural event in what has become a sustained effort by the U.S. government to address the disease of injury on the American population([85]). This document addresses the important burden of injury on society and highlights the impact of trauma on mortality and disability in America. It further attempts to solve the "neglected epidemic" of injury in America. However, the lack of emphasis regarding the concept of the "trauma system" was a major deficiency of the report ([97]). The report does not emphasize methods and approaches to providing the global care of the injured patient. Twenty-nine recommendations for improvement of care were proposed, however, there were no provisos for the system which would integrate these recommendations and bring them to life. This crucial step would be taken care of, not through governmental agencies, but through revolutionary EMS and trauma programs in select areas of the United States.

Accidental Death and Disability did however contribute significantly to what we today consider standard elements of trauma care. It highlights the importance of standards of care, protocols for pre-hospital care providers, credentialing standards for EMS providers, improvements in accident prevention, emergency first aid and medical care, ambulance services, emergency medical communication, use of air evacuation by helicopter, upgrading emergency departments, improvements and expansion of intensive care units to properly deal with injured patients and specifications for the construction of ambulances. It also called for rapid definitive care of injured patients in the hospital setting and suggested specialized physicians specifically trained and ready at all times to take care of injured patients. This recommendation later was integral in the establishment of a new specialty in medicine – Emergency Medicine. A strong case was made for the development of a system of trauma patient care, as well as a system of subsystem components essential to the success of an overall effective effort ([94]). For the first time the concept of varying levels of trauma care was born. The document called for the credentialing of four different levels of hospitals to treat trauma patients and suggested that outside credentialing agencies be designated to assign these categories. One of the most important and revolutionary recommendations made in the report was that hospitals and hospital staff be accountable for the outcomes of patients under their care. The creation of trauma registries and outcome analysis, including autopsy studies were therefore born.

Based on the recommendations of *Accidental Death and Disability*, United States Congress enacted the *National Highway Safety Act of 1966.* This legislation mandated the Department of Transport to decrease motor vehicle accident deaths, research to be done into car safety devices, coordination of pre-hospital care and the establishment of pre-hospital communication.

In 1971, United States Congress proposed a law consisting of program guidelines and technical assistance measures in order to create a nationally coordinated and comprehensive system of regionalized emergency accessibility and care for all American citizens ([97]). This led to the Emergency Medical Services Act of 1973 ([111]). The Act enabled the federal government to designate a lead agency role to the Division of Emergency Medical Services in order to develop regional comprehensive emergency medical service (EMS) systems. It also provided financial aid to states for the coordination of EMS activities ([112]).

The first civilian trauma units were established in 1966 at Cook County Hospital in Chicago and at San Francisco General Hospital in California ([79,113,114,115]). The first regionalized trauma system was in established in Illinois in 1971 ([94,97,116,117,118,119,120,121]). Lowe and Baker explained that the "team approach" to trauma care was of paramount importance in establishing this system of treating injured patients, which encompassed access to the system through rehabilitation ([113]). Hospital designation, triage and transport guidelines as well as the concept of a "burn center" were put into place. For the first time, a central bed registry and a patient distribution and triage program was established. In Illinois, there was an eight percent decline in highway mortality in the first 6 months of 1972 (following regionalization) compared to the same six month period in 1971, prior to regionalization ([121]). This decrease in injury related mortality was observed in spite of an increase in highway accidents and injuries during that same period. In 1973, R. Adams Cowley expanded the existing Shock-Trauma program at the University of Maryland to encompass the entire state and established the Maryland Institute for Emergency Medical Services (MIEMS) ([122],[123],[124],[125]).

By 1974, only 2 states (Maryland and Illinois) had established emergency medical systems with integrated organized trauma services within these systems. However, in 1974, the trauma system concept took off and slowly, many communities started to organize trauma care. There was however, little civilian outcome data demonstrating a positive effect for systematic trauma care at that time.

Waters reported a 38% reduction in motor vehicle accident mortality following introduction of a regionalized trauma system in Jacksonville, Florida ([126]). This was one of the first reports showing a beneficial effect on patient outcome with a systems approach to trauma care. The system included an emphasis on pre-hospital care, well trained pre-hospital crews, rapid response times and improved pre-hospital communication.

In 1976, the American College of Surgeons Committee on Trauma ([127]) assumed the leadership role in trauma system development with the publication of the first edition of *Optimal Hospital Resources for Care of the Seriously Injured* ([128],[129]). For the first time in 1977, Detmer et al. defined the four categories of hospitals designated as trauma centers which were to become the basis of today's level I, II, III and IV centers ([130]). More equipped centers were shown to have significantly less unacceptable care compared to less equipped, or lower level centers.

6.3.9 West and Trunkey Revolutionize Trauma Care

The first and landmark study critically evaluating civilian regionalized care for injured patients and comparing a regionalized to a non-regionalized area was published by West, Trunkey and Lim in 1979 ([131],[132]). This remarkable and original study was responsible for a new field of healthcare and health services research. They retrospectively studied one hundred consecutive motor vehicle fatalities in two counties (San Francisco and Orange County) in California between 1974 and 1975. The injured patients in San Francisco County were taken to a single trauma center and the patients in Orange County were transported to the closest receiving hospital (39 hospitals receiving injured patients). They excluded patients who were transferred from other facilities where they had received care prior to treatment in the study hospitals and patients who died prior to reaching hospital. Deaths were classified as clearly preventable, potentially preventable and not preventable by an expert panel.

Patients in Orange County were significantly younger and had injuries of lower severity than patients in the San Francisco County cohort. A panel of experts deemed that thirty-seven percent (11/30) of non-CNS related deaths in the Orange County cohort were judged to be clearly preventable compared to none in the San Francisco County cohort. Another 37% (11/30) of deaths in Orange County were judged to be potentially preventable, compared to only one death in San Francisco. This study was the first to begin to shed light on the importance of specialized, early definitive care of trauma patients and the magnitude of bringing injured patients directly to appropriately staffed, experienced and equipped care facilities.

Orange County was regionalized in 1980. Following the study by West, a complementary autopsy study ([133],[134]) was performed on patients injured in motor vehicle collisions in Orange County before and after trauma care regionalization ([135],[34],[136]). Cales retrospectively evaluated the outcomes of patients following implementation of a regionalized trauma system in Orange County by reviewing trauma deaths via an expert panel. This was the first ever before and after study of regionalized trauma care and served as a standard to which numerous subsequent studies would be compared. Fifty-eight deaths occurring prior to regionalization were compared to 60 deaths occurring following implementation of a trauma system. Potentially preventable death rates dropped from 34% prior to regionalization to 15% following regionalization ($p<0.02$). Fifty-four percent of potentially preventable deaths occurred in patients transported to non-trauma centers, compared to 4% of patients transported to trauma centers. They also found that the death rate from vehicular trauma dropped from 15.7 per 100,000 population to 13.9 per 100,000 ($p < 0.03$) in the first year following regionalization and from 15.8 per 100,000 to 12.4 per 100,000 after 2 years of regionalization ($p < 0.02$). These remarkable and convincing results were strengthened due to the fact that the patients in the post-regionalization cohort had higher Injury Severity Scores (ISS) and median age compared to those in the pre-regionalization cohort. The improvement in outcomes was in part attributed to the aggressive approach to the care of the traumatized patient following regionalization which was suggested by an increased percentage of patients who received surgical interventions ([136]). Even though there has been some debate over the statistical methods (i.e. preventable death rate analysis) used to demonstrate efficacy in the early studies of trauma systems ([137],[138],[139],[140],[141],[142],[143]), these results are not only impressive, they also are responsible for the changes in trauma care occurring over the following 30 years.

The studies out of Orange County disclosed to the public, for the first time, the problem of inadequate trauma patient care due to the absence of a system. Backed by public demand, governments and healthcare authorities were forced to be accountable for trauma outcomes to the public. The scientific evaluation of trauma systems and their impact on society by West and Trunkey from the 1970s are unparalleled in terms of both their originality and impact on trauma care systems. These studies are the basis of modern systematic trauma care as we know and take for granted today.

6.3.10 Advanced Trauma Life Support

A sentinel paper in the Bulletin of the American College of Surgeons in 1967, 'Death in a Ditch' by Dr. JD Farrington was the first to highlight the importance of training and protocols for pre-hospital care workers ([144]). This course was designed and implemented in Minocqua, Wisconsin. Standardization of training, protocols and equipment required in ambulances were in introduced and implemented.

Prior to 1980, there were no standardized protocols or programs to train physicians in the appropriate care of the injured patient. In 1976, an orthopedic surgeon from Nebraska initiated the Advanced Trauma Life Support (ATLS) Course for training physicians in trauma care, after his wife and 3 children were killed when he crashed his plane ([145]). The care that his injured wife and children received was poor and this motivated the surgeon to create a course in order to train physicians with little chance to practice trauma treatment skills in the acute management of injured patients. This course was revised and adopted by the American college of Surgeons Committee on Trauma in 1979. It has since become an international standardized trauma training program, further contributing to the standardization of trauma care across regions.

6.3.11 Modern Day Trauma Systems

In 1985 and 1988, the Committee on Trauma Research of the National Research Council and the Institute of Medicine published "*Injury in America, A Continuing Public Health Problem*" ([146]) and "*Injury Control, A Review of the Status and Progress of the Injury Contro, Program at the Centers for Disease Control*" ([147]). These reports were a follow-up to the *white paper* and looked at the progress that had been achieved since 1966 in trauma treatment and prevention and made extensive recommendations regarding the future of trauma care and trauma systems. These recommendations were based on the extensive body of scientific evidence which had surfaced since 1966 regarding trauma system effectiveness. The committee stated that trauma was a public health problem whose toll was unacceptable. They called for the nation to address the problem through research and legislation. The challenge proposed in *Injury in America* was to establish injury prevention and treatment as a recognized interdisciplinary field of scientific evaluation and ongoing research. The 1985 report was again expanded on and reassessed in 1999 in the report put out by the Institute of Medicine; "*Reducing the Burden of Injury - Advancing Prevention and Treatment*" ([148]). This report re-emphasized the point which had been highlighted previously in *Accidental Death and Disability*, *Injury in America* and *Injury Control* that the investment in injury research in the United States did not balance the magnitude of the problem of injury. It further emphasized the positive impact of systems of trauma care on the outcome of injured patients and called for the development of more trauma systems throughout the country.

Trauma systems and regionalized trauma care has seen multiple changes and improvements over the years (Figure 2). Future challenges include the identification of specific components of trauma systems and their impact on outcome, as well as the extension of the excellent results demonstrated in urban areas to the rural setting. The advent of telemedicine promises to improve trauma care in these rural and often inaccessible areas, however further research in this area is required ([149],[150],[151]). Furthermore, aircraft (helicopter and fixed wing) are being used to transfer critically injured patients from rural centers to urban tertiary trauma centers.

6.4 Process of Regionalization, Building a "Trauma System"

The basis for the regionalization of trauma care or the development of a "trauma system" is the need to link all aspects of trauma care in order to maximize efficiency, pool resources and improve outcomes. A comprehensive trauma system links hospitals, pre-hospital care and other emergency medical services, post hospital care facilities (rehabilitation and long-term care centers), as well as health care and public safety agencies ([152]). Ideal trauma systems includes prevention, access, acute hospital care, rehabilitation, and research activities ([153]). These systems have been developed in order to direct seriously injured patients to specific facilities on local, regional, and state/province wide bases. The two main purposes of regionalized trauma care are to improve the quality of care and to decrease its cost ([154]).

Prior to embarking on development and implementation of a new trauma system, a regional needs assessment should be performed. This is vital to effective planning of a system and the addressing of regional needs ([155],[131],[156]). Following an in-depth needs assessment, a specific sequence of events must be followed: (1) establish authority; (2) develop trauma criteria; (3) democratize the process; (4) obtain outside review and verification; (5) formalize designation; and (6) ensure viability through assessment of ongoing needs and quality assurance ([18],[153]). Various authoritative authors and associations have published guidelines and recommendations regarding the specific process of regionalization ([157],[153],[123],[158]).

The American College of Surgeons Committee on Trauma clearly outlines the importance of emphasizing the trauma system, rather than the trauma center as being integral in improving trauma patient outcome ([153]).

> *"Care of the injured patient requires a system approach to ensure optimal patient care. A systematic approach is necessary within a facility; however no one trauma center can do everything alone. Thus, a system approach is necessary within an entire community regardless of its size...If resources for optimal care of the injured patient are to be used wisely, then some concentration of resources should occur. This type of resource allocation should allow patients to move to the highest level of care available and, ideally, should also avoid excessive and inappropriate expenditure in a time of limited medical resources."*

Integral to the trauma care system is the designation of definitive trauma care facilities. These facilities provide the full spectrum of trauma care to injured patients in the most efficient and effective manner. The overall goal of the system is patient care and outcome, however efficiency and proper use of resources is emerging as an important aspect of trauma systems. Every trauma system or regionalized trauma area should have a "lead hospital". The lead hospital should be the hospital with the highest level of care (highest designation) in the area. In highly populated urban areas the lead hospital is usually the level I trauma center, however, in systems with decreased population density, level II or III centers may serve as the lead hospital. The basic structure and requirements for trauma center designation are outlined in Tables 1 and 2 (adapted from: *Resources for Optimal care of the Injured Patient: 1999:* American College of Surgeons, Committee on Trauma, 1998)([153]).

West identified eight essential elements which were integral to an inclusive trauma system based on criteria from the American College of Surgeons ([123]). These criteria were: (a) the presence of a lead agency with legal authority to designate trauma centers; (b) the use of a formal process for trauma center designation; (c) the use of American College of Surgeons standards for trauma centers; (d) the use of an out-of-area survey team for trauma center designation; (e) limiting the number of designated trauma centers in a community based on assessment of population need; (f) the application of written triage criteria that form the basis for bypassing non-trauma center hospitals; (g) the presence of ongoing monitoring systems for trauma centers; and (h) the state-wide availability of trauma centers. The integral steps in developing a regional trauma system are ([123]):

6.4.1 Basic Data

The first step is defining the magnitude of the problem in the area to be regionalized. This can be carried out using autopsy studies ([133],[134]), preventable death studies ([137]), regional trauma reviews ([159]), and/or epidemiologic studies. Out-of region experts should be recruited in order to provide objective assessments of the system in place. Limitations of these methods are discussed in section 7. – “The Problem”.

6.4.2 Develop a Comprehensive Regional Plan

The regional plan should deal with patient care from the time of injury until the end of their rehabilitation. It should be based on guidelines from the American College of Surgeons ([157],[160],[161]) and have local surgeons heavily involved in planning and development.

The plan should address the following issues:

- Pre-hospital Care
- Air Transport
- Triage
- Trauma Center Designation
- Quality Assurance
- Specialty Care Programs
- Research
- Rehabilitation
- Prevention and Public Education
- Disaster Planning

6.4.3 Identify Barriers to Change

By identifying barriers to changes prior to attempted implementation, a young system can develop strategies to overcome these changes. The major barriers to change are usually economic.

6.4.4 Develop a Management Structure

A lead agency must be identified and given formal, legal authority for trauma center designation.

6.4.5 How to Implement the Plan

Once the plan has been developed, all regional hospitals should be encouraged to participate and undergo formal verification.

An "inclusive" approach to trauma system design has been adopted by trauma system planners ([110]). This approach is designed to improve the quality of care provided to injured patients by developing strategies for overcoming problems of access, cost and variation in the quality of services. Planning and implementing a system of trauma care is a huge undertaking ([162]). It requires intensive study, coordination and financial commitment. The problem of access for patients without health insurance and those in rural areas have become paramount to the "inclusive" system. These problems are constantly being investigated and commitments on the part of systems for the care of these patients are vital to the success of these systems in the future.

Trauma centers serve as the hubs of these systems. Trauma centers also exist in areas without formal trauma systems in place. In these areas they are usually not designated as trauma centers, but act as "defacto" or "functional" centers ([163]). Tertiary trauma centers (level I centers) are responsible for receiving the most seriously injured patients directly from the field (in most cases) as well as accepting and guiding transfer from secondary and primary centers. They also serve the purpose of being leaders in trauma care and prevention programs for the region. They are also responsible for conducting trauma related research.

6.5 The Elements of a Trauma System

Trauma care systems can be defined as an "*organized approach to the acutely injured patient that provides personnel, facilities, and equipment for optimal care on an emergency basis within a defined geographic region*"([164]). Geography, topography and population density vary in habituated areas throughout the Western world and therefore trauma systems have been designed as a citywide system in one locality, a regionalized system encompassing multiple counties or communities in another, or a state/province-wide system in other areas([164]). This will obviously impact on the services provided and the design of the system.

A model trauma care system includes the basic concept of "inclusiveness". An inclusive system encompasses all aspects of trauma from prevention of injury until the patient returns to their pre-injury baseline level of function. The key elements of regionalized trauma systems are: (1) a lead public agency with legal authority to establish and enforce trauma system policy; (2) facility categorization; (3) trauma center designation; and (4) the implementation of triage and transfer protocols which identify patients in need of transport to definitive care at a designated trauma care center ([97,165,166]). Even though these elements are essential and common across all trauma systems, individual variations exist. These variations are present in the methods different communities use to design, implement and run their systems. These differences are profound in the area of the process of trauma center designation ([165]). Bazzoli et al identify three key elements integral to trauma care regionalization: pre-hospital care, organization of hospitals and inter-hospital transfer agreements ([167]). By assuring appropriate and timely inter-hospital transfers, patients can be appropriately treated in a system encompassing remote and rural areas ([168]).

The American Trauma Society (ATS) identifies four fundamental components necessary for trauma systems and eight key infrastructure elements that are critical to trauma system success ([169]):

6.5.1 Fundamental Components

- Injury Prevention
- Pre-hospital Care
- Acute Care Facilities
- Post-hospital Care

6.5.2 Key Infrastructure Elements

- Leadership
- Professional Resources
- Education and Advocacy
- Information Management
- Finances
- Research
- Technology

- Disaster Preparedness and Response – Conventional and Unconventional

Time-distance relationships between injured patients and definitive and appropriate care are vital to any trauma system design ([94]). Systems need to be created with geographic, time-transportation factors and maximum health delivery capabilities of a region in mind ([170]). Boyd appropriately points out that in order to design and implement an effective regional trauma system, focusing on one component of the subsystem will not be as effective as an overall and comprehensive view of the sequence of events as they affect the course and final outcome ([94]).

Another crucial element involved in running and maintaining an effective regionalized trauma system is quality improvement. Effective and continuous quality improvement programs depend upon concurrent monitoring of the events involved and surrounding the care of the trauma patient ([26]). The information for quality improvement programs is usually stored in a trauma databank, maintained either at the individual institutions within the system, or in a centralized databank for the entire system, state/province or country. Important elements to be evaluated include; facts related to the patient's injury event, injury severity, process of care and outcome.

Pre-hospital triage algorithms are integral to the optimal care for the injured patient. Injured patients need to be taken to the appropriate level facility which is prepared, properly staffed and equipped to handle the trauma patient. Various schemes have been proposed for the pre-hospital triage of trauma patients. The most widely used is probably the American College of Surgeons Triage Algorithm ([171],[153]). Triage schemes have been shown to be effective at decreasing trauma mortality ([172],[173],[174]). The schemes or algorithms outline strategies for transporting the seriously injured patient to an appropriate center, bypassing lower level centers, which are often closer to the scene of the accident. A proportion of overtriage is necessary in order to eliminate dangerous false negatives which occur in the field ([21]), however, excessive over-triage has a significant impact on trauma centers in terms of both inappropriate healthcare resource utilization and costs ([175],[176]). More worrisome than overtriage is undertriage, which occurs in some systems, where seriously injured patients are not appropriately triaged to trauma centers due to lack of pre-hospital emergency system compliance with triage protocols ([177]). There are new and innovative methods which are emerging for the strategic placement of trauma centers and trauma resources which will hopefully eventually aid in appropriate and timely pre-hospital triage availabilities ([178],[179]).

Trauma centers remain a key component in the systems approach to the acute care of the severely injured patient ([180],[181]). Designation of these centers is integral to improving outcomes ([163],[182]). By having designated centers committed to the resource allocation and care of injured patients, improvements in both morbidity and mortality have been demonstrated. However, the system encompasses all phases of care, from pre-hospital through acute care and rehabilitation. The creation and running of an effective system requires the complete commitment from medical and allied health care professionals, as well as from regional health boards, governmental agencies and communities. Furthermore, even though the designation of trauma centers shifts more severely injured patients to designated hospitals ([183]), trauma center care has been shown to significantly reduce length of stay and cost of care compared to injury severity matched patients transferred from a non-trauma facility ([184]). Patients directly transported to trauma centers also have less missed injuries than transferred patients ([185]). However, it has also been demonstrated that hospitals in remote areas that do not posses all elements necessary for the designation of trauma centers, can have similar, if not better, outcomes than those meeting criteria ([186]). Furthermore, various elements required for designation and accreditation of trauma centers have come into question in the literature ([187]). Issues of the draw-backs of over-triage are discussed in section 6.14 – Geriatric Trauma.

Surgical leadership has been described by some as being vital to maintaining an effective trauma system ([155],[112],[188]). The American College of Surgeons Committee on Trauma emphasizes the role of the trauma surgeon in the design, implementation and running of a trauma system and trauma center ([153]). The American Association for the Surgery of Trauma (AAST) expands on this and requires that a trauma surgeon be ([189]):

- Actively involved in the process of prehospital triage and treatment of trauma patients
- Thoroughly knowledgeable of the diagnostic options and treatment available in the emergency department and understands how to use them in the most appropriate and cost-effective manner

- Able to prioritize and coordinate the resuscitation and treatment of multiple serious injuries while coordinating care between multiple services and subspecialties
- Expert in the operative and nonoperative management of life-threatening and limb-threatening injuries
- Responsible for the comprehensive management of the injured patient in the critical care unit, including hemodynamic monitoring, ventilator management, nutrition and posttraumatic complications
- Integrally involved in the rehabilitation of the injured patient
- Responsible for monitoring outcomes, identifying deficiencies in care when they exist, and correcting any identified deficiencies
- Actively involved in trauma education, research and injury prevention
- An advocate for the optimal care of trauma patients in public forums

Another key element in the overall running of a trauma system is prevention ([161]). In fact, prevention is probably the single most effective way to decrease mortality and morbidity associated with injury.

The American College of Surgeons has defined eight criteria essential to the running of a trauma system([157]):

1. Authority to designate, certify, identify, or categorize trauma centers
2. Existence of a formal process to designate or otherwise identify trauma centers
3. Use of ACS standards to designate/identify trauma centers

4. Inclusion of on-site verification during the designation/identification process and use of out-of-area surveyors
5. Authority to limit the number of trauma centers based on the need for trauma services
6. Existence of prehospital triage protocols for trauma patients
7. Existence of a process of monitoring trauma center performance
8. Statewide coverage of trauma system

Rutledge examined the association between pediatric trauma system elements and per capita pediatric trauma death rates in North Carolina ([190]). He found that the only element of regionalization associated with pediatric trauma-related mortality in multivariate analysis was advanced life support. Elements such as trauma centers, emergency telephone access (911), and other medical resources had no significant association with mortality.

After extensive review of the literature, it is apparent that there is an overwhelming lack of good evidence for the components that go into building and running regionalized systems of trauma care. In order to design new systems and update current systems, an evidence based approach to the components of trauma care must be employed. This is the foundation for this thesis.

6.6 Changes in Regionalization over the Years

After the initial boom in trauma center designation in the late 1970s and early 1980s, many trauma centers closed or "de-designated". Between 1983-1990 there were 66 trauma center closures across 14 U.S. States ([152]). These closures were mostly secondary to inadequate hospital reimbursement, uncompensated care for trauma patients, high operating costs, managed care environments and lack of physician support ([16,139,191,192,193,194,195,196]). Due to these factors it is very hard for a trauma center to survive and prosper without governmental support and a strong commitment from both hospital administrators and staff ([99,197,198,199,200]).

In Canada, hospitals treating trauma patients, especially severely injured patients with complex injuries, are under-funded by governmental agencies and uncompensated for the essential service they render to the community ([201,202]). This occurs in spite of the fact that trauma systems and tertiary trauma care centers have been shown to be cost-effective and provide care at a reduced cost compared to treatment programs for other diseases, when quality adjusted life-years are included in the evaluation of cost ([203,204]). Due to the universal healthcare system in place in Canada, reimbursement for hospitals and physicians is not a factor. Overall healthcare costs are lower when compared to the United States ([205]), but this translates into scarcity of resources, a strained system([206]) and often poorly equipped and staffed pre- and in-hospital emergency medical systems.

Trauma centers must provide care for all injured patients brought through their doors and therefore they have become a focal point for concerns about caring for the uninsured ([110]). In the United States, trauma patients are more likely to lack health insurance coverage than patients admitted to hospital without trauma and thus financial disincentives have encouraged many hospitals to not seek trauma center designation and have forced many trauma centers to give up their trauma center status. Trauma care is an expensive commodity and communities, states/provinces and countries will have to find a way to pay for them ([207,208,209,199]).

The question of reimbursement for treating the uninsured injured has become a major issue in trauma center and trauma systems management in the US in recent years ([210,211]). This issue revolves around the location from which funds will and must come to pay for the care of these patients. The lack of hospital reimbursement and physician compensation for caring for these patients has led to many hospital closures and discourages young physicians to seek careers in trauma and older physicians to abandon ship. While referring to the burden of the injured, Thompson points out that "*there is a tendency for the trauma patient to arrive at an inconvenient time, need precious resources for near-untreatable injuries, demand the best operating room and intensive units, and leave without paying the hospital or physicians*" ([181]).

In 1991 a survey was sent to 635 trauma centers from across the United States which included requests for information concerning financial reimbursement, revenue, cost containment and other economic related queries ([194]). Of the 274 hospitals responding to the survey, 159 (58%) responded that their center was facing serious financial problems and another 99 (36%) reported minor financial problems. These problems were reportedly secondary to increasing numbers of uninsured patients, declining reimbursements, and declining governmental support.

The nature of injuries and management strategies for the care of the injured patient has dramatically changed over the last 2 decades. Safer cars, decreased violence in urban areas and non-operative management have changed the scope of trauma care in Western nations. Engelhardt evaluated the changes which occurred in a level I trauma center over 15 years between 1985 and 1999 ([212]). She found that injury severity (mean ISS went from 15.9 to 10.7) and length of stay (mean LOS went from 8.0 to 5.9 days) significantly decreased over the 15 years studied. Furthermore, there were significant decreases in penetrating injury admissions and the frequency of craniotomy, thoracostomy and laparotomy.

6.7 The Impact of Trauma Care Regionalization

The initial fervor for trauma system implementation was backed by very few studies and lacked the large amounts of evidence which were to come over the years ([213,214]). However, since the late 1960s there have been over 30 studies demonstrating a positive impact on survival in regionalized compared to non-regionalized trauma systems (Tables 3 and 4, Figure 2). Furthermore, the lack of a trauma care system has been also been repetitively shown to contribute to substandard care and outcomes ([104,215,216,217,218]).By centralizing the care of severely injured patients in to a few highly specialized centers, as well as creating corridors for direct entry and easy exit from acute care, trauma systems significantly improve the outcome for injured patients and change the pattern of preventable mortality from delays or inadequate interventions to postoperative care errors ([219]). The impact of hospital volume and specialized services and procedures has been repeatedly shown to impact on outcome in other areas of surgery and medicine ([162,201,202,220,221,222,223,224,225,226,227,228,229,230,231,232]). Aggregated population-based evidence ([121,182,233,234,235,236,237,238,239,240,241,242,243,244]) has demonstrated a 15 to 20% improved survival rate for seriously injured patients following trauma system implementation ([245]). Glance questioned ACS trauma center volume criteria in 2004 ([246]). He found that among severely injured trauma patients in the National Trauma Databank there was no demonstrable volume-mortality relationship for either blunt or penetrating injuries.

In order to appreciate the key studies which measured and proved the effectiveness of the regionalization of trauma care, one must first understand the statistical methods which form the basis of most of these key papers. There are two chief methods; (1) panel studies which evaluate preventable deaths in the study population and (2) studies utilizing TRISS methodology which compare outcomes to North American trauma norms.

Panel studies have been used all over North America as well as in the United Kingdom and Germany in order to assess the effectiveness of trauma care. They were the first methodology employed in assessing the impact of regionalization ([156]) and are also commonly used in order to demonstrate deficiencies in care prior to regionalization ([247],[104]) and used to fuel the fight for support toward regionalization in the community and government. The most prevalent methods used are those which compare trauma deaths in a period prior to regionalization to trauma deaths in a similar period following regionalization. The panel of local and sometimes external trauma care experts meets and assigns labels to patient outcomes (most commonly: definitively preventable, possibly preventable, and not preventable). Early studies utilizing this methodology relied on subjective accounts of panel members relying on implicit criteria. The panels consisted of one or two experts who assigned preventability to a mortality. However, these method have evolved to a more stringent approach to preventable death evaluation which now typically involve multiple panels of diverse experts who make decisions based on explicit criteria by using standardized information abstracted for each patient ([248],[156]). These studies have been repeatedly criticized for their methodological and statistical flaws

([249,250]). Inter-rater reliability of preventable death judgments has been shown to vary widely between studies ([137,251,252,253,254,255]) and it is therefore vital to have impose strict guidelines on panels to improve inter-rater reliability and add power to these largely opinion-based study methods. Regardless of the major flaws associated with these studies, they were the best available methods for evaluating systematic trauma care in the past and were vital to establishing the current state and body of knowledge regarding systems of care.

Panel studies of preventable death classification have come under much criticism over the years following the initial studies presented in this review ([256]), however, they none the less provided the basis for the population based studies which were to come and were integral at the time they appeared in the literature in getting the trauma system concept off the ground ([137,140,143,257,258]). Furthermore, at the time, they were the best evidence that was available. Without these preventable death studies, the questions which we face today regarding morbidities, functional outcomes, cost-effectiveness, variability of care, issues of posttraumatic stress and the efficacy of specific trauma system elements could not have occurred ([258]).

The second method of evaluating trauma system effectiveness examines the outcomes of injured patients using TRISS methodology in order to determine a probability of survival for patients in the cohort. This probability of survival is based on national outcome norms for trauma patients; patients in the Major Trauma Outcome Study (MTOS) ([259,260,260,143,261]). The MTOS is an outcome database of approximately

160,000 trauma patients treated between 1982 and 1989 at 139 hospitals throughout the United States and Canada. The TRISS method for survival analysis utilizes the Trauma Score (TS) ([262]) and later the Revised Trauma Score (RTS) ([263]), the Injury Severity Score (ISS) ([264,265,266]) and patient age in order to determine the probability of survival (P_s) based on MTOS norms ([267,268]).

Flora's Z-statistic ([269]) compares the proportion of deaths among the observed group to the National norm (based on the MTOS). Flora's statistic is population-based and produces a "Z-score" which represents the level of significance reached between the actual survival of the study population and the P_s determined by TRISS methodology. If the Z-score is greater than 2 standard deviations away from the mean, it is considered statistically significant, or equivalent to $Z = 0.05$.

Shackford ([270]) was one of the first to use the TRISS methodology and the MTOS in order to compare the P_s in a cohort of patients to the MTOS. Shackford found that in the first year following establishment of a regionalized trauma system in San Diego County, severely injured patients ($TS \leq 8$) had a P_s of 18% and an actual survival of 29%. This evidence was subsequently used by many in order to push healthcare systems and governments to establish organized systems of trauma care.

San Diego County instituted a regionalized trauma system in 1984. Guss subsequently performed a before and after preventable death evaluation in the County ([271,272]) using the validated autopsy review methodology proposed by West ([273]).

Preventable death evaluation involves the calculation of a preventable death rate (PDR) which is the proportion of all deaths judged to have been preventable if optimal care had been delivered ([137]). Guss found that by expert panel evaluation, 2 out of 211 deaths (1%) were preventable post regionalization compared to 20 out of 177 (11.4%) pre-regionalization ($p < 0.001$). Similar to the Orange County and San Francisco County patients, the decline in mortality post regionalization was mostly attributed to a decline in mortality from non-central nervous system deaths.

Shackford studied the effect of regionalized trauma care on outcomes of "major trauma victims" in the first 5 months post-regionalization and compared it to the period immediately prior to the implementation of a system in San Diego County using the medical audit committee technique for assessing optimal or suboptimal care ([274]). He found suboptimal care was rendered in 32% of cases prior to regionalization, the implementation of a trauma system decreased the proportion to 4.2% ([275]). Preventable deaths occurred in 13.6% of fatalities prior to implementation, compared to 2.7% following system implementation. Shackford subsequently looked at a subset of severely injured trauma patients (Trauma Score of ≤ 8) in the first year after trauma care regionalization in San Diego County ([274]). He compared actual survival to predicted survival based on the Major Trauma Outcome Study (MTOS) ([259]). Following regionalization, the probability of survival in blunt trauma patients was 18% compared to the 29% survival observed ($p<0.05$). In penetrating trauma, the probability and observed survivals were 8% and 20%, respectively ($p<0.05$).

Mullins evaluated the outcomes of trauma patients before and after institution of a regionalized trauma system the risk of death in level I trauma centers improved following implementation of a regionalized system in the North Willamette region of Oregon between 1984 and 1991 (odds ratio = 0.65 post regionalization) ([237]). The establishment of a regionalized trauma system also shifted the more seriously injured patients to the level I centers ([276]). Mullins then evaluated the influence of the implementation of a statewide trauma system in Oregon on the location of hospitalization and outcome of injured patients before and after regionalization ([238]). In Oregon, following statewide regionalization, chances for an injured patient being admitted to a level I or II trauma center increased and the chance of dying decreased.

A further study was done in order to attempt to control for temporal trends in advancements in medical and surgical care of injured patients ([239]). In this study injured patients in Oregon and Washington were compared before either state had a regionalized trauma system (1985-1988) as well as when only Oregon had a trauma system in place (1990-1993). Following trauma system implementation in Oregon, there was a significant risk reduction for death in patients with Injury Severity Scores > 15 (Odds Ratio = 0.8, CI = 0.70-0.91) compared to Washington. Pediatric mortality was also shown to be positively influenced by system implementation in Oregon, compared to Washington ([235]). Secular trends in trauma mortality are best adjusted by these types of studies which compare two systems over the same time period ([277]).

Kane evaluated the survival of seriously injured patients in Los Angeles County prior to (1982) and following (1984) implementation of a regionalized system of trauma care ([236]). There was an observed significant improvement in the adjusted odds of survival following regionalization (odds ratio = 1.455, p-value = 0.048) compared to the period prior to the establishment of the system. Cayten reported on mortality following motor vehicle collisions in the Hudson Valley region of New York from 1987 to 1996 ([278]). There was also a significant decrease in motor vehicle collision mortality which was related and attributed to the establishment of a regionalized trauma system between 1990 and 1995.

Nathens evaluated the effect of trauma systems throughout the United States. He looked at data from states with organized trauma systems in place and compared them to those without regionalized trauma care ([279]). States that contained regionalized trauma systems (n=22) had a 9% lower crude mortality rate compared to those without regionalized care. After sub-analysis for motor-vehicle collisions, areas with organized trauma systems had a 17% reduction in mortality compared to those without systems.

Nathens also studied the effect of regionalized trauma care on motor vehicle crash mortality throughout the United States between 1979 and 1995 ([40]). He found that it took approximately 10 years following regionalization of care to start to see a decline in mortality. By 15 years, mortality from motor vehicle collisions decreased by 8%. The 10-year interval between trauma system implementation and the improvement in outcomes was attributed to the necessary time for trauma system maturation, development of trauma triage protocols, inter-hospital transfer agreements, trauma center organization, and ongoing quality assurance. These factors, however, were not assessed in this study and remain hypotheses.

Clark critically re-evaluated the aforementioned studies performed by Mullins ([237]), Cayten ([278]) and Nathens ([40]), which used data from the Fatality Analysis Reporting System (FARS), in order to test the accuracy of their results and assess the conclusions that were drawn regarding the effectiveness of trauma systems from these studies ([280]). He found that the positive impact of trauma system regionalization was less convincing when all available data was displayed and potential confounding factors were assessed. Mortality following trauma was found to be decreasing throughout the United States and this contributed to the declining rates of mortality following injury. Clark's findings are controversial and have caused much debate ([281]). However, even if trauma systems do not impact on national mortality as much as some believe, they have and do definitely contribute to superior care for injured patients.

Jurkovich and Mock compared patients with serious injuries in three cities: Seattle (Washington), Monterrey (Mexico) and Kumasi (Ghana) ([282],[283],[284]). Seattle is considered to have the most advanced EMS service in the world, Monterrey has a basic EMS service and Kumasi has no EMS system. Major differences also obviously existed in hospital capabilities and socioeconomic factors. Overall survival for seriously injured patients were; Kumasi (36%), Monterrey (45%) and Seattle (65%). The increased survival was primarily attributed to decreased pre-hospital deaths, further highlighting the importance of the "system" in the outcome of seriously injured patients.

In July of 1998, a symposium was organized at the Skamania Lodge in Stevenson, Washington ([285]). The symposium was titled: "Trauma Systems – Evidence, Research, Action." The symposium was planned in order to assemble health care professionals from various disciplines to critically review the available evidence concerning trauma system effectiveness and was a huge success ([286,287]). Prior to the symposium, a comprehensive review of the literature was undertaken by the organizing committee and key articles concerning trauma system effectiveness were selected, summarized and sent to participants ([288]). The articles were then critiqued by the participants at the symposium and summarized in an important paper by Mann et al. in a supplement to the Journal of Trauma ([12]). Mann concluded that there was evidence supporting the effectiveness of regional trauma care systems in reducing in-hospital mortality. However, further outcome studies were required including studies based on 30-day post discharge mortality and the evaluation of morbidities.

Outcomes have also been shown to improve as time passes following establishment of a trauma system ([289,42,290]). As the system matures, mortality for severely injured patients declines. O'Keefe was able to show a positive survival advantage for injured patients with ISS $\geq$ 16 over 10 years at a single level I trauma center between 1986 and 1995 ([291]).

The effects of regionalization in Canada have not been as extensively studied as the systems of trauma care in the United States. However, the impact of regionalization on the outcome of trauma patients in the province of Quebec has been studied in depth over the last 15 years ([174,217,42,292,293]). This process is examined in the first part of this thesis.

In the early years of trauma care regionalization, designation of trauma care centers does not lead to increases in patient volume at designated trauma centers. Instead, there is a redistribution of patients, with the more severely injured patients being transported to the higher level centers ([34,117]). However, once a system becomes established and is running efficiently, outcomes improve ([289]) and proportions of trauma patients being transported to higher level centers increase ([176,294]). The increase in patients is usually secondary to the triage and transport of patients with low injury severity injuries. Pre-hospital care workers and dispatchers prefer to err on the side of over triage in order to not miss significant occult injuries ([295,177]). Furthermore, triage algorithms are designed to overtriage less severely injured patients ([160,145,296,297]). These factors contribute significantly to the high costs of running a level I trauma center ([165]).

Tables 3 and 4 outline the evidence supporting trauma care regionalization, as well as the impact of regionalization on areas which have implemented these systems. Studies comparing regionalized to non-regionalized areas are presented (before and after, MTOS comparison, regionalized versus non-regionalized area).

What we know and have demonstrated through extensive review of the available literature is that regionalized trauma systems work. The systems have been repeatedly shown to improve outcome following injury and have revolutionized trauma care over the past three decades. What we don't know is why these systems work and which components making up the system are responsible for the observed improved outcome. We also do not have information with regards to what degree components making up the system contribute to improved outcomes, as well as which components are not associated with improvements in outcome or may actually demonstrate a negative association with patient outcome. The question to be answered is which components making up regionalized systems of trauma care are responsible for the improvement in outcomes observed and to what degree. Elucidating these components will lead to the creation and running of evidence-based, cost efficient trauma care systems for the future. Component-based evaluation will also encourage areas without these systems to implement tailor-made systems to serve the specific population served in a cost-efficient manner based on components which are associated with the most survival benefit.

6.8 Trauma System Variations in Different Regions

Trauma systems vary substantially within countries, however, they vary even more significantly between countries. These differences do not only exist secondary to the varying commitments of countries to trauma care, but also due to differences in training, credentialing and demographics([298]). The profound differences in economics, demographics and availability of resources make the understanding of available systems both interesting and important to the study of trauma systems. The following is a brief overview of current trauma care systems and non-systems throughout the world.

6.8.1 Canada

Regionalization of trauma care in Canada lagged several years behind the United States ([299]). The Royal College of Physicians and Surgeons of Canada introduced the Trauma Association of Canada (TAC) in 1983. The society was founded in order to provide a multidisciplinary vehicle for the promotion and development of trauma systems throughout the country ([300]). The first province to regionalize trauma care was Quebec in 1993. A detailed account of the evolution of regionalization in the province of Quebec is presented in the first part of the results section of this thesis (Implementation of a Trauma Care System: Evolution through Evaluation).

The integrated model of trauma care being used in many areas of the United States is uncommon in Canada ([301]). It was not until 1993 that the Trauma Association of Canada (TAC) defined guidelines for the accreditation and designation of trauma centers ([302]). These guidelines are similar to and based on the guidelines established by the American College of Surgeons Committee on Trauma ([153]). A voluntary trauma center accreditation and audit program was started by the TAC in 1996. In 2002, 19 trauma centers in Canada had undergone successful accreditation by the TAC ([303]). Some provincial trauma systems also have their own accreditation programs. A mandatory accreditation process throughout the entire country is inevitable ([304]). There are significant between center differences regarding the availability, composition and leadership of the initial management team ("trauma team") as well as the admitting service for injured patients ([303]). There is also major variations in the pre-hospital care trauma patients receive in Canada. Pre-hospital care for injured patients ranges from basic life support, to advanced life support, to hybrid basic/advanced life support, and until 2003, physicians.

British Columbia faces particular problems in terms of trauma care, the most important of which is accessibility. The vastness of the land, topography, weather conditions and population distribution, all make access to care very difficult. In the late 1980s, the BC provincial government expressed concerns about the province lagging behind other jurisdictions regarding acceptable standards for trauma care ([305]). This led to the development of a provincial ambulance system in 1991, the designation of trauma centers and the development of triage and transfer protocols.

Sunnybrook Medical Center in Toronto was one of the first tertiary trauma centers in Canada. It was established in 1976 and serves the inhabitants of metropolitan Toronto and the surrounding area ([306]). It also is a major trauma referral center for the province of Ontario. Boulanger et al. compared injured patients at a Level I trauma center in Toronto, Ontario, Canada (Sunnybrook Trauma Center) to a similar cohort of patients treated in Baltimore, Maryland, USA (R Adams Cowley Shock Trauma Center) between 1986 and 1990 ([307]). Patients injured in motor vehicle collisions in the two cohorts with similar injuries had similar mortality rates and discharge dispositions. Differences were seen in the number of Intensive Care Unit (ICU) days, the likelihood of ICU admission and costs. Severely injured patients (ISS ≥ 16) directly transported to American Level I trauma center were twice as likely to be admitted to the ICU, had longer ICU stays (USA = 15.4 days, Canada = 8.4 days) and had shorter hospital stays (USA = 18.5 days, Canada = 26.2 days) in the United States compared to Canada. These differences are most likely secondary to a more aggressive approach to the initial management of patients in the USA and the greater availability of ICU beds, as well as the importance of malpractice litigation in the US. The shorter hospital stays in the United States Level I trauma center are probably secondary to managed care group pressure to discharge patients in the US compared to the lack of such external pressures in Canada.

In June of 1990, the Ministry of Health in Ontario designated 11 hospitals throughout Ontario to be lead hospitals in the rendering of trauma care. Stewart, evaluated the effect of this designation on mortality at the Victoria Hospital following motor vehicle collisions, by comparing outcomes pre-and post-trauma center designation ([308]). He showed a major improvement in outcome the outcome of patients injured in motor vehicle collisions following trauma center designation. The z-scores went from z = -0.40 (pre-designation) to z = +0.72 (post-designation).

In 1997, the Vancouver General Hospital initiated an integrated trauma program. The program included a trauma unit which cared for general, orthopedic, burns and plastic surgery trauma patients. Development of consensus-driven clinical guidelines, a performance improvement program and an integrated trauma registry were also introduced at that time. These changes led to decreased mortality compared to the MTOS data following introduction of the program ([309]). The same group also showed that in British Columbia, outcomes were significantly better if injured patients' initial contact with a trauma center was at a designated center, compared to those first being assessed and treated at a non-designated center ([310,311]).

6.8.2 United States

In 1987, only two states had all eight essential components of regionalized trauma systems put forth by the American College of Surgeons Committee on Trauma ([153,312,123]). Nineteen States and the District of Columbia lacked one or more essential component of a regionalized trauma system. The remaining 29 states had not yet begun to regionalize trauma care. By 1993, there were 5 states which possessed the requirements of an inclusive trauma systems ([313]). Deficiencies leading to incomplete trauma systems were mostly secondary to failures to limit the number of designated trauma centers based on community need, the absence of pre-hospital triage guidelines which allow hospital bypass and centralized trauma registries.

Bass updated the data regarding trauma systems in the United States in 1999 ([314]). He used a similar survey as was used in 1987 and 1993 which looked at eight essential elements of regionalization. There were still only five states meeting all requirements for trauma systems, however, 28 states met six or seven criteria, and another 10 states met between one and five criteria (in 1993 only 18 states met six or more criteria).

In 1991, there were 21 states in the United States which had formal trauma systems in place ([315]), this increased to 35 in 2002 ([316]). This increase was mostly due to the multiple studies concerning the efficacy of regionalized trauma systems in reducing trauma related mortality performed and published in the 1990's. In 2003, MacKenzie et al. compiled an inventory of trauma centers throughout the United States([316]). They found that the availability of trauma system services varies widely throughout the USA. In 2002, there were 1154 trauma centers in the US (190 level I, 263 level II). Numbers of trauma centers (all level) per million population ranged between 0.19 (Arizona) and 42.0 (North Dakota). The number of level I and II centers varies widely from 0.19 (Arizona) to 7.8 (North Dakota) per million population. Furthermore, six states have categorized all or nearly all short-term general medical/surgical hospitals into 1 of 5 levels of trauma care. Four states have categorized over half their hospitals into 1 of 4 categories and twenty-four states do not maintain any level III, IV or V trauma centers. Even though the numbers of trauma centers have increased dramatically over the last 15 years, the problems of geographic distribution of trauma centers and underserved areas, particularly rural areas, remains important and unresolved in the United States ([317]).

In the US, hospitals that are designated as trauma centers are more likely to be publicly (36.6%) rather than privately run compared to non-trauma centers(63.4%) as opposed to non-trauma centers (22.1% public, 77.9% private)([316]). Trauma centers are also significantly larger hospitals (12.9% with ≥ 500 beds, compared to non-trauma centers – 3.3%) have commitments to teaching (15.2 versus 3.0%), have residency training programs (29.1 versus 11.7%) and offer more specialized services compared to non-trauma centers. Level I and II centers (>90%) are significantly more likely to be located in metropolitan areas compared to level III (49%), and IV/V centers (16%). Level I (80.5%, 41.4%) and II centers (76.2%, 42.0%) are more commonly associated with hospital systems and participate in hospital networks compared to level III (55.5%, 34.1%) and IV centers (34.8%, 28.1%).

Trauma systems in the United States are evolving. Changes are being realized due to the fact that even though the systems approach to trauma care is thought to be ideal, many areas are not willing, or able to realize the comprehensive trauma system described by the ACS ([318]). It is for this reason that tailor-made, evidence-based, cost-effective systems are necessary in order to assure 100% participation in trauma systems.

6.8.3 Europe

In 1988, the Royal College of Surgeons of England found what they called "*significant deficiencies in the management of injured patients*" in the United Kingdom ([319]).

They stated that 33% of trauma related deaths in a cohort of 514 patients with major injuries were preventable. The UK performed a similar study to the North American MTOS in 1991. Their study, the United Kingdom Major Trauma Outcome Study included 14,648 seriously injured patients treated in 33 hospitals between 1990 and 1991 ([320]). Mortality following blunt trauma was found to be significantly higher than in the MTOS cohort (408 actual deaths; 295 predicted, $p<0.001$), however mortality was lower than MTOS for penetrating injuries (15 actual deaths; 19.3 predicted, $p=0.04$).

Anderson preformed a retrospective study of 1000 trauma-related deaths from injury in 11 districts in England and Wales in 1986 ([321]). He found that of the 514 patients admitted to hospital alive, 102 deaths (20%) were judged to be preventable. Almost two thirds of all non-central nervous system related deaths were judged to be preventable. Preventable deaths were largely due to failure to stop bleeding, prevent hypoxia, and the delay in surgical treatment. The authors concluded that a system of trauma care could eliminate many of these preventable deaths.

In response to the aforementioned preventable death studies, a comparative study was carried out in order to assess the effectiveness and potential impact on outcome from regionalizing trauma care in the United Kingdom. The North West Midlands region was chosen an experimental system to evaluate systems of trauma care in the U.K. ([322],[323]). Trauma related mortality was compared before regionalization (1990) and after regionalization (1993) in the North West Midland region and a control area. Following regionalization, crude mortality rates did not change between the experimental and control groups, however, following injury severity standardization, mortality rates were 0.8% lower in the experimental region and 1.6% lower during out of hours care. These modest improvements are very different from those seen in North America following implementation of a trauma system.

Regionalized trauma care in the United Kingdom lagged much behind that in North America. Level I equivalent trauma centers were not designated until 1992. These trauma centers became the hospitals most equipped to receive and treat injured victims, however, they were not the exclusive hospital providers of trauma care due to a lack of structured trauma patient triage guidelines ([324]). In the United Kingdom, only 7% of the Gross National Product is spent on healthcare and therefore monetary support for trauma systems is hard to come by ([325]). Furthermore, in spite of very rudimentary trauma systems in the U.K., there are fewer deaths following motor vehicle collisions than in the U.S., Canada, and other European countries with superior trauma systems. The lower mortality rates in the U.K. are most likely secondary to greater compliance with road safety laws among the British.

Based on the aforementioned report published by the Royal College of Surgeons of England in 1988 ([319]), several initiatives were proposed and implemented in the UK. These included; improvements in pre-hospital care, training of physicians in trauma management and resuscitation techniques, the reconfiguration of trauma care systems, and the development of audit programs to assess the effect of these measures. Lecky evaluated the effects of the implementation of system changes in 1988 in a study published in the Lancet in 2000, which examined the outcomes of injured patients in England and Wales between 1989 and 1997 ([326]). Over the eight years there was a significant reduction in the odds of death, however there was no adjustment for temporal trends in trauma related prevention programs or advances in the surgical management of injured patients or their resuscitation.

Polytrauma is a rare occurrence in the U.K. (1/1000 accidents) ([325]). This highlights the importance of the centralization of trauma care. In order for hospitals and staff to be comfortable and proficient at caring for the multiply injured patient, the number of centers receiving and managing injured patients must be restricted. Today, in-hospital and pre-hospital trauma care in the UK closely resembles that in the US. ATLS principles are practiced almost universally in hospitals and specialized trauma teams are employed in the initial management of the injured ([327]). Furthermore, ALS is being used more and more in the pre-hospital setting. A National Trauma Service has been proposed by the Royal College of Surgeons of England and the British Orthopedic Association with the aim of creating a comprehensive country-wide integrated trauma system incorporating all aspects of trauma care.

In 1995-96, a study was published comparing trauma patient outcome between a trauma center in the United Kingdom (North Staffordshire Hospital, North West Midlands, UK) and a trauma center in the United States (Oregon Health Sciences University, Portland, Oregon, USA) ([328]). When seriously injured trauma patients (patients alive at trauma center with ISS>15) were controlled for injury severity and were compared in terms of mortality, they produced similar outcome results.

France has a unique pre-hospital system which employs physician intensivists and nurse anesthetists in pre-hospital units (land or air) ([329]). The French believe strongly in the "stay and stabilize" approach to pre-hospital care and attempt to stabilize patients on-scene prior to transport. Patients are transported to the nearest facility, unless they are deemed to be in distress and are therefore transported to a more equipped hospital. There are no designated trauma hospitals in France.

Germany was the first country to adopt systematic trauma care nationwide. The distinct geopolitical and population density advantages in Germany compared to North America provided for an optimal nationwide system of care which was designed to provide organized care to any injured patient in the country within 20 minutes of injury ([31]). In Germany, there is 24-hour trauma coverage in hospitals receiving injured patients ([330]) as well as the wide use of a helicopter transport system for trauma patients.

Secondary to a large and often difficult to negotiate terrain, helicopters are used as a major tool for the swift transport of injured patients to hospital ([331]). Helicopters are based at 51 stations throughout the country and provide service to the entire country ([332,333]). All rescue crews (land and air) are coordinated by special pre-hospital rescue centers to ensure maximum efficiency and speed. Furthermore, physicians specially trained in trauma care treat the patients on-scene prior to helicopter transport to hospital. The aggressive treatment of the injured in Germany, with what is the most inclusive and widespread national trauma system in the world, has contributed to a dramatic drop in mortality following polytrauma from 40% in 1972 to 18% in 1991. Level I to IV trauma treatment centers (as defined by the American College of Surgeons) do not exist in Germany. However, university hospitals or major urban hospitals with dedicated trauma units function as level I centers and receive the majority of major trauma and polytrauma. The German Society of Traumatology has designated three categories of trauma centers ([334]). The lowest grade hospitals approximately corresponds to ACS level IV centers, the middle grade approximately corresponds to ACS level III standards and the highest level corresponds to ACS levels I or II.

Outcomes were seen to improve following implementation of a systematic approach to trauma care at the Uldağ University Medical School Hospital in Bursa, Turkey in 1996 ([335]). Prior to 1996, there was no coordinated trauma care within the hospital. In 1996, a trauma team was assembled and was put in charge of the global care of the injured patient. This team included surgical leadership and 24-hour presence which was previously lacking, trauma protocols and guidelines were established and twice daily trauma rounds were commenced. The hospital met ACS level I criteria. Crude mortality dropped from 32.5% to 23.3% following in-hospital trauma system implementation. Furthermore a significant improvement in the z-score was seen using TRISS methodology form -2.47 pre-implementation to 0.55 post-implementation. A similar study was completed in Stockholm, Sweden comparing a pre-trauma care reorganization period (1987-88) to a post-reorganization period (1991-93) in a single academic center ([336]). Inappropriate care was shown to significantly decrease following reorganization, as well as time to definitive care.

The development of a trauma system in Armenia was aided by cooperation with the Boston Medical University in Boston ([337]). The US trauma system expertise was used to find deficiencies in trauma care and to implement improvements. This led to establishment of a level I trauma center, introduction of training programs for pre-hospital workers, implementation of postgraduate medical training programs in trauma for staff, development of medical information systems, restructuring of the trauma receiving area and establishment of an accredited residency training program in emergency medicine.

A recent Swiss study evaluated the potential benefit of regionalizing trauma care in Switzerland in using the American model of direct transport of injured patients to trauma centers ([338]). This prospective study very crudely compared outcomes for injured patients transported to a trauma center to those transferred from a non-trauma to a trauma center. The findings found a very modest possible effect of implementation of a regionalized system of care in Switzerland.

The Netherlands has a highly advanced trauma system. The system includes all aspects of care and incorporates a pre-hospital helicopter system to rapidly transport injured patients from locations at great distances from hospital ([339]). Ten hospitals with neurosurgical facilities have been designated by the Minister of Health as regional trauma centers for the country. The majority of injured patients are transported directly to these centers.

Spain has seen dramatic improvements in survival following implementation of a highly advanced pre-hospital care system ([340]). Constant re-evaluation and epidemiologic studies have provided Spain with a system that is constantly evolving. The system includes pre-hospital triage protocols and pre-hospital notification of the patient status to the receiving center. Italy has similarly seen recent changes in both the pre-hospital and in-hospital trauma system. Changes have improved the way ambulance crews are trained and function as well as the designation of specialized trauma treatment facilities with in-house surgeons and anesthesia capabilities ([341]). Belgium, on the other hand does not have organized in-hospital trauma care and there are no specialized physicians or teams to treat the injured ([342]).

Joosse demonstrated that TRISS methodology ([343]) using coefficients derived from the Major Trauma Outcome Study ([259]) in the North America was not applicable to

European populations [344]. Unfortunately, to date there are no widely accepted substitutes being utilized in North America or in Europe [345].

6.8.4 Australia / New Zealand

In 1991, in Sydney, Australia, elevated, preventable hospital mortality for trauma patients secondary to high volumes of blood loss during the resuscitative phase of in-hospital trauma care were observed [346]. Subsequent to this observation, a regionalized trauma care system was introduced for the first time in Sydney in 1992. This trauma system included designated trauma centers, pre-hospital triage guidelines, placing surgeons in charge of hospital trauma services and education of physicians regarding appropriate trauma care. In one tertiary trauma center, survival for trauma patients improved by 17% following introduction of the new guidelines [347].

In 1993, a two-year study was undertaken in Victoria in order to assess the adequacy of trauma care for patients who died on motor vehicle collisions in Victoria, Australia which has no formal system of trauma in place [348,349]. They reported that of the 1175 problems, only 11% were due to "*system inadequacies*". The other problems found were in management errors (81%), technique errors (3%), delays in diagnosis (2%), and diagnostic errors (4%). Errors in the management of the 120 fatalities were committed in the pre-hospital phase of care (16%), the emergency department (51%) and intensive care unit (12%). The assumption that "*system inadequacies*" account for only 11% of problems or errors occurring in the 1175 errors found in these 120 deaths is extremely nearsighted. Errors in diagnosis, treatment, and delays to definitive care have all been shown to decline using the systematic approach to trauma care.

Due to the aforementioned inadequacies, Victoria decided to regionalize trauma care in 1998. The Victorian system was designed to transport injured patients to " the highest designated trauma service accessible in 30 minutes" ([350]). The trauma system included the designation of three inner city hospitals as major trauma units (2 adult, 1 pediatric). The remaining hospitals were designated from most to least specialized based on their ability and resources to treat injured patients.

Approximately 90% of the Australian population lives in highly populated urban areas. However, the 10% of the population that lives in rural areas are often extremely far from urban trauma care ([351]). There are three levels of in-hospital care available to injured patients in Australia. In increasing level of trauma care readiness, they are; (1) country district hospitals (10-60 beds), (2) tertiary referral centers, metropolitan trauma hospitals (level II - up to 200 beds), (3) tertiary referral centers, major trauma hospitals (level 1 - up to 200 beds). Referral from country district hospitals is usually directly to major trauma hospitals.

The motor vehicle collision rate in metropolitan Australia is twice that of rural Australia, however, the mortality rate is double. This is due to the tremendous distances between the site of injury and the location of definitive care, problems with inter-hospital transfer of injured patients, inadequate resuscitation of seriously injured patients prior to inter-hospital transfer and physicians inexperienced in trauma care managing patients with complex injuries ([352,348,353]). The advent of telemedicine promises to improve trauma care in these rural and often inaccessible areas ([149,150,151]). Furthermore, aircraft (helicopter and fixed wing) are being used to transfer critically injured patients to urban tertiary trauma centers ([354]).

Trauma care in New Zealand is not as advanced as in other areas of the industrialized world. There is no formal system in place and trauma care is delivered in an "ad hoc" manner ([355]). The lack of a formal system is mainly due to inadequate funding. Injury patterns are mostly due to blunt mechanisms as there are strict gun control laws on handguns and police do not carry firearms. Due to the fact that in most areas, there is only one hospital present and therefore to which all trauma patients are transported, a quasi-trauma system exists.

6.8.5 Asia

China has a very complex trauma care system. There are five models or systems of pre-hospital care in use ([356]). These systems are in place in order to maximize efficiency of resources for the area served. In some areas patients are transported to the nearest hospital, whereas in others where more specialized centers exist, patients are preferentially transported to more equipped facilities.

Japan's trauma system operates based on three levels of hospital care. Patients are first transported to the nearest facility and then transferred from lower level centers to higher level centers based on injury severity ([357]). Pre-hospital care workers are not trained in advanced techniques and even basic life support standardized training and protocols are lacking.

In Hong Kong, 7 level I trauma center equivalents function as the major receiving hospitals for trauma patients ([358]). Triage protocols are not established, but are in the works. Injury patterns and characteristics are similar to Canadian provinces with low numbers of penetrating injuries and a large proportion of low injury severity hip fractures among the elderly.

Trauma is a huge problem in Thailand. Approximately 25% of all patients presenting to emergency departments in Thailand are trauma-related ([359]). There are 1.4 million traffic collision patients per year and injury is the second leading cause of death for all ages combined. Despite the huge burden of injury, trauma has not received as much attention or governmental support as Western countries. There is a lack of trauma training for physicians or pre-hospital workers as well as a lack of protocol or system in the pre-hospital care phase. Only 0.1-7.4% of patients are transported to hospital by ambulance, with the rest transported to hospital by themselves (81.3-99.7%) or by volunteers (0.1-18.4%). Transport is usually to the closest hospital. In the last few years there have been efforts at injury prevention and in trauma training for physicians.

6.8.6 India

Systems of trauma care are virtually non-existent in India. There is a complete lack of organized care, despite a huge burden of injury ([360]). A lack of a National lead agency to coordinate trauma care does not make the organization of care easy and is a huge barrier to change. This coupled with the economic situation of the country does not lend to organized systems of care. Automobile safety regulations and traffic laws are almost non-existent and not enforced leading to unsafe vehicles and increased accidents. Pre-hospital transport consists mostly of transport to the nearest hospital by family, friends or ambulance. Many rural areas are not serviced by ambulances. The areas that are serviced receive haphazard pre-hospital care with a complete lack of training and standardized protocols for ambulance personnel. One third of all ambulances serve only as transport vehicles with a complete absence of emergency medical staff. Almost half of hospitals do not have inter-hospital transfer agreements.

6.8.7 The Middle East

Israeli authorities recognized deficiencies in trauma care in the late 1980s. In 1990, the first trauma center in Israel was inaugurated in Jerusalem. In 1991, Trunkey and Rivkind hypothesized by applying US data to Israeli population based data, there was justification for four to eight regionalized trauma centers in the State of Israel ([361]). They further outlined the plans for an inclusive trauma care system encompassing access, pre-hospital, in-hospital care and rehabilitation of injured patients in Israel.

In 1992, the Israeli government adopted the American College of Surgeons guidelines for trauma systems ([362]). Gradually, five additional trauma centers were opened throughout the country. Acknowledging a continuing deficiency in the area of civilian trauma care, the Israeli Ministry of Health, in 1996, designated 24 hospitals according to American College of Surgeons trauma center criteria. Six hospitals were designated as level I centers. However, there was and still is no regionalized inclusive system of trauma care in any area within the entire country. The 24 hospitals designated by the government as trauma centers were surveyed in 1996 in order to assess the structure and process components of trauma care services available to injured patients in Israel as well as to identify deficiencies in the organization of trauma care in Israel ([363]). Multiple variations in resources between centers and deficiencies in systematic trauma care existed throughout Israel. These shortcomings underline the importance of the systematic approach to trauma care as well as all the standardization that comes with it.

The Israeli authorities accepted the importance of ACS criteria and guidelines in the establishing and maintenance of trauma systems, however, also realized that the different demographics, injury characteristics, mechanism of injury, patient populations and available resources necessitated modifications to the "system". In order to evaluate these differences in trauma system care and their associated impact on outcome, DeKeyser, compared trauma patients treated at Hadassah Hospital in Jerusalem, Israel to similar patient treated at Fairfax Hospital in Virginia, USA in 1995 and 1996 ([364]). The patients treated in Jerusalem were less often injured in motor vehicle collisions than their US counterparts and were of different age characteristics. Mean ISS values were higher in the US sample and length of stay was shorter. Crude mortality was also higher in the US hospital. Factors predicting outcome also differed between centers. Although determinations of the superiority of either system cannot be made from this study ([365]), it is obvious that the differences in demographics, injury and treatment are important between the two hospitals, which can probably be extrapolated to the rest of the countries. In 2004, Peleg demonstrated that following the introduction of a regionalized trauma system there was a "*steady significant reduction in the inpatient death rate of severe trauma patients hospitalized at all level I trauma centers in Israel between 1997 and 2001*" ([366]).

Institution of a rural pre-hospital trauma system in Northern Iraq and Cambodia decreased trauma related mortality in these low-income countries. Between 1997 and 2001, 135 paramedics and 5200 lay first responders were trained to provide in-field trauma care in these areas where there is a large proportion of land mine injuries on a daily basis ([367]). Through a novel approach to pre-hospital care in low income areas, a core group of 22 health care workers were selected from each of the target areas to undergo a three year training program consisting of 150 hours of intensive courses with six month working periods in between sessions. They were supplied with medical backpack kits which were equipped based on the level of certification they had received. The trained health care workers were encouraged to build local networks of lay first responders within their area, train them in 2 day courses and use them to decrease response times in the surrounding villages. Prior to the implementation of this novel regionalized system of care, mortality form trauma was 40%. Following implementation of the system of superior care and rapid response and pre-hospital times, the mortality rated dropped to 14.9%. These results are both encouraging and remarkable ([368]). Furthermore, they highlight the point that trauma systems need to be tailored to community-specific needs and need not follow the rigid American model of regionalization in order to improve outcomes following trauma.

Iran has no formal system of trauma care, however, in Tehran there are a few hospitals which see most of the civilian trauma and act as "trauma centers" ([369]). An emergency medical service consisting of ambulances transports patients to the nearest hospitals and there is no pre-hospital trauma triage system in place to assure that severely injured patients are brought to facilities with adequate resources and experience. Furthermore, triage is even more difficult in Iran as the majority of injured patients are transported to hospital by bystanders, instead of by ambulance. Within the "trauma centers" there is no designated trauma team and injured patients are admitted to the general surgical service. Iran sees a much higher proportion of penetrating trauma than most Western countries (16% of severely injured patients). Tehran University of Medical Sciences established a trauma registry in 1996 in three hospitals that received the bulk of trauma patients in Tehran. Preventable death rates in teaching hospitals in Tehran, which probably have the most advanced trauma care in the city, are unacceptably high ([370]). A large part of these preventable deaths could benefit from a systematic approach to the injured patient.

6.8.8 South Africa

South Africa faces tremendous obstacles in terms of trauma care. These obstacles occur secondary to gross inequities in care, pre-hospital service inadequacies and overcrowding of tertiary care centers ([371]). Access to care is a major concern and alost half of patients arrive at hospital by private vehicle. Alcohol is associated with 60% of injuries in Cape Town ([372]) and rape and violence against women are prevalent problems in South Africa. No formal pre-hospital triage protocols exist, and the choice of hospital is decided upon by family, friends or EMT crews.

6.9 Access to Care – Pre-Hospital Care and Transport of Injured Patients

Pre-hospital transport and care of injured patients is paramount to an effective and efficient system on trauma care. Transport occurs by ground ambulance ([373,374,375,292,376,377,378]), by air ([241,379,380]), by bystanders ([381,382]) and even by taxi ([382]). Pre-hospital care of injured patients has been surrounded by much controversy ([383,384]). This controversy involves the appropriate care of the trauma patient on-scene and on-route to the treatment facility and the evidence regarding the superiority of either system has, in general, been poor and contradictory ([385,386,387,388]).

Before 1967 Advanced Life Support (ALS) was not a factor in the pre-hospital care and transport of injured patients. All trauma and medical patients were transported to hospital by Basic Life Support (BLS) or non-trained crews. The first mention of ALS in the pre-hospital setting was by Pantridge who conceptualized a mobile intensive care unit, which could transport patients with myocardial infarction to hospital and provide advanced care on-scene and en-route ([389,390]). Since that time pre-hospital advanced life support units and systems have been introduced, developed and expanded in many advanced emergency medical systems throughout the world. Through the belief that pre-hospital ALS would decrease morbidity and mortality, fostered by the medical community and further glorified by the media, ALS soon became commonplace in many cities and rapidly expanded to include all aspects of the treatment of pre-hospital patients ([391]). Although never validated as beneficial by a prospective, randomized trial including all areas of pre-hospital trauma, ALS has blindly become widely accepted as being the gold standard of care in many systems. In 1990, 98.5% of the 200 largest cities in the United States had ALS-response capabilities and 82% had ALS responders responding to all emergencies ([392]). Among 25 midsize urban U.S. cities (population: 400,000 to 900,000), 100% had ALS units and 22% consisted of ALS units being dispatched to all emergencies ([393]).

Basic Life Support (BLS) techniques, such as external hemorrhage control, extrication, protection of the spine, providing artificial respiration and circulation as well as supplemental oxygen therapy are non-invasive, easy to perform, require little added on-scene time and can often be performed on-route by minimally trained emergency medical technicians. These techniques have been widely accepted as being necessary for the acute treatment of trauma patients in the pre-hospital setting. However, in the last 10-15 years, ALS in the pre-hospital setting has also become accepted as being necessary for victims of trauma and has been widely implemented.

Although advanced techniques such as endotracheal intubation, intravenous access, administration of medications and fluid therapy are being used by many emergency response teams, to date, we do not know the clear benefits of these invasive and time consuming interventions. ALS has been shown to be effective in medical patients experiencing cardiac arrest ([394,395,396,397]), however there is insufficient scientific proof that these methods are effective, are being performed properly, and are not detrimental to the trauma patient. In the pre-hospital setting, ALS techniques may be useless and deleterious to trauma victims, not only by prolonging scene time ([398]) and therefore increasing the time to definitive care, but also by administering treatments which may be harmful to the patient in the pre-hospital setting, whether performed correctly or not.

Pre-hospital care for trauma patients is provided by emergency medical personnel using either Basic Life Support (BLS) or Advanced Life Support (ALS) techniques. BLS or "Scoop and Run" consists of non-invasive interventions such as wound dressing, immobilization, fracture splinting, oxygen administration, and non-invasive cardiopulmonary resuscitation. ALS encompasses all of the previously mentioned BLS techniques in addition to invasive procedures, including: intubation, initiation of intravenous access (IV) with fluid replacement, administration of medications, and in rare cases application of pneumatic anti-shock garments (PASG). The rationale for the use of on-site ALS in trauma is that these interventions will reduce the rate of physiological and haemodynamic deterioration thus stabilizing the patient prior to arrival at the hospital. It is expected that this will subsequently result in increased chances of survival. The paradox is that on-site ALS increases the amount of time that is spent on the scene, and hence increases the delay to definitive in-hospital care. To this date, the controversy between the "Scoop and Run" versus "Stay and Stabilize" approach to pre-hospital trauma care remains unresolved and has been the subject matter of a limited number of studies, most of which are based on small numbers of selected patients. Studies supporting ALS have failed to adequately demonstrate an association between on-site ALS and increased survival among patients with major trauma

([277,399,400,401,402,403,404,405,406,407,408]). Studies supporting BLS have shown higher survival rates for patients treated using the "Scoop and Run" approach compared to those that were treated using on-site ALS ([23,217,374,376,382,386,391,401,409,410,411,412,413,414,415,416,417,418,419]). The validity of these studies is often compromised due to the lack of control for confounding variables and appropriate comparison groups.

A study by Schmidt et al in 1992, compared trauma patients with equivalent Injury Severity Scores (ISS) transported by helicopter in Germany to patients transported by helicopter in the U.S. In Germany, patients received treatment by a paramedic and a trauma surgeon and in the U.S. by a paramedic and a nurse. They found that the German patients received significantly more advanced interventions, including IV fluids, endotracheal intubations and thoracic decompressions than the American group. This led to a decrease in early mortality and improved outcome compared to patients in the Major Trauma Outcome Study (MTOS) ([333]).

We have previously shown through meta-analysis of all published literature concerning pre-hospital trauma outcomes between 1966 and 1998 that for patients receiving ALS compared to these receiving BLS adjusted odds ratio for dying is 2.59. The crude odds ratio is 2.92. The conclusions of the review were that the aggregated data in the literature have failed to demonstrate a benefit for on-site ALS provided to trauma patients and support the “scoop and run” approach ([386]). In this study, the mean on-scene time for ALS treated patients (patient n=11,323) was 18.5±3.8, and for BLS patients (n=4,784) was 13.5±2.4 minutes (p=0.005).

Trunkey and Lewis suggest that some ALS skills are necessary and others waste precious time in the field. They explain that endotracheal intubation is a necessary skill and potentially lifesaving procedure in the pre-hospital setting, however intravenous access and fluid replacement may be of no benefit and inefficient ([378,420]). Due to the fact that only one third of crystalloid solution remains in the intravascular space and very little is given en-route to the hospital (700ml in study cited); there is no benefit in prolonging scene time to obtain intravenous access. Lewis describes the futility of performing ALS procedures for the trauma patient in the field as follows:

> *"...you have a patient who is progressively bleeding over the time following the accident until he gets definitive care, and there is basically nothing the paramedics can do that will effectively reverse that process. The patient who is not bleeding significantly before he gets to the hospital obviously does not need the paramedics...The patient bleeding rapidly, with severe head injury, who has lost control of his airway and needs emergency treatment, may be helped by intubation, but other paramedic services are really not going to significantly benefit him. The patient who needs it most is the one who will arrest from hemorrhage within 10-20 minutes. That person is losing blood at a fairly rapid rate, and the time it takes for paramedics*

to start an IV far exceeds the benefit of the fluids they can give..." *([421]).*

We are reminded that even in our highly advanced and technical society, that the most precious commodity in the treatment of the trauma patient is time. Recently there has been a flurry of papers demonstrating a negative effect or lack of effect of pre-hospital endotracheal intubation on survival and neurological outcome ([422],[423]). Eckstein recently reported on outcomes of patients receiving pre-hospital ALS compared those who did not ([424]). Patients who did not undergo pre-hospital intubation had a greater than five times increased odds of survival compared to those that underwent the procedure. On-scene time was not prolonged by performing ALS techniques which suggest a deleterious effect of the intervention not related to time. A prospective clinical trial performed in the pediatric population also demonstrated a lack of benefit for pre-hospital intubation in terms of survival and neurological outcome ([425]).

Are we able to group urban and rural systems into one category when discussing pre-hospital ALS for trauma? Could prolonged transport times be associated with increased benefit with advanced on-scene interventions? Messick studied 12,417 trauma deaths in a rural state. He showed that mean trauma death rates/10,000 people in BLS counties was 8.2 ± 2.2 versus 6.1 ± 1.3 in ALS counties ($p=0.0001$) ([426]). He was able to show that in this rural county ALS was associated with a significantly lower death rate in trauma. Unfortunately the number of trauma patients in each study group was not cited, therefore we must assume that there were equal amounts of cases in both populations.

There are those who believe that blunt and penetrating injuries should not be characterized in the same category and paramedics/EMS responders should treat these two groups differently. Penetrating trauma victims benefit less from ALS than do blunt trauma patients. Blunt trauma patients can be further sub-grouped into those with vascular disruption (internal hemorrhage) and those with traumatic cardiac arrest, tension pneumothorax and head injury, in whom field ALS techniques are probably more beneficial ([427]). Unfortunately it is probably inefficient and not cost-effective to train paramedics to differentiate these different subgroups in the field. It is also impractical, because many injured patients will possess a combination of penetrating and blunt injuries following trauma.

One of the key principles in trauma patient management is that of the "Golden Hour" or "Golden Period." This period is defined as the immediate time after injury when resuscitation and stabilization will be most beneficial to the patient ([97]). As time passes following most critical trauma, tissue hypoxia increases and the chance of survival or chance of good post survival prognosis decreases ([428],[429],[381]). In all trauma patients it is critical to balance the need for pre-hospital care and the need for prompt transport of the patient to hospital for definitive care.

Brill argues that the question of whether to provide ALS or BLS in the pre-hospital setting depends on whether restorative treatment can be given in the field or not. If one can identify those patients who can benefit from pre-hospital ALS and can be given definitive treatment in the field then the choice would be to "stay and stabilize." On the other hand if pre-hospital ALS cannot provide definitive treatment, it is futile to prolong transport to hospital where definitive care awaits, therefore the choice should be to "scoop and run." In a study of 3,200 time critical patients brought to the emergency department, the interval between onset of criticality (possibility of death or of physical or functional limb or organ loss) and first restorative treatment (treatment expected to end criticality) for any condition, was the measure most related to survival. The efficacy of restorative treatment was shown by a survival rate of 70% among 85% of all critically injured patients who received at least one restorative treatment. Amongst the 15% of critically injured patients who received appropriate but not restorative treatment, the survival rate was 19.5% ([430]). Brill showed that survival is directly related to timeliness of definitive care in critically injured patients. One could hypothesize that if ambulance crews could determine the difference between restorative and definitive treatment for injured patients in the pre-hospital setting, we could achieve maximal survival for trauma patients. As of yet there have unfortunately been no successful methods which can be applied in the field to determine which injured patients should be treated in the field with ALS techniques and which should receive prompt evacuation to the nearest hospital or trauma center.

Hedges determined factors contributing to on-scene time amongst ALS crews who treated 109 blunt trauma victims. He was able to show a strong correlation between on-scene time and subsequent transport time, which inferred that paramedics were tailoring their on-scene interventions according to hospital distance from treatment site.

Paramedics also spent more time on-scene with patients who had lower TS or GCS. Interestingly, even though on-scene time increased with severity of injury, ALS interventions including I.V. placement, endotracheal intubation, and application of MAST were not predictors of on-scene time ([431]).

Gratton in 1991 tried to determine if it was possible to decrease paramedic scene time in treating physiologically unstable trauma patients by changing the paramedic protocol to allow them to perform certain procedures such as I.V. line placement, administration of boluses, and endotracheal intubation before establishing contact with the base station. He showed that it was indeed not possible to decrease scene time in these patients, which leads us to conclude that the major factor in on-scene time is time to perform ALS procedures, or due to severity of injury – not due to base communication time ([432]).

Donovan in 1989, studying medical cases transported by BLS and ALS crews, showed that the means ± SD scene time for ALS treated cases (14.56±8.88 minutes) was significantly greater than that of BLS treated cases (6.11±2.80 minutes). He showed that the increase in scene time was due to I.V. placement time. ALS patients receiving no I.V. attempts had mean ± SD scene times of 6.63±3.11 minutes, the mean for patients with successful I.V. placement was 19.64±6.87 minutes and for those with I.V. attempts but no success, 19.65±9.50 minutes ([433]).

Sampalis, in 1997, showed that the use of on-site I.V. fluid was associated with an increase in mortality risk in trauma patients. He showed that this is exacerbated by an increase in pre-hospital times, although it was not the only factor. The mean on-scene time for the I.V. group was 23±7.6 minutes, and the mean time for the group not receiving I.V. fluids was 19±95 minutes (p=0.001) ([376]).

The use of on-scene ALS procedures by paramedics leads to an increase in scene time as compared to BLS, 18.5 versus 13.5 minutes respectively in our study (total ambulance runs = 16,107). The extra five minutes that ALS adds to scene time has a detrimental effect on patient outcome. These additional five minutes are detrimental to the trauma patient by delaying time to definitive treatment and the techniques being employed during this time do not appear to decrease mortality.

In addition to increasing pre-hospital delays, the argument against "Stay and Stabilize" is strengthened because none of the specific ALS interventions has been proven to be beneficial for the pre-hospital management of severely injured patients. The rationale for using on-site IV line placement and fluid infusion is that it will control haemodynamic deterioration. The amount of fluid infused, however cannot compensate for the blood lost in a severely bleeding patient, for such cases the definitive treatment is surgery ([403,391,434]). The time required to start an IV on the scene is a matter of debate with certain authors reporting minimal times between 2-4 minutes([406,435,375,436,437,438]) while others show times of 12 minutes or more ([439,418]). There are no controlled studies evaluating the impact of IV placement on patient outcome.

Similarly with IV placement, the effectiveness of on-site intubation in improving outcome of severely injured patients has not been adequately evaluated. The rationale for on-scene intubation is that this intervention will maintain airway patency and oxygenation ([440]). As with IV placement, the argument against intubation is that it causes significant delays to definitive in-hospital care. Contrary to IV placement, however, there is some agreement that in certain severely injured and unconscious patients intubation should be initiated at the scene or en-route ([440],[402],[23]). The only ALS intervention subjected to evaluation by randomized controlled trials is the pneumatic antishock garment (PASG). A series of such studies failed to demonstrate any benefit and in some cases showed an increase in adverse outcome rates associated with the use of this apparatus ([441],[442],[443]).

The unresolved controversy and division of opinion regarding the on-site management of trauma patients is reflected in the regional variation of pre-hospital patient management protocols. This variation is observed quite profoundly in Canada where the type of on-site care available to trauma patients ranges from EMT provided BLS to physician provided ALS. The type of pre-hospital care available to trauma patients is determined by regional policies that are dictated by local political, cultural and economic factors as well as the influential opinion of local experts.

6.10 In-Hospital Care – Characteristics of Trauma Treatment Centers

The categorization of hospital based on their ability to care for injured patients was first suggested by Youmans and Brose in 1970 ([444]). They conceptualized a classification system for hospitals treating injured patients in order to assure quality of care within a community. The initial classification system comprised: "major emergency facilities", "emergency facilities" and "provisional emergency facilities". These classifications later gave birth to level I, level II and level III trauma treatment centers.

Designated trauma centers have been shown to decrease mortality, complication rates, and length of hospital stay compared to non-trauma centers ([234],[243],[244],[445],[446]). Verification has also been shown to improve the process of care within trauma centers ([310],[311],[447]). As a trauma center matures following designation, outcomes have also been shown to improve ([448]). Table 1 describes the trauma center designation structure put forth by the American College of Surgeons Committee on trauma. Table 2 outlines the requirements for trauma center designation by level of designated center ([153]). An overview of a centers role and requirements as part of a system of trauma care follows:

6.10.1 Level I

Level I trauma centers are tertiary care facilities that are the focal point of a regionalized trauma system. These centers often, but not always occur in university hospitals. The facility must be capable of providing leadership and total care for every aspect of injury, from prevention to rehabilitation ([180]). In-house specialties essential for the initial treatment and resuscitation of the injured must be in-house 24-hours a day (general surgery, emergency medicine, anesthesia). Furthermore, other important sub-specialties caring for trauma patients must be available 24-hours a day (plastic, cardiac, thoracic, neuro, and orthopedic surgery, ophthalmology, radiology, critical care medicine, otolaryngology, and obstetrics and gynecology). Level I centers are required to admit at least 1200 injured patients per year and are responsibility for undertaking research and education in injury prevention and treatment. They are expected to be leaders in education, prevention and outreach programs. Level I trauma centers have been shown to be associated with better outcomes for severely injured patients compared to level II centers ([449]).

6.10.2 Level II

Level II trauma centers function in a similar capacity to level I centers, however, they do not have the extensive resources and facilities as level I centers. They are required to provide initial definitive trauma care to injured patients regardless of injury severity. Not all subspecialties treating trauma patients are required, however, the level II center must provide initial treatment and stabilization of all patients. Patients may be transferred to level I centers following stabilization. The level II center is not required to undertake research activities in trauma care, however, needs to be committed to public education in trauma prevention. Data from North Carolina shows that patients with major injuries managed in level II centers can have similar outcomes to those treated in level I centers ([450]).

6.10.3 Level III

Level III centers usually occur in communities which do not have access to level I or II centers. These centers must have the capability to manage the initial care of the majority of injured patients and have transfer agreements and corridors set up for transfer of patients that exceed the hospitals resources and capabilities. These centers must be involved in prevention and have an outreach program for its referring communities. Transfer of severely injured patients from a level III to a level I center is associated with improved outcome compared to transfer from an undesignated hospital ([451]). In a well-functioning trauma system these centers treat patients with low injury severity and a corresponding low mortality ([452]).

6.10.4 Level IV

Level IV centers are those centers treating and stabilizing injured patients in rural areas without other hospitals. They are the "de facto trauma centers" in these regions due to geographical location ([180]). They are responsible for providing Advanced Trauma Life Support care ([171]) in remote areas where no higher level of care is available prior to transfer to an advanced level center. Surgeons are usually not present in these facilities.

Within trauma centers, the development of a designated trauma service or "trauma team" in order to appropriately manage injured patients and supervise their overall care has repeatedly been shown to decrease mortality and improve efficiency ([453],[454],[455]). These services are responsible for the overall care of the injured patient from the moment they arrive at the emergency department door until discharge or transfer to a long term care or rehabilitation facility. They coordinate the care rendered to the polytraumatized patient from multiple consulting medical, surgical, and allied health services teams. The impact these units have demonstrated with regards to the decreased the morbidity and mortality associated with trauma is mostly due to having experienced people deal with this subset of patients, having particular needs and making sure that nothing is missed due to poor coordination from consulting healthcare teams. Trauma teams significantly improve care of the injured patient by providing an organized approach to the care of the multiply injured patient. Surgeons or senior surgical residents are typically in charge of the initial resuscitation of injured patients, however emergency medicine physicians and residents have been shown to produce comparable outcome results ([456]). Although the trauma team is activated for most trauma arrivals in many hospitals with trauma team availability, the appropriateness of this has been questioned in recent years ([457],[179]). Trauma team activation is costly to the system and is a major resource expenditure both in terms of equipment usage, infrastructure and personnel.

Dedicated trauma programs and trauma teams have also been shown to significantly improve outcomes in severely injured patients within trauma established centers ([309],[458],[455]). These programs increase costs and require substantial commitment from both hospitals and healthcare workers, however by having an organized dedicated program caring for all injured patients within a center, leads to decreased mortality, improve process, and reduction in missed injuries.

The presence of in-house coverage by a trauma or general surgeon at level I trauma centers has recently received much attention in the literature. The ACS requires an in-house senior surgical resident to be in-house 24-hours a day to evaluate, resuscitate and manage injured patients. However, many surgeons believe that the presence of in-house staff surgeons improves outcomes and some hospital and trauma systems have required 24-hour in-house staff surgical coverage. The requirement for this has not been evidence-based, is costly to the system and takes its toll on staff surgeons. The new evidence seems to demonstrate that in centers where senior surgical residents initially assess and treat injured patients, and where timely staff backup is available, there is no deleterious effect with respect to outcome ([459],[460],[461],[462]). However, this contentious issue remains unresolved and is heated with much emotion and debate. Similar debate has begun regarding the evidence for the ACS requirement for level I trauma centers to have residency training programs in general surgery to be in-house 24 hours a day. Offner showed that resident participation in the care of injured patients did not affect outcome, however, it did improve efficiency as measured by hospital length of stay and emergency department hours ([463]).

The evaluation and management of severely injured patients requires significant institutional commitment and the commitment of skilled personnel ([17]). Volume has been associated with improved outcome in various surgical subspecialties([221],[227],[464],[465],[466]). Recently, there has been much debate over the American College of Surgeons requirements minimal trauma center volume in order for designation ([153]). Numerous studies have been published over the last few years with conflicting results regarding the correlation between volume and outcome. Several studies have shown that volume has a positive correlation with survival ([467],[468],[469],[470],[471]), however others have demonstrated a lack of association ([186],[246],[472],[473],[474],[475]) . Guidelines for level I trauma center verification require 1,200 admissions per year. Many centers in the US and Canada cannot meet these requirements, however, do meet all other requirements for level I status. If we continue to require centers to maintain certain volume profiles in order to obtain designation and accreditation, shouldn't we first assure that volume indeed has a positive impact on survival?

Cooper looked at risk adjusted inpatient mortality rates following trauma in New York State trauma centers ([473]). He found that the 35 New York State trauma centers not meeting ACS criteria for minimal volume requirements had lower, however not significantly lower, crude and risk-adjusted mortality rates than the 8 centers meeting ACS volume criteria.

6.11 Urban Trauma Care Systems

Urban areas are characterized by large populations concentrated in small geographic regions. The epidemiology of the cause of injury of patients in these areas consists of violent crimes, drug-related crimes, gang warfare and large indigent populations ([18]). These clientele characteristics are the major cause for the overwhelming numbers of trauma centers which have closed in urban areas throughout the 1990s and early part of this decade ([152]). Economic reimbursement from indigent patients and the uninsured for trauma care is difficult to obtain and trauma centers suffer economically for their commitments to treat the injured.

Other important issues in urban trauma care systems are the viability of trauma surgery as a specialty in these times of decreasing penetrating injuries and increased utilization of non-operative management. Patton and Woodward examined the effect of these issues on the viability of urban trauma centers and found that although trauma center admissions at their level I facility are on the decline, patient age and injury severity remained unchanged and the operative productivity of trauma surgeons remained unchanged over the five year period between 1995 and 1999 ([476]).

6.12 Rural Trauma Care Systems

Rural trauma care systems face unique problems. These problems are related to the fact that the areas encompass great land mass, however contain a minority of the population. This contributes to prolonged transport times, difficult patient access, sparse populations, small hospitals and limited financial and human resources ([373,477]). All of these hurdles contribute to poor outcomes, however, the common denominator in poor outcome is time to definitive surgical care ([478]). Dr. Eastman makes an accurate and important point in his paper from 1992: "Blood in our Streets – The Status and Evolution of Trauma Care Systems" ([18]). He states that the "*grave mistake thus far has been the attempt to impose the "urban model" on the rural area.*" He goes on to write that "*this has led to a sense of defeatism and has impeded the development of rural trauma care systems.*" Dr. Eastman later calls for a "*system that addresses the specific needs of rural America. The critical feature will be the linkage between existing systems and sharing of resources.*"

Rural trauma systems have not received as much attention or funding as urban systems and little is known about the applicability of urban research and data to rural settings ([479]). Rogers calls rural trauma the "neglected disease of the nineties" ([480]), a reference to the white paper's claim that trauma was the neglected disease of the sixties and seventies ([109]). He points out that 21,413 manuscripts were published on trauma related topics since the white paper in 1966, however only 270 of them (1.2%) are specifically related to rural trauma. The lack of investigation of the needs of rural communities with regard to injured patients occurs in spite of the fact that rural accidents are two-times as likely to result in death compared to accidents occurring in urban areas ([481]).

Rural communities cannot be expected to fit the urban model of trauma system care and must have systems designed to fit their specific needs ([482],[483]). Patients injured in rural areas have different demographics and injury patterns than their urban counterparts ([242]). Emphasis should therefore be placed on maximizing basic principles needed to save life and limb and creating rapid corridors to definitive care. It is ineffectual to waste resources and time trying to acquire and set up highly sophisticated training programs and equipment installation in rural areas. Most patients who die unnecessarily in rural areas can be saved with relatively straightforward and basic techniques. Waller notes that in rural areas the "*need is not for activities that require more money or scarce personnel, but rather for different organizational patterns*" ([484]). Unfortunately, most of the work regarding trauma systems and trauma centers has been concentrated on urban areas.

The differences between urban and rural trauma patients is highlighted by the fact that in urban areas, initial stabilization at non-trauma centers has been repeatedly shown to poorly impact on outcome ([136],[162],[174],[485]), whereas in rural centers initial stabilization and subsequent transfer is necessary secondary to long pre-hospital times and low population densities. Furthermore, initial stabilization and subsequent transfer does not negatively impact on outcome in rural areas ([486]). Sub-categorization of rural trauma centers as level III, IV and V in order to guide transfer of patients has also come under scrutiny ([487]) as the benefits of this strategy have not been based on evidence.

The evidence concerning trauma system effectiveness in rural areas is conflicting. Mann showed that mortality among seriously injured patients treated in nine remote rural counties in Oregon (ACS level III and IV hospitals) did not improve following trauma system implementation ([488]). This occurred in a state where significant improvement in survival had been previously demonstrated in urban areas following regionalization of care ([237],[238],[239]). The same group also demonstrated improvements in process of care following trauma system implementation in rural trauma centers based on review of diagnostic and therapeutic interventions taught in the ATLS course ([489]).

Trauma regionalization has been shown to be valuable in rural settings and leads to decreased mortality compared to non-regionalized areas. In rural areas without regionalized trauma care, the rural hospital plays a major role in the care of all severity of injured patients ([490]). All injured patients are taken to the closest hospital and are then transferred, if necessary, to more equipped centers. Implementation of a regionalized system in a rural area leads to a redistribution of patients, with severely injured patients being transported and transferred to hospitals with greater resources and trauma care capabilities ([491],[492]). Regionalized trauma care and trauma center designation has also been shown to prevent mortality in rural areas ([493],[494],[495],[496]) and this beneficial effect occurs irrespective of patient volume ([494]). Esposito studied preventable trauma deaths and inappropriate care in a rural state without regionalized trauma care (Montana) ([252]). He found that the overall preventable death rate (pre- and in-hospital) was 13%, in-hospital preventable death rate was 27% and the overall rate of inappropriate care was 33%. These results are not dissimilar from those reported in other rural ([251]) and urban areas lacking regionalized trauma care ([156],[217],[136]). Esposito later evaluated the effect of trauma system implementation in the rural state of Montana ([497]). In Montana preventable death rates decreased following implementation of a regionalized trauma care system from 13% to 8%. He was also able to demonstrate decreases in inappropriate care.

Karstead identified 266 severely injured patients in a rural area with regionalized trauma care (North Coast EMS region of California) over 3 years ([498]). Key components of the rural trauma program included: (1) warning of the receiving hospital of the impending arrival of a trauma patient using triage criteria; (2) early mobilization/activation of a pre-organized trauma team in the emergency department; and (3) improved efficiency by regional hospitals and pre-hospital care providers through system review and modification. Mean pre-hospital time in this rural system was 55 minutes. There was a significant reduction in mortality in the rural trauma system compared to the MTOS (z-score= -2.33, p=0.02). This study supports the notion that a systematic approach to a region with limited resources improves outcome for injured patients.

Zulick evaluated the outcomes following trauma in a level II rural trauma center in Cooperstown, New York using TRISS methodology ([495]). Mean transport time for non-transferred patients was 1.6 hours. He found that mortality for patients being treated at a level II trauma center in a rural area was comparable to patients with similar injury severity being treated at level I centers (Z = -0.9). Wenneker observed improvements in preventable death rates (42% to 14%, p<0.025), surgeon's response time and time to surgery following designation of a level II trauma center in a rural area (Napa County, California) ([496]). These improvements occurred despite increased injury severity scores. Norwood observed similar improvements in outcome following implementation of ACS level II criteria in a rural based hospital in northeastern Texas ([499]). Norwood demonstrated outcome results that exceeded MTOS standards in a rural-based level I trauma center in Urbana Illinois ([500]).

Mullins found that there was no survival benefit for seriously injured patients by categorization of hospitals in rural areas with ACS trauma center criteria ([487]). These results were found when comparing a rural area with rural trauma center categorization (Oregon) to one without (Washington). The results in the two differing rural systems were probably secondary to the fact hat in both systems, a large proportion of seriously injured patients were being transferred from rural to urban centers (Oregon - 63%, Washington – 70%). Rogers showed similar results in Vermont which is a rural state without a statewide formal trauma system ([501]).

6.13 Pediatric Trauma

Injured children represent 25% of all injured patients in the United States ([312]). One out of every two children who dies in the United States dies secondary to injury ([502]). Regionalized trauma care systems have also been studied to assess their effect on outcomes in the injured pediatric population. In 1980-82, Ramenofsky examined 100 consecutive pediatric trauma deaths in Mobile, Alabama ([503]). He found that 53 patients were potentially salvageable and attributed their mortalities to deficiencies in six separate phases of the EMS/trauma system.

Pediatric trauma care services have evolved from experience in the care of adult trauma patients ([502],[504],[505]). However, it was not until the 1970s that it was realized that children, like adults should be included in a comprehensive trauma system ([506]). Due to the fact that there is considerable overlap in the treatment and resuscitation between pediatric and adult trauma patients, most children's regional trauma programs have been developed as part of the overall emergency medical system of trauma care. Furthermore, there is little evidence that trauma systems impact positively on the outcome of injured children ([507]).

In 1999, Hulka performed a comprehensive critical review of the literature concerning pediatric trauma system and trauma center effectiveness ([508]). There was no consistent high-level evidence suggesting that trauma systems or pediatric trauma centers were beneficial to the outcome of injured children. The results of this study should not discourage healthcare authorities and physicians providing trauma care to injured children from believing in systematic trauma care for injured children, rather they should encourage further evaluation of pediatric trauma care and raise the point that the organization of trauma care for children can probably not be correctly evaluated, nor can the system be set up and run in the same way as that of adult trauma systems. Obviously regionalized adult and pediatric trauma systems co-exist, however we must recognize and evaluate the important differences between these two groups of anatomically, physiologically and emotionally different populations.

The influence of a statewide trauma system on pediatric hospitalization and outcome was assessed by comparing outcomes from a state with regionalized trauma care (Oregon), to one without regionalized care (Washington) ([235]). Seriously injured children in both states had lower likelihoods of being admitted to rural hospitals than adult patients. The risk-adjusted odds of dying for severely injured children in Oregon (regionalized trauma care), was significantly lower than in Washington (no regionalized trauma care).

Organized trauma systems appear to improve outcomes in the pediatric population ([503], [509], [510], [511], [512], [513]). Haller evaluated the influence of a regionalized trauma system on pediatric trauma outcomes ([509]). Over seven and a half years, more than 1000 severely injured children with life threatening injuries were preferentially transported to a level I regional pediatric trauma center in Baltimore, Maryland. Haller showed that mortality following pelvic fractures in this pediatric population had a mortality of 1.4%. This is significantly less than reported mortality from similar injuries in non-regionalized pediatric hospitals. Furthermore, they were able to show excellent morbidity results and long-term outcome results for children with severe head injuries using a regionalized approach to pediatric trauma care. Unfortunately, there was no comparison group in this study, however, these results are still very encouraging.

Outcomes following trauma do not seem to be influenced by trauma center volumes in the pediatric population ([474]). Furthermore, Osler evaluated the outcomes of injured pediatric patients treated at specialized pediatric trauma centers throughout the United States and compared them to pediatric patients treated at adult trauma centers ([514]). He found that although pediatric trauma centers were associated with decreased mortality, the patients treated at these centers were less severely injured. After adjusting for injury severity score, pediatric trauma score, age, mechanism of injury and ACS verification status, there was no difference in survival between dedicated pediatric trauma centers and adult trauma centers treating injured children.

Many pediatric surgeons believe that injured children are best cared for at pediatric trauma centers ([509,515]). Knudson tackled the question of whether pediatric trauma patients could be adequately managed at adult trauma centers ([516]). She compared injured children treated at a level I trauma center which cared for patients of all ages to MTOS outcomes. TRISS analysis demonstrated a major survival advantage for these children compared to MTOS standards (only 2 unexpected deaths, 7 unexpected survivors over a 30-month period). TRISS methodology has been validated in the pediatric trauma population ([517]).

6.14 Geriatric Trauma

The elderly are taking a more prominent role in trauma systems. Males 0-39 years old were the number one group admitted to hospital secondary to injury in 1980, the number one group admitted to hospital secondary to injury in 1999 was females greater than 65 years old ([518]). Between 1992 and 1995, 147 million injury-related visits were made to emergency departments in the United States. Twenty-four percent of the visits were due to falls, making falls the number one cause of external injury ([519]). Patients injured in falls are more often elderly ([8]) and require longer hospital stays than younger patients ([520,521]).These patients also have been reported to have lower mortality rates, due to lower injury severity ([156]). However, many studies have shown a correlation between high mortality rates in geriatric patients and co-morbid conditions as well as in-hospital complications ([522,523,524,521]). Amongst elderly patients, those older than 80 years old have worse functional outcomes than those between 65 and 80 ([58]).

Trauma systems have not been designed with the geriatric patient in mind. This is underscored by the fact that injured geriatric patients (>65 years old) with equivalent injury severity indices, have higher case fatality, complication rates and longer hospital length of stays compared to patients under 65 years of age ([525]). Severely injured geriatric patients have been shown to benefit from regionalized trauma care. In a retrospective before and after study, Mann was able to show a 5.1% increase in 60 day survival for geriatric patients with ISS > 15 during the implementation phase of a trauma system in Washington compared to the pre-regionalization period ([526]).

Geriatric patients experiencing traumatic injury have increased length of hospital stay and hence increased direct health care utilization ([521],[523],[527],[528]). Surgical and emergency room costs in trauma centers are primarily related to the length of patient stay ([529]). The length of stay for geriatric patients following trauma is longer when compared to that of younger patients and is likely due to increased rehabilitation needs and waiting time for convalescence placement ([521]).

Our group performed a retrospective study consisting of major trauma patients in four tertiary trauma centers in Quebec between April 7, 1993 and March 31, 2000 ([176]). A total of 29,669 trauma patients fulfilled eligibility criteria and were included. During the seven years of the study, there was an increase in the volume and presentation of patients injured in falls ($p<0.01$), patients with extremity injuries ($p<0.01$), single injuries ($p<0.01$) as well as injuries to single body regions ($p<0.01$). Patients injured in motor vehicle collisions were mostly young and had multiple injuries of high severity as opposed to elderly patients who were for the most part, injured in falls and experienced isolated injuries of low severity. There is an overwhelmingly high proportion of elderly patients injured in falls, experiencing isolated extremity injuries of low severity being treated at tertiary trauma centers. Revision of pre-hospital triage protocols should be considered and studied in order to transport trauma patients to appropriate facilities.

The increasing numbers of patients treated for isolated orthopedic injuries following falls at tertiary trauma centers in Quebec is important, both in terms of allocation of resources and quality of care. Falls are usually associated with older age and, in most cases, involve single injuries to extremities ([530]) as well as low injury severity scores, as demonstrated in this study. The majority of these injuries are isolated long bone or pelvic fractures, requiring the care of an orthopedic surgeon and not a Level I trauma center with specialized general surgeons, neurosurgeons, nursing and intensive care resources. Finelli et al. showed that mortality in geriatric patients increases with age for all injuries, with the exception of falls ([523]).

The geriatric patient who suffers any injury is at increased risk of mortality and requires prompt specialized care due to lower physiologic reserves and decreased ability to handle physiologic stress. Patients injured in falls tend to be older and have fewer and less severe injuries. However, because of co-morbid conditions, the risk of complications and mortality is high in this population. As a result these patients consume a significant proportion of the resources available at tertiary trauma centers due to the requirements for specialized care, rehabilitation and longer hospital stay ([531,528,523,59,521,527]). The issue is whether these patients require treatment at a tertiary trauma center as opposed to a secondary or less specialized center.

In a study done by Oreskovich et al., only 7 out of 100 consecutive trauma patients over 70 years old were independent for their activities of daily living at one year post injury, compared to 96 patients pre-trauma ([59]). Seventeen (20%) of these patients required home assistance following discharge from hospital, whereas 61 patients (72%) required full nursing home care. The low functional outcome for elderly patients admitted to trauma centers contributes to the increased length of stay while patients are awaiting beds in rehabilitation centers and nursing homes. This waiting period is a major source of prolonged length of stay and inappropriate use of acute care beds in tertiary trauma centers.

In view of the higher requirements of this population for specialized geriatric care, longer hospital stay and prevalence of pre-existing chronic co-morbid conditions, the resource allocation of a tertiary trauma center for the post-acute care management of these patients may indeed be counter cost-effective. Trauma care at tertiary trauma centers would be more efficient and the multiple resources that comprise a regional trauma program would be best used if haemodynamically stable patients with isolated orthopedic injuries of low injury severity could be treated at secondary centers or at secondary centers specializing in the care of the elderly. At this point, a more extensive analysis of this population is warranted in order to verify if indeed these patients could be treated without the multidisciplinary resources of a tertiary trauma center while ensuring an adequate level of care.

6.15 Trauma Registries

Trauma registries, databanks or databases are repositories for information regarding the care and outcome of injured patients. The term "Trauma Registry" refers to a data system created either in an institution or on a regional level, with its primary purpose being the evaluation of trauma care ([532]). These registries are vital to the quality improvement programs which are vital to assuring high-quality and appropriate outcomes and process of care within a trauma center and within a trauma system ([533],[534]). Registries generally receive patient care and outcome information from trauma centers involved in the care of injured patients and are maintained or administered within trauma centers themselves, at the coordinating center for the trauma system, within the state or province or even at the level of the entire country. Many centers and systems contribute data to their own local database (usually by hospital or state/province) as well as to a national database. Information related to injuries includes facts/data related to the patient's injury event, the injury severity, the pre-hospital care of the patient, the in-hospital care of the patient, the process of care and the outcome ([26]). The terms "data element", "data point", and "variable" are used interchangeably when describing information entered and contained in a trauma registry ([532]). Early registries mainly consisted of mortality as outcome data ([38]). However, as these databases mature and more and more research is being done into the process and outcomes of trauma care, there is a push to include more detailed morbidity indicators, complications, post-discharge follow-up data and quality of life indices. Many registries are now including many or all of these items.

Hospital-based trauma registries serve multiple purposes including: outcomes research, quality improvement, injury epidemiology, injury surveillance, clinical research applications, injury and treatment trend analysis and evaluation of resource utilization ([532,535]). The ultimate goal being the acquisition, management, and use of information on the injury severity, care and outcome of injured patients in order to improve individual provider, institutional, and system performance as well as patient care and outcome. Regional, Statewide and National registries are more often used in trauma system evaluation and for epidemiology and surveillance ([536,537]).

The main purpose of a hospital trauma registry is to obtain, code, sort and score the information required for these registries. Further to these functions, the trauma registry has the role of reporting individual and aggregate results of the ongoing evaluation process. A trauma registry can provide important information about costs and benefits of and intervention ([26,538]). In the current climate of health care reform and cost containment these data are vital to making cost-efficient and efficacious decisions regarding the entire process of care of the injured patient, from injury prevention to the moment of injury to post-hospital discharge rehabilitation. Implementation of an inclusive trauma system improves in-hospital trauma patient documentation and hence improves trauma registry quality ([539]).

The first computerized trauma registries were conceptualized and developed in the United States in the early 1970s ([540],[541],[542]). These registries enabled the Major Trauma Outcome Study (MTOS) which was the first registry based outcome study. It was a retrospective descriptive study consisting of injury severity and related outcome ([259]). Between 1982 and 1987, 139 hospitals in the United States and Canada submitted demographic, etiologic, injury severity and outcome data to the study which included data on 80,544 injured patients. The study established norms for trauma outcome which systems and hospitals were able to use in order to compare themselves. This tremendous effort and benchmark study, published in 1990 is the standard to which trauma systems compare themselves until today.

The type of registry software used varies widely between trauma centers in the United States ([316]). In 2002, Collector (Digital Innovation, Inc, Forest Hill, MD) was used in 27% of trauma centers, followed by Trauma One (Lancet Technology, Inc, Boston, Mass) (13%) and Trauma! (Digital Innovations, Inc) (13%).

Trauma registries contain different data points and these data points need to be checked to assure accuracy and completeness at regular intervals. In a study reporting the completeness of data entry on a total of 18961 trauma registry records in the Florida trauma system, complete records were found in only 22.8% of patient entries over 1 year ([543]).

Registries typically classify and code injuries and death based on the International Classification of Diseases, Injuries and Causes of Death (ICD) manual, which is now in it's ninth edition (ICD-9) ([544]). For hospitalized patients or deaths caused by either injury or poisoning, the ICD-9 provides "external cause" of injury codes, or E-codes, to which the underlying mechanism related to the injury is assigned. Trauma related injuries are represented by codes E800 to E999 which allow researchers and hospitals to precise information on the mechanism of injury which caused the accident.

Even though registries have been shown to have many shortcomings ([277],[545]), they remain the backbone for quality assessment activities in monitoring regional trauma care systems. Without them, most of the advances and improvement in patient outcomes seen with regards to trauma systems, could not have been accomplished ([546]). They remain the backbone of quality assurance in regionalized trauma care.

6.15.1 Quebec - Quebec Trauma Registry (QTR)

The Quebec Trauma Registry was established in 1993. All trauma centers throughout the province of Quebec collect data on trauma victims that are then submitted to the Registry. The primary goal of the registry is to improve the quality of care for trauma victims. By applying statistical methods to data from the registry questions to many clinical questions have been answered and new hypotheses formulated. The registry was therefore designed not only to improve quality of care, but to improve the process of care, decrease injury morbidity and mortality and in quality assurance. At the present time, there are a total of 59 centers in Quebec contributing data to the registry. These consist of: 6 tertiary centers (4 adult, 2 pediatric), 25 secondary and 28 primary centers.

Inclusion Criteria:

- Death as a result of injury
- Admission with hospital stay ≥ 3 days
- Admission to the ICU
- Interhospital transfers

Exclusion Criteria:

- All injuries with the primary diagnosis consisting of: intoxication, drowning, electrocution and burns

- Admissions secondary to a complication of injury

The Registry database was constructed in Paradox®. There are sixty-seven individual tables with injury data in the database. The same data is collected in all the participating trauma centers. Data entry is performed by qualified personnel at each hospital during the admission and is completed following patient discharge. Medical archivists and specific trauma registry personnel abstract the data from the patient's chart once the entire chart has been completed and all test results and medical summaries are intact. Computerized edit checks are performed on a regular basis to ensure that the data are complete and accurate. Reports are produced on a yearly basis.

6.15.2 Canada - National Trauma Registry – (NTR)

The Canadian Institute of Health Information (CIHI) in conjunction with the Trauma Association of Canada (TAC) launched the Canadian National Trauma Registry (NTR) in 1997. Data are submitted by hospitals in all Canadian Provinces and Territories. Deadline for data submission is the end of June of each year in order to be entered in the CIHI's annual report. The goals of the NTR are to ([547]):

- Contribute to the reduction of injuries and related deaths in Canada by providing data which allow the examination of national injury epidemiology
- Facilitate provincial and international injury comparisons
- Increase awareness of injury as a public health problem in Canada
- Assist injury prevention programs
- Facilitate injury research

The NTR currently contains two separate datasets. The Minimal Data Set (MDS). And the Comprehensive Data Set (CDS). The MDS is created using the Hospital Morbidity Database (HMD) at the CIHI which contains demographic, diagnostic and procedural information on all admissions secondary to injury in Canada. The sources for the MDS include CIHI's Discharge Abstract Database (DAD) for all provinces except Manitoba, Quebec and Saskatchewan, which do not submit all inpatient discharge abstract to CIHI. For these three provinces, data is submitted from hospitals to the provincial Minister of Health, who then submits them to the CIHI. Selection of patients to be included in the MDS is based on specific external cause of injury codes (E-codes). A list of CIHI E-Code inclusions and exclusions can be found in tables 5 and 6, respectively. A third dataset, the death data set is currently under development. It will include data on all deaths in Canada as a result of injury, regardless of hospitalization. There has been a recent attempt at benchmarking the Canadian dataset for comparative and research purposes ([548]).

The CDS includes data on injured patients with major trauma treated in 23 acute care hospitals throughout Canada. Inclusion criteria for the CDS include ([549]):

- Injury Severity Score > 12
- An appropriate External Cause of Injury Code (E-code) (Tables5 and 6)
- Patient was treated at an acute care facility (tertiary care center)
- Admission to hospital is not an inclusion criteria; patients who meet the above inclusion criteria and who are treated in the Emergency Department (ED) and discharged home or transferred to another acute care facility can be included.
- Patients that are Dead on Arrival (DOA) are excluded, whereas patients that Die in Emergency departments (DIE) are included.
- DIE is defined by a patient who dies in the ED following any active treatment or resuscitation by the trauma team or ED physician after the patient enters the ED.

6.15.3 United States - National Trauma Databank (NTDB)

The largest trauma registry in the world is the American College of Surgeons National Trauma Databank (ACS – NTDB). The foundations for this database consisting of data on injured patients from all over the United States were laid down and conceptualized in 1966 in the National Academy of Sciences / National Research Council's "white paper" ([109]). The NTDB is designed to provide national and regional benchmarking for use in trauma center and trauma system performance improvement, as well as to provide data for trauma-related clinical research ([550]). It was started in 1989 and now contains over 450,000 cases form 130 trauma centers in 28 US states and territories. These 130 centers represent 25% of the level I and II centers in the United States. The annual call for data goes out in March of each year to all participating trauma centers. Data received by the ACS by July 1 are included in the Annual NTDB Report, distributed every October.

The goals set out by the ACS for the NTDB are to ([551]):

- Improve the quality of patient care
- Provide an established information system for the evaluation of injury care and preparedness
- Develop better injury scoring and outcome measures
- Provide a rich source of data for clinical benchmarking, process improvement, and patient safety

Inclusion criteria required for patient entry into NTDB include ([552]):

- Patients with at least one injury ICD-9 diagnosis code in the range of 800-959.9 (injury code as a result of a traumatic event, excluding poisonings and drownings), excluding 905-909 (late effects of injury), 930-939 (foreign bodies), and 958 (early complications of trauma).
- At least one of the following:
    - Admission > 24 hours
    - Dead on arrival (DOA)
    - Patients who die after receiving any treatment while on hospital premises
    - Patients who are transferred into or out of the hospital

The American College of Surgeons Committee on Trauma's NTDB utilizes NATIONAL TRACS® software for the collection, storage, analysis and reporting of data concerning injured patients throughout the United States. Work on TRACS commenced in 1991 and it was unveiled in 1992. It is a commercial microcomputer-based software package providing data capable of supporting and with its main goals to facilitate:

- Treatment and prevention of injury
- Quality assurance
- Cost effectiveness of care
- Trauma reimbursement
- Outcome-based trauma care research

NATIONAL TRACS software was developed at the request of the Committee on Trauma by the Software Development Group, which is comprised of a group of interested trauma surgeons, coordinators and registrars, and is funded by the ACS. It allows individual hospitals to enter data into hospital-based computerized trauma registries, which then is easily submitted to the NTDB for compilation of the National Trauma Registry.

The hope is that eventually there will be an inclusive national trauma registry throughout the United States. However, in the near future this seems improbable, if not impossible. In 2004, 32 states reported active trauma registries ([553]). Unfortunately the quality, quantity and datapoints are not equivalent across the registries.

6.15.4 United States - National Pediatric Trauma Registry (NPTR)

The National Pediatric Trauma Registry (NPTR) is a multi-institutional database which collects information on pediatric trauma patients from all over the United States ([554]). Forty-four hospitals contribute data to this database. Twenty-two (48%) are designated trauma centers. Every hospital submits data on three paged registry forms that are completed for all children admitted with injury as a primary ICD-9 diagnosis.

6.16 Injury Severity Scoring Systems

Trauma scoring systems allow a comparison of the outcomes of a single institution, a group of institutions, a regionalized area, or a province or state's outcomes to a national standard. They are further used within centers or systems for quality control outcome analysis and research reporting. The two major approaches to injury severity classification include evaluation of anatomic injury and physiologic status of the injured patient, or some combination thereof ([555]).

6.16.1 Glasgow Coma Scale (GCS)

The first injury severity scoring system devised was the Glasgow Coma Scale (GCS), developed by Teasdale and Jennett in 1974 ([556]). This system was designed to evaluate the severity of injury in patients with head injury. The GCS started off with three elements; best motor response (5 elements), best verbal response (5 elements), and eye opening (4 elements). In 1977 the GCS underwent one change, with the addition of a single element to the best motor response bringing the overall score up from 14 to 15. The score decreases with increasing severity of injury (Table 7). The scoring system has many limitations including its inability to precisely evaluate coma and insufficient intervals for evaluating many disease states. However, it is extremely simple to apply and reliable in untrained hands. A study out of New Jersey was able to demonstrate high sensitivities for the motor component of the GCS alone and the authors suggested that only this component be used in pre-hospital triage schemes in order to simplify on-scene triage decisions ([557]) this was confirmed in Australia in a cohort of multi-casualty patients ([558]). The GCS has been found to have poor correlation with the head component of the AIS ([559])(see next section – AIS).

6.16.2 Abbreviated Injury Scale (AIS)

The need for a standardized scoring system for characterizing injuries secondary to motor vehicle collision was established in the 1960s when the first generation of motor vehicle collision research teams began studying trauma as a disease. In 1970, the American Medical Association Committee on Medical Aspects of Automotive Safety along with the Association for the Advancement of Automotive Medicine (formerly the American Association for Automotive Medicine) and the Society of Automotive Engineers coordinated and effort to develop a method for quantifying injuries sustained in motor vehicle accidents ([560,561]). In 1971, the Abbreviated Injury Scale, or AIS was born. It is based on a dictionary created based on expert judgment of the severity of various injuries ([562]). The AIS was modified in 1974 ([563]) and 1975 ([564]). In 1976, the first AIS dictionary of injuries was published (containing >500 injuries) ([565]). In 1980, further modifications improved the coding of head injuries and adjustments in scoring based on outcome ([566]).

The original construction of the AIS was in order as an assessment tool for injury severity. However, the evolution of the concept of trauma care systems and the creation of trauma registries for use in outcome assessment fostered expanding of the AIS to areas outside motor vehicle collisions, including penetrating trauma. The 1985 revision addressed these issues and additions were made, primarily in the areas of vascular trauma and integumentary injuries ([567]). It also expanded on the range and severity of injuries in order to allow easier, more precise coding.

The 1990 revision of the AIS (AIS-90) were designed to improve the system based on two decades of research on and using the system ([568]). The AIS-90 includes specific rules for coding as well as solutions to several coding dilemmas previously identified by users of the system. Also, synonyms and parenthetical descriptors were added in order to ease coding of certain injuries. Pediatric injuries were reclassified in certain circumstanced, based on the differing severity of certain injuries from adult injuries.

The AIS assesses injury based on a scale of 1 (mild), 2 (moderate), 3 (serious), 4 (severe), 5 (critical), and 6 (fatal / unsurvivable) in each of eight body regions (head, neck, face, abdomen, thorax, upper extremities, lower extremities, spine). The AIS code for each injury a patient sustains consists of a six digit numerical code, along with a decimal to indicate the AIS severity code (see below). The AIS, however, is deficient in its ability to describe multisystem injuries. The AIS system is crucial in the calculation of the ISS (see below).

AIS Coding = A B CD EF . G

A: Body Region Injured
B: Type of Anatomic Structure Injured
CD: Specific Anatomic Structure Injured
EF: Level
G: AIS Severity Code

Recent evidence shows that the worst injury may be able to better predict outcome and provide better discrimination and regression model fit than a combination of AIS scores (see ISS, NISS) ([569]).

6.16.3 Injury Severity Score (ISS)

In order to overcome the deficiencies of the AIS in evaluating multiple trauma, the Injury Severity Score (ISS) was developed by Baker in 1974 ([264,570]) and revisited by Copes in 1988 ([265]). To date, it is the most widely utilized methodology for grading injury severity. The best application of the ISS is to provide a method to control for the variability in trauma severity in outcomes research ([571]). The ISS is derived by taking the three highest AIS score, squaring them and adding the sum of the squares. The minimum ISS is one (low severity injury) and the highest score is 75 (high severity injury). Even though the ISS is scored as a continuous variable, it must not be used as one in statistical analysis and evaluation of patient severity. An ISS of 18 is clinically no different than one of 19 or 20 and therefore ISS values should be grouped into broad categories in order to correctly identify groups of injured patients. Various authors and groups have used diverse ISS categorizations in the past. The most popular are: 1-15, 16-24, ≥25 and 0-12, 12-25, 25-50, 50-75. The ISS score has been shown to be well correlated with mortality, however less so for penetrating injuries.

The ISS performs well for both blunt and penetrating injuries ([572]). It has been evaluated by numerous skeptics and attempts have been made to discredit its usefulness and appropriateness in the contemporary setting ([250,573,574,575,576]). Rutledge demonstrated how in some cases, the ISS was unable to differentiate between inappropriate and poor care and injury severity ([574]). It is however, still the best system available for comparing injury severity amongst groups of patients and for controlling for case-mix variations between injured patient populations. It has been and still is the most widely utilized system in the literature ([112]).

Whereas the Injury Severity Score (ISS) is utilized for grading injury severity in the English speaking world, the Polytrauma Schlüssel system (PTS) was established and is utilized in German speaking countries ([334]). It has many similarities to the ISS.

Trauma systems are a relatively new innovation in the care of the trauma patient. As these systems continue to evolve and more regions are adopting and developing the concept of the systems approach to the care of the injured patient, research and new innovations are constantly becoming available. One of the fundamental elements of all trauma systems and of trauma care since the beginning of time is the concept of triage and transport of patients from the site of injury to the site of care. The continued interest in triage systems has resulted from the problem of getting the right patient to the right hospital at the right time ([577]).

The New Injury Severity Score (NISS) was developed in order to circumvent the problem with the failure of the ISS to account for multiple injuries in a single body region. The NISS incorporates the three most severe injuries (highest AIS scores) regardless of body region ([578]). Therefore, if a patient has three severe injuries in a single body region, they are all accounted for. The NISS has been shown to be a more accurate predictor of short-term mortality than the ISS ([579]). Two studies have demonstrated better discrimination and calibration for the NISS compared to the ISS ([579,580]), one has observed better calibration but equivalent discrimination ([581]), and three showed no advantage for the NISS ([582,583,584,585]).

6.16.4 TRISS

Based on the TS, the ISS, and age, Champion developed a tool for predicting trauma patient mortality ([267,343]). The TRISS method involves logistic regression modeling to predict survival for each injured patient. Predictions are made based on the patient age (over or under 55), ISS, and the RTS. Each measure is weighted by a formula derived from the outcomes and demographics of patients in the Major Trauma Outcome Study (MTOS) ([259]) which is comprised of approximately 160,000 trauma patients treated between 1982 and 1989 at 139 hospitals throughout the United States and Canada.

Statistical details and interpretation of results based on TRISS analysis are discussed in section titled – The Impact of Trauma Care Regionalization. Other more recent models for predicting trauma outcomes have been published ([586]), but as of yet have not gained even close to the popularity that TRISS has in the literature.

In brief, statistical methods used to evaluate trauma outcomes using TRISS methodology the *Z-score*, *M-score* and the *W-score*. The *Z-statistic* described by Flora, compares outcomes between two subsets of a population of injured patients ([269]). It quantities the actual number of deaths in the test population and the predicted number of deaths based on MTOS norms. A negative *Z-score* implies that the number of deaths predicted from the baseline population exceeds the number observed in the test population. A positive *Z-score* implies that the test population had excess mortality compared to the MTOS cohort.

The *M-statistic* is a measure of the injury severity "match" between the study population and that of the baseline population (MTOS cohort). Values range between zero and one. The closer the *M-statistic* is to one, the better the match of injury severity. The *W-statistic* was developed to further analyze a population with a statistically significant *Z-score* and to standardize comparisons between trauma centers with varying patient volumes ([587],[577]). The *W-statistic* gives the average in the number of survivors per 100 patients as compared with the population norm. Non-statistically significant populations (Z-scores) are assigned a *W-statistic* of zero.

TRISS methodology has been shown to be an accurate measure of assessment of hospital performance when compared to national norms, however it is an inappropriate measure for comparing outcomes between trauma centers ([588]). It is currently the most widely used trauma scoring system and outperforms most other systems in predicting mortality ([589]).

6.16.5 International Classification of Diseases 9th Edition Injury Severity Score (ICISS)

The International Classification of Diseases Injury Severity Score (ICISS) was developed by Osler in 1996 ([590]) and is based on the ninth edition of the World Health Organization's *International Classification of Diseases* (ICD-9) nomenclature system for hospital coding ([544]). The ICISS score is based on calculated survival risk ratios (SRR) using the North Carolina Trauma Registry for each ICD-9 code. The SRR is calculated by dividing the ICD-9 code occurs in a surviving patient by the total number of times the code occurs in the database. The ICISS score is calculated by multiplying all the SRRs for a given patient. In a group of 3,142 injured patients treated in New Mexico, the ICISS outperformed the ISS at a highly statistically significant level ($p<0.0001$) ([590]). ICISS had a lower misclassification rate and a higher receiver operating curve characteristic than the ISS. ICISS was also validated and evaluated using 821,455 patients hospitalized in North Carolina. It was found to be an extremely accurate predictor of hospital survival (accuracy 95.9%) ([591]).

Hannan was better able to predict survival with the ICISS compared to TRISS in patients with blunt injuries using the New York State Trauma Registry data ([575]). Similar results were demonstrated in New Mexico ([590]). Furthermore, ICISS is a better predictor of resource utilization, hospital length of stay and hospital charges compared to the ISS and TRISS ([592,593]). It has also been shown to be more accurate and less expensive to calculate than the APACHE II ([594]) and outperforms both the established diagnosis related group (DRG) system and the 3M product APR-DRG as a predictor of survival, hospital length of stay and cost ([595]).

The ICISS has been shown to be a better predictor of survival compared to the ISS and TRISS ([592]), however, this is not the only attractive feature of the ICISS over the ISS. The ICISS is based on ICD-9 coding and therefore does not require AIS coding by trauma registry personnel. It therefore removes an additional element of error in coding as well as the obvious economic advantage of relying upon hospital records ICD-9 coding as opposed to trauma registry recorded AIS values for predicting survival and assigning injury severity.

6.16.6 A Severity Characteristic of Trauma (ASCOT)

Champion attempted to improve on the accuracy of TRISS in predicting mortality by developing A Severity Characteristic of Trauma (ASCOT) scoring system in 1990

[596]. The ASCOT was based on Anatomic Profile, which is a system devised based on AIS scores. The Anatomic Profile encompasses four components: A – head, brain and spinal cord injuries; B – thoracic and anterior neck injuries; C – all other major injuries; and D – all minor injuries. Any AIS score > 3 in each category are squared and summed in order to get the final ASCOT score. Component D was found to be unhelpful in predicting mortality and was therefore dropped form the final ASCOT system. Age characterization was stratified and based on five broad categories. ASCOT is used to determine a probability of survival, similarly to TRISS, using age, RTS and Anatomic Profile. Various studies have compared TRISS to ASCOT in ability to accurately predict survival in trauma patients. There have been three well conducted studies which showed an advantage for ASCOT over TRISS ([597],[598],[599]). Unfortunately, when TRISS and ASCOT were applied to the ACS-NTDB there were major disagreements ([600]).

6.16.7 Acute Physiology and Chronic Health Evaluation (APACHE II)

The Acute Physiology and Chronic Health Evaluation (APACHE II) system was created and validated in the prediction of mortality and quality assurance in patients admitted to adult intensive care units (ICU) ([601],[602]). The scoring system consists of 12 physiological variables, premorbid health status and patient age. The results concerning the ability of the APACHE II as a predictor in injured patients is conflicting. The APACHE II has been shown to be a good predictor of mortality in trauma patients admitted to ICUs compared to the ISS, RTS and TRISS ([603],[604],[605]). However, others have shown poor predictor ability of the APACHE II in trauma patients ([606],[607]).

6.16.8 Trauma Score (TS), Revised Trauma Score (RTS)

The Trauma Score (TS) was developed by champion in 1981 ([262]). It was developed as a field triage scoring system (see below), utilizing four physiologic parameters; systolic blood pressure (SBP), capillary refill (CR), respiratory rate (RR), and respiratory expansion (RE). These physiologic parameters were combined with the GCS in order to assess patients injury severity for appropriate triage to trauma centers. Probability of survival had been shown to correlate well with the TS and therefore it's applicability in injury severity scoring was highlighted. The trauma score was derived by modifying the Triage Index, which was mathematically derived. Weighted values are assigned for each factor and are summed to obtain the Trauma Score. The weights of each constituent of the score were decided upon by a consensus panel of experts. The values range from 0 (most severe injury – worst prognosis) to 16 (least severe injury- best prognosis) ([343]) (Table 9). The TS has been shown to be reliable in predicting survival in blunt injuries and even more reliable in penetrating trauma ([608],[609]) and to have strong inter-rater reliability ([610]). It may have some applicability in the pre-hospital setting ([610]). The TS has also been shown to be able to predict patients in whom resuscitation is futile and therefore should be discontinued in the trauma bay (TS $\leq$ 3) ([608]).

In 1989, Champion reevaluated the TS and devised the Revised Trauma Score (RTS) ([263]). Capillary refill and respiratory expansion were excluded from the RTS as they were found to be extremely difficult to assess in the field and were very subjective. The TS was also found to underestimate the severity of head injuries and this issue was also addressed in the revised scoring system. The RTS comprises three variables: the respiratory rate, the systolic blood pressure and the GCS. A value of 0-4 is assigned to each variable and then the scores of each variable are summed. The equation for the overall RTS = 0.9368 GCS(c) + 0.7326 SBP(c) + 0.2908 RR(c), where (c) is the coded value (Table 10). It was developed using a logistic regression model and the MTOS data set. Total RTS scores range from 0 to 7.84, increasing scores correspond to decreasing injury severity. RTS scores of ≤ 11 accurately identified over 97% of fatally injured patients in the original analysis.

6.16.9 Pediatric Trauma Score (PTS)

Most triage adult trauma scoring and triage systems do not appropriately score injury severity in the pediatric population. This is secondary to both the inability to use the verbal component of the GCS as well as the unpredictability and unreliability of the heart rate, respiration rate and blood pressure through the various stages of childhood and under stress. In order to circumvent these problems, Tepas developed the Pediatric Trauma Score (PTS) in 1987 ([611]). This scoring tool is composed of six variables (weight, maintainability of airway, systolic blood pressure, central nervous system status, presence of open wound, skeletal fractures) scored from -1 to +2. The overall score ranges from -6 to +12, with a lower score corresponding to a higher injury severity. The PTS has been shown to be a reliable predictor of severity and outcome when compared to the ISS ([611]). PTS scores of ≤ 8 identify patients at increased risk of death ([612]). A flurry of tudies have shown the RTS to be equivalent to the PTS in assessing injured pediatric patients in the prehospital setting ([613],[614],[615],[616]). These studies question the need for a burdensome and extra triage tool for injured children in the setting of a universal system, the RTS, which seems to work for all ages.

6.17 Trauma Triage Systems

Integral to an effective and well running trauma system are ambulance triage and decision policies ([617]). In battle or disaster situations, the term triage is applied to the orderly process of sorting patients into treatment or logistical hierarchies based on injury severity and salvageability ([343]). The NATO handbook on emergency war surgery defines triage as being based on the "principle of accomplishing the greatest good for the greatest number of wounded or injured soldiers" ([88]). In civilian day-to-day trauma situations, the term triage refers more to the steps that must be taken in order to identify the patient at risk and to match existing resources to patient needs within a healthcare system. More broadly, it refers to assuring that the right patient reaches the appropriate facility at the right time ([403]). The underlying features of all triage systems rely in estimating injury severity and probability of survival.

There are a multitude of triage systems being used throughout the world. Even though these systems are based on complex statistics, they are simplified down to whole number scoring systems for specific variables in order to allow them to be easily calculated by the treating teams in a rapid and straightforward manner. The injury variables which are included in these systems are interdependent and each variable in the real-life situation does not stand alone, however, in order to simplify the scoring systems each variable is assigned a certain point value, irrespective of the other variables and irrespective of patient age, sex, extrication time or other co-morbidities. Certain triage criteria for injured patients have been shown to be of low yield in identifying severely injured patients requiring direct transport to a trauma center and trauma team activation within trauma centers ([295]).

The Triage Index (TI) was developed in 1971 in order to predict the necessity of hospitalization post trauma ([615]). The TI included both easily attainable anatomic information about the injuries sustained as well as information about the patient's physiologic state. Later in 1979 Bever and Veenker developed the Illness-Injury Severity Index (IISI) ([618]). This triage system was to be used in the field for the triage of injured patients to appropriate centers. Neither the TI nor the IISI were widely adopted as most trauma systems at the time were in their infancy and a large proportion of major communities did not yet have organized trauma systems in effect and lacked the appreciation for the systems approach to trauma care. These systems also lacked the evidence to support the usefulness of these systems.

It was not until 1980 that triage systems for trauma patients became more popular and many communities and systems began to adopt triage protocols for trauma patients. The Triage Score was developed by Champion in order to aid in the appropriate triage of injured patients ([296]). Champion realized that early deaths following trauma were due to injuries to one of three vital systems; the central nervous system, the cardiovascular system and the respiratory system. He found that the most important variables predictive of mortality from the three vital systems studied were: eye opening, verbal response, motor response, capillary refill and respiratory chest expansion. Each of the variables received a score of zero if it was normal and one point was added with increasing injury severity. Based on the Triage Score, the Triage Index (TI) was developed (Table 8). The TI was created in order to quantify the degree of physiologic derangement as well as prognosis. This system was too complex to be used in the field and was mainly used for quality assurance and comparison between trauma systems.

In 1981, Champion improved on the Triage Score by adding respiratory rate and systolic blood pressure. This new triage system was called the Trauma Score (TS) ([262]) (Table 9). The point system was adjusted and inverted; the score decreased with increasing injury severity.

In 1989, Champion re-evaluated the Trauma Score and determined that capillary refill and respiratory expansion were too difficult to evaluate accurately in the field. These two items were dropped to bring into being the Triage Revised Trauma Score (T-RTS) for use in the field and the Revised Trauma Score (RTS) for use in outcome evaluation ([263]) (Table 10). The T-RTS increased the sensitivity and decreased the specificity compared to the TS, it also led to more accurate predictions of injury severity for patients with serious head injuries. The RTS is currently the most widely used field triage system. The variables are easily and quickly measured in the field, however it is somewhat cumbersome in that the measured elements require conversion to an RTS points scale for quantification ([577]).

In 1982, in an effort to decrease the amount of minor trauma arriving at trauma centers and create a simplified field triage scoring system, the CRAMS scale was developed ([297]) (Table 11). This simple 10-point scale was based on the acronym CRAMS representing the five components measured: Circulation, Respiration, Abdomen, Motor, and Speech. The variables were easily measured and the calculation is simple. It is based on scores of zero to two for each variable, however, the measurements are highly subjective. It is also not possible to calculate the probability of survival from the scale. A score of less than or equal eight indicates major trauma and indicates the necessity for trauma center transport. CRAMS has been shown to be easy to apply ([619]) and to have greater sensitivity and poorer specificity compared to the T-RTS in identifying major trauma ([620]).

In 1986, Koehler developed the Pre-Hospital Index (PHI) for the pre-hospital triage of trauma patients ([621]). This system was validated in a multi-center study in 1987 ([622]). The PHI comprises four components: systolic blood pressure, heart rate, respiratory status, and level of consciousness. Each variable is assigned a value between 0 and 5. Injuries of increasing severities have higher scores. Four points are added to the overall score if there is a penetrating torso injury. The maximum score (most severely injured patient) is 24. A score between 0-3 corresponds to a minor injury, 4-7 moderate injury, >7 severe injury. By combining the mechanism of injury with the PHI, a sensitivity of 78% can be reached ([623]).

Also trying to decrease admissions to trauma centers, in 1990, Baxt and colleagues introduced the Trauma Triage Rule (TTR) ([624]). The TTR defined major trauma as any injured patient whose systolic blood pressure was less than 85 mm Hg, whose motor component of the GCS was less than 5, or who had sustained penetrating trauma to the head, neck or trunk. They found that both the sensitivity and specificity for detecting major trauma of the TTR were 92%.

Based on elements of the RTS, combined with specific injuries, injury mechanisms and patient characteristics, the American College of Surgeons (ACS) Committee on Trauma (COT) ([145]) has outlined an algorithm for the triage of trauma patients to trauma centers. This system is based mostly on expert opinion and has not been subject to rigorous evaluation. The system is designed to overtriage injured patients to trauma centers, in order to avoid missing significant injuries.

7. The Problem

Rigid adherence to the classic "trauma system" model outlined by the American College of Surgeons([157],[161]) or other governing health authority overseeing a trauma system ignores the considerable variation in both the specific communities' needs and priorities for trauma system development and maintenance. It is unrealistic for most regions and centers to adhere to the blanket system design and implementation criteria secondary to both costs and available resources ([625],[626],[139]). Cities, municipalities, regions, provinces, states and countries need to develop their own trauma systems based not only on the specific needs of the community served, but also based on the existing hospitals and available resources ([627],[324]). Hackey eloquently points out that "*in some states, participants may regard prehospital communications and training as the most pressing problem, whereas others may emphasize data collection, the creation of standards for classifying and/or designating institutions as trauma centers, or other concerns*" ([110]). Unfortunately, to this date, we do not know which elements making up a regionalized trauma system impact on patient outcome, and to what degree ([25]). Furthermore, designated trauma centers and established trauma systems have been shown to possess different characteristics or elements ([315]). By requiring communities to adhere to the all or none recipe for trauma system creation and maintenance, we have discouraged many areas from regionalizing trauma care due to both high costs and the lack of the availability of a trauma system specifically designed in an evidence-based manner to fit their specific needs.

Trauma systems have been designed to improve the outcome for injured patients and have been repeatedly demonstrated to be effective([628]). They have proven to be one of the most important advances in the care of the injured patient over the last 30 years. These systems have been traditionally based on the United States model of trauma care regionalization. The current goal for most regions is to create a system that as closely as possible resembles this model ([31]). However, patient demographics and regional variations in geography, population profile and etiology of injuries differ between regions. Currently there are no guidelines for the implementation of local trauma systems tailored to specific regional needs. There are also no modern era studies assessing the impact of trauma care system variations on patient outcomes.

A multitude of studies over the last three decades (Table 3 and 4, Figure 2) have demonstrated the survival benefit of regionalized trauma care systems. However, there have been no studies which have looked at which elements or components of the system are responsible for that benefit and to what degree. We have attempted to answer the following questions through the research methodology used in these studies: Are all components of these systems indeed necessary? Can some elements be dropped? Should resource allocation be shifted in order to concentrate scarce resources into proven components of these systems?

Systems of trauma care have been developed, adapted and improved upon based largely on expert opinion ([629],[301]). Mullins explains that: "*we are in transition from an* *era when trauma systems were designed on the basis of speculation to an era when trauma systems should be revised on the basis of conclusions dependably derived from data analysis*" ([281]). Even though there is good evidence from many systems showing that these systems improve outcome, the elements making up these systems were not fashioned in an evidence-based manner and therefore we do understand the contribution of individual elements to the efficacy of the system ([630]). Rutledge highlights the reality that trauma systems have been mostly developed based on informal consensus development ([26]). Informal consensus development is the oldest and most prevalent approach to the selection of interventions involved in the treatment of injuries. Rutledge further points out that interventions designed, implemented and assessed based upon information gained from informal consensus development are often of poor quality and may be far less effective than initially thought. This is well highlighted by the decades of use of MAST pants for the treatment of patients in shock. These devices were introduced and implemented secondary to expert consensus panels, however, years later were scientifically evaluated and shown to be detrimental to injured patient outcome ([443],[386]). Rutledge explains:

> *"The days of opinion-based and data-free decision making should be over. A growing emphasis on careful analyses of trauma-related data sources is the wave of the future in informed decision making in health care in general and in trauma in particular."* ([26])

This thesis picks apart all levels of regionalized trauma care throughout North America; from the most organized and cohesive systems to non-regionalized areas. This effort has been undertaken in order to attempt to understand what works and try and fix what does not work with the ultimate goal being to improve efficiency and efficacy of these systems for the future. The series of studies which comprise this thesis have been specifically designed to evaluate the components of modern day trauma care systems in order to enable the creation of evidence-based, component-oriented trauma systems for the future. These systems will be designed and tailored to the specific region served in order to satisfy regional variations, resources, demographics and needs.

Regionalized systems of trauma care are effective. Regional variations in available resources, demographics, trauma epidemiology, and system maturity have been associated with different outcomes. A single model of care applied to any area is effective; however, development of the ultimate system may depend on several factors. These factors include: geography, epidemiology of trauma, available resources and infrastructure, financial limitations, accessibility, and feasibility.

8. Purpose of the Project

Trauma care in Canada and the rest of North America has seen important changes over the last 30 years([631]). The regionalization of trauma care, which has occurred in many North American regions, has shifted the scope of trauma patient management from hospital-based care to a systems approach. A regionalized approach to trauma care (a trauma system) consists of the global care of the injured patient from the time of injury until the end of rehabilitation.

Regionalized trauma systems have repeatedly been shown to improve outcomes. However, we do not know which elements of these systems and to what degree these elements improve outcomes ([139],[313]). Surgical quality measurement can exist in three domains: structure, process and outcomes ([464]). Our objective is to bring an evidence-based approach to the creation and running of trauma systems, based on "outcomes" related to specific elements which make up the "structure" of the systems and contribute to the "process" of care which make up these systems.

The series of studies comprising this project aim to examine the individual elements or components of a trauma system and their effect on patient outcome (morbidity and mortality). By examining the relationship between individual elements making up a trauma system and their relationship to patient outcome, the project will define policy guidelines that would be implemented at the regional level in order to create efficient and evidence-based trauma systems. This thesis provides the information required to define which elements of a trauma system are important to patient outcome and to what degree and will have implications on the treatment of trauma patients throughout North America.

Trauma systems were designed based on expert opinion and experience. The elements that make up these systems were not put together in an evidence-based manner. We therefore, do not understand the benefits of the specific elements, which make up each of these categories. If we can understand which elements contribute to improved trauma patient survival and decreased morbidity, we could design cost-effective trauma systems. The surgical literature is full of statements and guidelines which are based on opinions and educated hunches ([632]). Trauma systems are no different. Even though level-one evidence is extremely difficult and probably impossible to obtain regarding trauma system components, we should still seek evidence in order to make policy and clinical decisions regarding trauma systems for the future.

Furthermore, if we can elucidate the elements that are beneficial in areas with differing demographics, we could begin to design tailor-made trauma systems, which would respond to the needs of the community served. Regions contemplating establishing new trauma systems could design these new systems using evidence-based criteria. They could decide which elements are vital to their system based on mortality / morbidity results, as well as the relative importance of each element. This would avoid the blanket usage and advocacy among many communities of the American model of regionalization which has been applied by many regions, even though the individual components of the system have not been subjected to critical evaluation ([633,634]).

This will be the first study to evaluate the specific elements which go into building a trauma system / trauma center. These elements were created by committees based on their experience in treating trauma patients in urban hospitals and in war-time scenarios. The creation of these systems was not evidence-based and although these systems have been shown to work and improve outcomes, we as of yet do not understand which elements of these systems are responsible for the improvement in outcome, to what degree these elements contribute to improved outcome, and which elements do not. This thesis attempts to answer these questions.

9. Hypotheses

Specific hypotheses tested include:

1. Continuous evidence-based re-evaluation of a regionalized trauma system with evaluation-based responses can improve patient outcome over time

    -See section 13.1 – Implementation of a trauma care system: Evolution through evaluation

2. Component-based outcomes can be elucidated and assigned to specific elements making-up a mature regionalized trauma care system

    - See section 13.2 – The association between trauma system and trauma canter components and outcome in a mature regionalized trauma system

3. Trauma system components and outcomes related to those components differ in urban and rural trauma centers and trauma systems

    -See section 13.3 – The impact of differing trauma system resources and in-hospital trauma care availability in rural and urban trauma centers

4. Component-based outcomes can be elucidated and assigned to specific elements in both regionalized and non-regionalized trauma care areas throughout North America

-See section 13.4 – The elements of regionalization – An evidence-based approach to the creation and running of trauma systems in North America

We will use the data from all North American trauma centers contributing data to three trauma databases in order to attempt to answer the following questions:

A. Are there specific trauma system / trauma center elements which are associated with improved outcome?
B. Are there specific trauma system / trauma center elements which are not associated with improved outcome?
C. Are there specific elements associated with improved outcome in different demographic areas?
D. Which elements of a trauma system / trauma center are integral when creating a system?
E. Is there an ideal trauma system? Can different systems be designed to fit different community needs?
F. To what degree does each trauma system element impact on morbidity / mortality?

5. Expert-opinion with respect to the design and importance of specific components and their impact on outcome in regionalized trauma systems is not a reliable method for designing trauma systems when compared to objective evidence-based criteria

-See section 13.5 – A comparison between expert opinion regarding trauma system element significance and outcome-based effectiveness of trauma elements

10. Objectives

This will be the first study to evaluate the specific elements which go into building a trauma system / trauma center. The ultimate goal of the project will be to define the model by which regional trauma care systems should be developed and structured in order to address the specific needs of the population. This will be accomplished by comparing morbidity indicators and mortality rates for different types of trauma systems and attributing them to specific components present in different systems. By looking at these associations, the project will define policy guidelines that could be implemented at the regional level, with the ultimate aim being the establishment of efficient trauma care systems that will address the specific needs of the population served.

Several factors including patient demographics, injury epidemiology and geographic population density should be taken into consideration in defining regional trauma care requirements. The current project will produce the information required to define these guidelines and will have implications on how trauma patients are treated in Canada and the United States. Eventually this evidence will improve the overall quality of care provided to trauma victims throughout North America.

Although the principle focus of this research will be to continue with the ongoing evaluation of the trauma care system in North America, the results are expected to have an impact on trauma care systems throughout the world.

11. Expected Impact

Identification of specific components of regionalized trauma care systems and their relationship with patient outcome will enable non-regionalized areas to develop cost-effective, evidence-based, regionalized systems tailor-made to fit their needs. It will encourage areas which were not willing to, or not financially able to buy the "whole package", to put into place the most cost-effective components of a system. Furthermore, the contribution of each component of the system to outcome will give systems already in place necessary data to improve resources within the system and provide evidence to enable them to make educated decisions about prioritizing system resources for the future.

12. Material and Methods

Specific details concerning precise methods undertaken in completing the various sections of the overall project are described with relation to the specific section (see below). The materials and methods described in this section are related to the overall approach towards the undertaking of the entire project. The thesis comprises five separate sections which detail different aspects of the research program

12.1 Data Sources

Three databases were used in order to link outcome with trauma system components and demographics. The QTR, NTR, and NTDB have been described in detail in sections 12.6.1, 12.6.2, and 12.6.3.

The Quebec Trauma Registry Database was obtained directly from the Quebec Ministry of Health through the Quebec National Trauma Research Program. The projects described in this thesis were performed as part of the program and were endorsed by the program.

The Canadian Institute for Health Information (CIHI) National Trauma Registry (NTR) was obtained directly from the CIHI as part of a Canadian Health Services

Research Foundation (CHSRF) grant for trauma research (Principle Investigator: Dr. John S Sampalis).

The American College of Surgeon Committee on Trauma (ACS-COT) National Trauma Databank (NTDB) was obtained directly from the ACS-COT. Dr. Gregory Jurkovich was instrumental in securing the databank for this research.

The SK&A Healthcare QuickDisk version 2.0® was purchased from SK&A Information Services - 601 Main Street, Suite 650, Irvine, CA. 92614 and used in the linkage procedures for the NTDB (see section 12.6.3). The SK&A Healthcare QuickDisk is a database of all of the American Hospital Association (AHA) Data on hospital characteristics throughout the United States.

12.2 Computer Software

All databases were created in the Microsoft SQL version 7.0® software package for windows. Statistical analyses were performed using SPSS versions 11.0 and 12.0® software packages for Windows and Microsoft Excel Versions 2000, 2003, 2007 (Microsoft Office Software Package®) for Windows. Tables, figures, and text for publication, presentation and thesis preparation were prepared using Microsoft Word, Powerpoint and Excel Versions 2000, 2003, 2007 (Microsoft Office Software Package®) for Windows. Maps were created using Adobe Photoshop® Software Package for Windows.

12.3 Selection of Study Populations

Due to the fact that data from patients transferred or referred to trauma centers from other hospitals has been shown to introduce bias into data sets, these patients were removed from the primary analysis ([635]). Severely injured transferred patients in some areas have been shown to have significantly inferior outcomes compared to those transported directly to level I centers ([174]). However, transferred patients in a well-running, mature, urban trauma system should not have inferior outcome ([636]). Despite this observation, many areas of study in the current series of projects were from areas with rudimentary or non-existent trauma systems.

The question of what to do with transferred patients in trauma system research is a large area of contention. By including transfers in the cohort, a selection bias is introduced into the sample. It is possible that certain patients would be included in the cohort twice; once from the initial hospital and once from the receiving hospital (for example in the case of a patient stabilized at a level II or III center and then transferred to a level I trauma center for definitive care). Furthermore, the inclusion of transfers makes the allocation of outcome between the initial and secondary hospital difficult. For example, a severely injured patient initially transported to a level II center could be deemed too severely injured to be appropriately treated at the level II center or could be inappropriately treated at the level II hospital and then transferred to a level I center. If this patient was to die in the second hospital (level I), the mortality would be attributed to the level I center and a positive outcome would be attributed to the level II center for the same patient. This inherent risk in including transferred patients in the cohort would make the interpretation of results difficult. Furthermore, by including transfers, multiple outcomes can be attributed to one patient (one outcome at each center the patient is treated in) which would further bias results.

Subanalysis was completed for transferred patients in order to assess the effects of trauma system elements on this specific subset of injured patients. However, the results from these analyses must be carefully interpreted with the aforementioned biases in mind. Transfers remain and extremely important part of the trauma population. Conclusions regarding transfer policy and protocols are important and need to be evaluated further. However, transfer protocols were not the goal of this project. Results from the current thesis can be used to help design studies which look at improving these protocols.

12.4 Injury Severity Measures and Adjustment

Defining the severity of injury and the "major trauma patient" in research methodology is not as simple as it is in clinical medicine ([637]), however is extremely important in order to understand outcomes of a very heterogeneous group of patients ([638]). Injury severity was measured and controlled for using the revised trauma score (RTS) (see section 6.16.8), the injury severity score (ISS) (see section 6.16.3), and AIS body regions injured (see section 6.16.2) in the provincial cohort. Glasgow Coma Scale (GCS) (see section 6.16.1), (RTS) (see section 6.16.8), the injury severity score (ISS) (see section 6.16.3), patient age([639]), systolic blood pressure on arrival at the emergency department, and mechanism of injury (blunt versus penetrating) for the North American analysis. Hospital outcomes following trauma have been shown to be predictable from age, sex and diagnosis grouping in administrative databases ([640]), which are far inferior to the outcomes databases used in this series of studies.

Injury severity adjustment variables were chosen based on best-fit analyses within the logistic regression models. The Hosmer-Lemeshow goodness-of-fit statistic ([641],[642]) was utilized to define the best fit for the model and severity indicators were chosen based on this test. Goodness-of-fit statistics examine the difference between the observed frequency and the expected frequency for groups of patients. The statistic can be used to determine if the model provides a good fit for the data. If the P-value is large, then the model is well calibrated and fits the data well; if the P-value is small (smaller than alpha), then the model is poorly calibrated([643]).

12.5 Outcome Measures

12.5.1 Death

Death is the principle outcome measure used in all areas of health services research. In trauma, mortality is an extremely pertinent endpoint as injury usually occurs in previously healthy, young patients. Furthermore, trauma is a completely preventable disease and therefore death is both preventable and devastating when it occurs. Since the beginning of time, mortality has been used as the major endpoint in injury-related research and will continue to be used as such in the future. Even though we now have many surrogate outcomes for the quality of care provided to injured patients, mortality is still the main outcome of interest and remains the key to unraveling quality issues in trauma care. Long-term mortality, which has been shown to be increased following injury ([644]), was not assessed in these studies.

12.5.2 Discharge Status

Discharge status of trauma patients helps one understand the post-hospital demographics of the sample and is important from a global healthcare and policy perspective. It describes where a patient goes following discharge from hospital. This can be to either a rehabilitation facility, a long-term care facility (nursing home), home with help, home without help, transfer to another acute care hospital, death, other (most patients going to either a penitentiary, or discharged against medical advice). We use discharge status to describe the sample, and to understand the post-discharge demographics of the sample, however, do not use it as an outcome measure for trauma system components due to the lack of validation in the available literature. Discharge status may become an important outcome measure in trauma systems research in the future as has been done in other areas of surgical outcomes research ([645]).

12.5.3 Hospital Length of Stay

Hospital length of stay has been shown to be a good predictor of trauma system effectiveness ([646]). It represents a meaningful measure of resource utilization and can be used as a measure to improve care. Prolonged length of stay is and adverse outcome and is therefore used as an outcome measure in the series of studies and analysis presented here. Furthermore, hospital days are a good surrogate for overall costs of care ([647],[648],[649]), however the increasing length of hospital stay has minimal impact on the overall total cost of hospital admission ([650]). Hospital length of stay is used as both a crude and adjusted outcome measure in the studies comprising this thesis. Patients that die at any point in their hospitalization were excluded from hospital length of stay analysis.

12.5.4 Intensive Care Unit Length of Stay

ICU length of stay is a good surrogate for injury severity in patients that survive injury. Severely injured patients typically are treated in ICU and more severely injured patients typically have longer stays. Quality of care should, in theory, decrease ICU length of stay. Obviously, patients that die while in hospital may have very short ICU length of stays if they die early in their stay. This would often indicate more severe injury. ICU length of stay is used as both a crude and adjusted outcome measure. Patients that died at any point in their hospitalization were excluded from ICU length of stay analysis.

12.6 Linkage Procedures

12.6.1 QTR

In order to assure hospital anonymity, all hospital to survey linkage with the three databases was completed using unique identifier coding. The QTR was linked with the surveys based on hospital coding in the registry which was provided by the Government of Quebec. All hospital codes were encrypted prior to linkage with the database and unique identifiers were not disclosed to any researchers working with the dataset.

12.6.2 NTR

Unique hospital identifiers were unavailable for hospitals contributing data to the NTR. Linkage of hospital data with surveys was done through encrypted unique identifiers assigned to the surveys and to the hospital provided by the CIHI. The identifiers were linked between surveys and the NTR. Linkage was based on: province, mean age, years contributing to the registry, and mean number of patients treated per year. Linkage was possible in 64 (54%) of hospitals in the NTR. All hospital codes were encrypted prior to linkage with the database and unique identifiers were not disclosed to any researchers working with the dataset.

12.6.3 NTDB

Due to confidentiality issues and strict confidentiality laws in the US, the NTDB hospital unique identifier codes were unable to be provided to us by the American College of Surgeons. In order to circumvent this, probabilistic linkage techniques were employed in order to match the surveys with the unique identifier codes in the NTDB. Probabilistic linkage has been used successfully in other trauma database studies ([651]). To aid in the matching process and to increase linkage probabilities, the SK&A Healthcare Quickdisk, version 2.0 was used. This database of hospital resources, bed availability, university affiliation status, and demographics is put out by the American Hospital Association contains data on over 6000 hospitals across the United States.

Criteria used for matching between the three databases in the NTDB linkage are described in table 12. All variables were coded and numeric string variables were created as encrypted surrogates of all criteria to enable blinded matching. Order of precision for matching was as follows: ACS level (categorical variable), university affiliation (categorical variable), pediatric beds (dichotomous variable – present/absent), burn beds (dichotomous variable – present/absent), total hospital beds (continuous variable), trauma beds (continuous variable), and ICU beds (continuous variable). Attempts were firstly made to match hospitals on the basis of all criteria (see table), further matching iterations were completed following removal of one variable. Removal of variables began at the end of the sequence. Ordering of variables was selected based on the best fit of the model and highest predictability level.

Of the 120 hospitals returning the surveys, it was possible to match 64 (53.3%) hospitals. First iteration matching revealed 14 correct matches, 2^{nd} iteration – 20, 3^{rd} iteration – 39, and 4^{th} iteration – 31 matches. Duplicate matches were deleted. All hospital codes were encrypted prior to linkage with the database and unique identifiers were not disclosed to any researchers working with the dataset.

12.7 Survey Construction and Administration

Components of both systematic trauma care regionalization and in-hospital trauma care organization were ascertained from an in-depth review of the available literature regarding trauma system and trauma center effectiveness([628]) as well as from guidelines put forth by the American College of Surgeons Committee on Trauma ([153]). The questions were developed by the study authors and were selected so that they adequately represent the important trauma system and trauma center elements in a typical regionalized North American trauma system. Surveys included items concerning in-hospital (14 questions), system-based components (4 questions) and regional demographic variables. Identical surveys were created in both English and French (Figures 4 and 5).

Surveys were mailed to the director of trauma services at all hospitals contributing data to the QTR, NTR and NTDB. Surveys could be returned by mail, fax or e-mail. Self-addressed, postage paid envelopes were provided to the responders of the survey. The English and French cover letters mailed out with the surveys are outlined in Figures 6 and 7, respectively.

At one, two and three months following the initial mailing, trauma directors who had not yet returned the surveys were contacted by both telephone and e-mail requesting completion and return of surveys.

Survey responses were recorded in a de-identified encrypted survey database at the study coordination office. All paper, fax and e-mail responses were destroyed following entry of encrypted data into the database.

12.8 Confidentiality Issues

All hospital identifiers were encrypted prior to linkage with the outcome databases (QTR, NTR, and NTDB). This alleviated any possible identification or linkage of hospital name to outcome measures. Linkage procedures were undisclosed to all members of the research team who had contact with the data.

13. Results

13.1 Implementation of a Trauma Care System: Evolution Through Evaluation

13.1.1 Introduction

Trauma remains the fourth leading cause of death in North America and is the number one cause of death for individuals under the age of 45 years ([652]). In 1994, 8,687 people died following accidents in Canada and trauma was the fifth leading cause of death. Trauma is also the number one cause of potential years of life lost (PYLL) in Canada ([653]). Due to the prevalence of trauma and the large numbers of lives lost each year to this preventable and often treatable disease, many governments and health care systems have attempted to look for ways to prevent the occurrence of trauma and decrease trauma morbidity and mortality.

Throughout the years, many communities and health care systems have recognized the need for the regionalization of trauma care in order to utilize available resources in the most effective and cost-efficient manner possible ([97], [160], [157], [654], [655], [656]). Trauma care regionalization has been repeatedly shown to decrease mortality in many systems throughout the world ([279], [39], [40], [291], [301], [338], [290], [289]).

Based on the observation that in 1987, trauma-related mortality was 59.1 per 100,000 population in Montréal and 53.3 per 100,000 in the province of Québec ([657],[658],[659]),it was decided to study the trauma system in Montréal and Québec in detail. This was taken on in order to determine whether changes could be made to the system to improve outcome. When the study of the trauma care system in Québec began, there was no provincial system in place in terms of triage, specialized centers, communication between centers, quality control or pre-hospital treatment guidelines. The policy was that ambulances would transport trauma patients to the nearest emergency department (ED), regardless of the hospital's ability to manage trauma in the acute or post acute setting.

The purpose of this paper is to outline the implementation and evolution of a trauma care system and highlight the constant evaluation and subsequent changes that have been made to improve the system. Throughout the last decade, changes in the Québec trauma system have been evidence-based. This has been made possible by governmental support, hospital cooperation and a trauma registry, where every trauma patient's clinical status and outcome is recorded in detail. It is imperative to continuously reevaluate a trauma care system. Even today, after implementation of many successful changes, there continues to be a concerning level of trauma mortality.

13.1.2 Materials and Methods

This is a retrospective review of the scientific evaluation of the Quebec trauma system. The process of regionalization in Quebec is reviewed from the pre-implementation period until today and evidence-based changes that have occurred in order to improve outcome and efficacy over the years have been highlighted. Mortality statistics were abstracted from the Quebec trauma registry. The Quebec trauma registry consists of statistics on all trauma patients with major trauma-related injuries treated at hospitals in Quebec. Inclusion criteria into the registry consist of one or more of the following: (1) death as a result of injury, (2) admission with hospital stay ≥ 3 days, (3) admission to an intensive care unit (ICU), or (4) inter-hospital transfer.

Mortality rates for severe trauma were abstracted for patients treated for injuries at urban tertiary trauma centers in Montreal and Quebec City. There are three tertiary centers in Montreal (Montreal General Hospital, Hôpital Sacré-Cœur and Charles-Lemoyne Hospital) and one in Quebec City (Hôpital Hôtel-Dieu). Severe trauma was defined as (1) death as result of injury, (2) Injury Severity Score (ISS) > 12, (3) Pre-Hospital Index (PHI) > 3, (4) four or more injuries with abbreviated injury scale scores (AIS) ≥ 3, or (5) hospital stay of more than 3 days. Patients who died on-scene were excluded from analysis.

13.1.3 Results / Discussion

13.1.3.1 Trauma System Implementation

Prior to 1993, there were 26 hospitals in the Montréal area. No patient triage protocols were in place and therefore, patients were generally transferred to the nearest hospital with an Emergency Department. Based on the American College of Surgeons (ACS) criteria for trauma center categorization ([97]), three hospitals at that time were compatible with ACS Level I classification, eight were compatible with Level II, and fifteen with Level III ([217]). However, no hospital fulfilled all the criteria for a Level I trauma center recommended by the ACS guidelines. Even though three hospitals were more equipped to accept and treat major trauma and had a surgeon (or senior surgical resident) in house 24 hours a day in order to treat trauma (Level I compatible centers), the philosophy was to transport the patient to the nearest hospital with an ED regardless of severity of injury or the availability of facilities and personnel equipped to handle trauma.

In 1987-1988, prior to any trauma system being in place in Montréal, a study of 355 patients with severe trauma in the Montréal area was carried out. Results of this study were compared to the Major Trauma Outcome Study (MTOS) ([259]), which is an aggregate of approximately 50,000 trauma patients treated in over 100 Level I or II trauma centers in the United States and Canada. The results showed a significant increase in deaths compared to the MTOS for patients transported to Level I compatible hospitals ($p=0.0003$), Level II compatible hospitals ($p=0.0004$) and Level III compatible centers ($p<0.0001$). Thirty deaths occurred at Level I centers, where only 18.5 were expected, 27 at Level II centers (13.9 expected) and 13 at Level III centers (6.2 expected) ([217]). The increased risk of death from major trauma in Montréal compared to the MTOS, was alarming and sparked great interest as to the causes for this increase in mortality and into ways in which to decrease it.

Prompted by the aforementioned studies, the Québec provincial government defined trauma care as a priority in 1990 and began the process of establishing a regionalized trauma care system. In 1992, four hospitals in the province of Québec were selected to become designated trauma centers. Three of these hospitals were in the Montréal area and one was located in Québec City. Two of the Montréal area hospitals began their transition into ACS Level I trauma centers in 1992 and were designated as such in 1993. The accreditation of these trauma centers involved establishing a dedicated trauma team to be on-duty, in hospital, 24-hours a day. This team included physicians and/or senior residents from the following disciplines: general surgery, emergency medicine, anesthesia, neurosurgery, and orthopedic surgery. Twenty-four hour in-house emergency room and operating room nursing staff were also included in the level I team. Other specialties were to be available within 30 minutes after being called. The trauma team that initially treats the patient at the level I centers in Quebec varies between emergency medicine physicians, general surgery attending staff, and general surgery senior residents. This variation occurs between and within centers, depending on the specific hospital trauma team design and the time of day. No evaluation of whether in-house surgical attending presence versus availability has been reported in Quebec, however we are currently evaluating this element of trauma care.

The Québec government provided additional funding for the establishment, purchase and maintenance of trauma center equipment and facilities. These centers have designated trauma treatment rooms and diagnostic facilities devoted to trauma. In 1993, the provincial government also officially mandated an external review board, whose job it is to periodically visit each designated center and assure that the ACS standards are being upheld. This external review board has the mandate to make recommendations to the Health Minister regarding upholding of trauma center accreditation by individual centers.

As late as 1993, following the designation of trauma centers, protocols for the direct transport of patients with major trauma were still not established. However, some informal triaging did occur. Patients were often transferred from less specialized hospitals to the Level I trauma centers following stabilization at the nearest ED.

In order to evaluate the impact of the designation of 2 hospitals as Level I trauma centers in Montréal, a study was conducted comparing mortality of patients experiencing major trauma prior to establishment of Level I trauma centers (1987) and following designation of Level I centers (1993). Patients in the 1987 cohort were treated at three Montréal area hospitals which at the time were classified as having facilities compatible with ACS Level I. Patients in the 1993 cohort were treated at the 2 hospitals designated as Level I trauma centers. These hospitals had specialized trauma teams, equipment and trauma infrastructure in place. The two cohorts did not differ in terms of injury severity ([293]).

Among patients in the 1987 cohort, 20% did not survive their injuries, compared to 10% of those in the 1993 cohort. The decrease in mortality between 1987 and 1993 was significant (p=0.006). In comparison to 1993, patients experiencing major trauma in 1987 were twice as likely to die from their injuries (crude odds ratio = 2.1). Multiple logistic regression, adjusting for age, Injury Severity Score (ISS), body region injured and mechanism of injury, showed a significantly higher mortality risk for the 1987 cohort (relative odds ratio = 3.25, p=0.009). The benefit of trauma center designation increased with injury severity ([293]).

The policy in place in Québec between 1993 and 1995 was that all major trauma patients were to be transported to the nearest ED for stabilization and subsequently transferred to a Level I trauma center. To evaluate the efficacy of this system, a study was conducted to compare the outcome of trauma patients transported directly to a Level I trauma center (n=2,756) with patients who were first transported to a Level II or III center for stabilization and subsequently transferred to a Level I center (n=1,608). The two groups were similar in mechanism of injury, ISS, Revised Trauma Score (RTS) and Pre-Hospital Index (PHI), however the transfer group had more head and neck injuries. Overall mortality in the direct transport cohort was 4.8%, compared to 8.9% for the transfer cohort (p=0.001). The odds of death associated with being transferred was 2.96 compared to direct transport. Logistic regression analysis, adjusting for ISS, age, head or neck and extremity injuries, confirmed the increased risk of death in patients first stabilized and then transferred, compared to patients directly transported to Level I centers (p=0.02). The adjusted odds ratio was 1.57. Transfer to Level I or II centers was also associated with significantly increased length of intensive care unit stay and length of hospital stay ([174]).

Based on the observation of increased mortality among trauma patients who were transferred following stabilization at the closest ED, triage and transfer protocols for trauma patients were implemented in 1995. These protocols consisted of directives for emergency medical technicians, based on injury severity and transport distance. Directives dictated whether to transport patients with major injuries directly to a Level I trauma center, or to the closest ED for stabilization. Level II trauma centers were identified in 1994-95 and were designated as such in 1995-96. In 1995-96, Level III and stabilization centers were identified and designated.

In order to evaluate the effects of implementation of the triage and transfer protocols, a study was conducted to compare trauma deaths before and after implementation. For patients with severe injuries, mortality decreased from 52% to 18% in the pre- compared to the post-triage implementation years ($p<0.001$) ([42]). Direct transport of patients with major injuries to specialized trauma centers insures early definitive care and has significantly reduced mortality in our system.

13.1.3.2 The Pre-Hospital System

Until recently in Montréal, Advanced Life Support (ALS) was provided by physicians (MDs) at the scene. These MDs were dispatched based on severity of injury or patient status. The physician is dispatched to the scene in addition to an ambulance with two Emergency Medical Technicians (EMTs) trained in Basic Life Support (BLS). A physician was dispatched to all cases of major trauma when available. However, in 25% of the cases for which a physician was requested, one was not available.

In 1987-88, there was a significant increase in mortality seen among patients receiving ALS at the scene in addition to a significant increased chance of death among patients with a total pre-hospital time of over 60 minutes ([217]). A study which adjusted for type of injury, injury severity as well as level of pre-hospital and in-hospital care showed a threefold increase in the risk of mortality among patients with pre-hospital times of over 60 minutes. Furthermore, ALS at the scene was not associated with increased survival ([292]).

ALS provided at the scene by MDs in Montréal was shown to increase mean on-scene time by 6.5 minutes (p=0.0001). The delay was due to the administration of medications (5.7 min, p=0.0001), establishment of intravenous (IV) access (6.6 min, p=0.0001) and Pneumatic Antishock Garment (PASG) application (9.3 min, p=0.05). This delay in scene time translated into an increase in total pre-hospital time and was associated with an over two and a half times increase in the odds of death (p=0.009) ([660]). High rates of pre-hospital delays and inappropriate on-scene IV line initiation and intubation in potentially treatable trauma deaths were observed in a system without any guidelines, algorithms or treatment protocols for physicians providing on-site ALS ([661]).

Following these observations, guidelines were introduced in 1993 aimed at reducing pre-hospital times. Following implementation, mean pre-hospital times decreased from 62 minutes in 1992-93 to 44 minutes in 1997-98 ($p<0.001$) ([42]).

To evaluate the effectiveness of on-site IV therapy in Montréal, a study was conducted comparing the mortality of severely injured trauma patients receiving IV access and therapy on-scene to those who did not. After adjusting for patient age, gender, injury severity, injury mechanism, and pre-hospital time, the use of on-site IV fluid replacement was associated with a 2.3 times increased odds of mortality compared to patients receiving no IV therapy ($p=0.04$). Further analysis showed that IV therapy provided no benefit in patients with pre-hospital time less than 30 minutes. It also showed that for pre-hospital times greater than 30 minutes, it significantly increased mortality ([376]).

The increase in mortality seen with increased on-scene interventions and on-scene time led to a prospective cohort study of ALS vs BLS between 1993 and 1997. Three cities were compared: Montreal where physicians provide ALS, Toronto (province of Ontario) where paramedics provide ALS and Quebec City where emergency medical technicians provide BLS only. The results showed that overall mortality by on-site personnel was: physicians; 35%, paramedics; 24%, EMTs 18% ($p=0.001$). The overall mortality rate of patients receiving only BLS at the scene was 18% compared to 29% for patients receiving ALS (by paramedics or physicians)(p=0.001) ([374]).

Based on the observations above, it was decided that the physician treatment of trauma patients should be phased out of pre-hospital care. In the year 2000, unofficial guidelines were put in place to decrease the dispatch of MDs to trauma cases. These guidelines became official in 2002, when MDs were completely phased out of pre-hospital trauma care in Montreal.

It is the authors' belief that ALS has no beneficial impact on the outcome of severely injured trauma patients in an urban setting and in fact may be detrimental. We have shown that increased mortality is related to increased on-scene time ([660]), however mortality is increased in ALS treated patients irrespective of on-scene time ([374]). The only element of pre-hospital ALS, which may have a beneficial impact on head injured patients, is endotracheal intubation. However, this has recently come under scrutiny and has been shown to increase both morbidity and mortality in patients with traumatic brain injury who are admitted to hospital without an acutely lethal injury ([422]).

13.1.3.3 The Regionalization of Trauma Care

Trauma mortality rates have declined incrementally from the time of implementation of a trauma care system until today (Figure 3, Table 13). The gradual improvement in outcome for trauma patients in Quebec has directly corresponded with various changes in the way in which injured patients are cared for in the system based approach to trauma care in Quebec (Figures 8 and 9). As the system continues to evolve and mature we hope to see even better outcomes for these patients.

One of the major limitations of this descriptive study is the selection bias that is present in the data set. This is due to low levels of reporting of trauma patients into the database in the early years of regionalization. Due to low levels of reporting it is possible that there was under reporting of less severely injured patients and over reporting of more seriously injured patients. The results reported here do not represent an experimental study, they are simply meant to describe the data that is available over all years of regionalization in Quebec.

We believe that the recent withdrawal of ALS services from on-scene care in Montreal is another step in the direction of improving outcomes for trauma patients. This should decrease overall pre-hospital time in the "golden period" for trauma patients. In severely injured patients, time to definitive surgical care is vital to survival ([23],[378]) and intravenous fluid therapy and other ALS techniques are time consuming and may even be harmful to these time-critical patients. By transporting severely injured patients as quickly as possible to trauma centers we will hopefully be able to further decrease mortality. Pre-hospital physicians have recently been completely phased-out of the pre-hospital system in Montreal and an evaluation of paramedics in the Montreal pre-hospital setting is commencing, while elsewhere in the province, only BLS pre-hospital services are in place.

The positive effect of the regionalization of trauma care has been described by various authors over the last few years ([39],[290],[291],[289]). O'Keefe et al. showed that regionalization decreased mortality in patients with ISS greater than or equal to 16 ([291]). Peitzman et al. showed similar results for patients with ISS greater than 15 ([289]). Barquist showed that for patients experiencing blunt trauma in a newly created and still maturing trauma system (2 years after implementation), mortality rates were decreasing. This decrease in mortality reached statistical significance for the risk-adjusted cohort in the entire system ([290]).

The systems approach to trauma care or "trauma care regionalization" has been well studied over the last several years. The decrease in mortality achieved using this approach is significant and has been reproduced and studied in many systems. The future of trauma systems research rests in evaluating methods to improve on the current systems, not only in terms of mortality, but also in evaluating ways to decrease morbidity and reduce costs. We believe that in a mature regionalized trauma system such as ours, mortality can still be reduced further, however, there is a minimum mortality, which will eventually be reached. The emphasis should now be shifted towards morbidities (length of stay, ICU days, ventilator days, in-hospital complications, nosocomial infections and errors in management) and in identifying and finding ways to reduce delays to definitive care.

13.1.4 Conclusion

In Québec, over the last decade we have progressed from the lack of any trauma system to an organized and constantly evolving regionalized trauma care system. In this system official decisions are being taken following evidence-based evaluations. By decreasing on-scene time and by directly transporting trauma patients to specialized centers which are prepared to accept and treat severe injuries 24-hours a day, mortality has decreased significantly. In 1992, prior to the commencement of trauma care organization in Québec, the mortality rate from major trauma was 51.8% and after 10 years of evaluation and change the rate has decreased to 8.6% in 2002 (Figure 1, Table 1). Constant critical evaluation and change is vital in order to further decrease trauma mortality in a trauma care system.

13.1.5 Connecting Bridge between Studies in Thesis

The first part of the thesis dissected out a regionalized system of trauma care in a specific area from before inception until its current state. This system is currently highly regionalized and mature and improvements to the system over the years have been made thorugh evidence-based assessment. Evidence-based evaluation has allowed for evolution of the system which has led to decreased mortality. We used this mature system as the model for our component-based evaluation of trauma care systems. By applying component-based methodology to patients in a highly regionalized system we aimed to elucidate the most important components in the system as well as the degree of importance of each element.

13.2 The Association between Trauma System and Trauma Center Components and Outcome in a Mature Regionalized Trauma System

13.2.1 Introduction

Trauma care throughout Canada and the United States has seen important change over the last 30 years. The regionalization of trauma care, which has occurred in some Canadian and American regions, has shifted the scope of trauma patient management from an individual hospital-based approach to a systems approach. It consists of the global care of the injured patient, from the time of injury until the end of rehabilitation and the reintegration of the patient into the community with the return to regular activities of daily living ([17],[18],[23],[24]). The regionalized "trauma system" provides a continuum of services encompassing four phases of care: pre-hospital care, in-hospital care, rehabilitation and research driven quality assurance. The ultimate goal of these systems being to ensure that patients with severe injuries receive definitive and appropriate care in a timely manner ([19],[20]).

An integrated systematic approach has various advantages compared to a segregated service approach to the care of the injured patient. These advantages do not only impact on the process of care, they also positively impact on both short and long-term outcome following injury. The scope of trauma care requires integration of all levels of health care services including pre-hospital care, acute in-hospital care and rehabilitation. The range of injuries and body systems involved in trauma requires a multidisciplinary approach in the acute phase of care. The diverse nature of both short and long-term consequences of injury also requires the integration of various disciplines in order to fully rehabilitate patients following injury. Furthermore, the reintegration of these patients into society and to regular activities of daily living is also integral to a systematic regionalized approach to trauma care. High level care at each phase of the spectrum as well as a high level of continuity between phases contributes to the improvement in outcomes observed following the introduction of these systems.

The basis for the regionalization of trauma care or the development of a "trauma system" is the need to link all aspects of trauma care in order to maximize efficiency, pool resources and improve outcomes. A comprehensive trauma system links hospitals, pre-hospital care and other emergency medical services, post hospital care facilities (rehabilitation and long-term care centers), as well as health care and public safety agencies ([152]). Ideal trauma systems include: prevention, access, emergency services, acute hospital care, rehabilitation, and research activities ([153]). These systems have been developed in order to direct seriously injured patients to specific facilities on local, regional, and state/province wide bases. The two main purposes of regionalized trauma care are to improve the quality of care and to decrease its cost ([154]).

The American College of Surgeons Committee on Trauma clearly outlines the importance of emphasizing the trauma system, rather than the trauma center as being integral in improving trauma patient outcome ([153]):

"Care of the injured patient requires a system approach to ensure optimal patient care. A systematic approach is necessary within a facility; however no one trauma center can do everything alone. Thus, a system approach is necessary within an entire community regardless of its size…If resources for optimal care of the injured patient are to be used wisely, then some concentration of resources should occur. This type of resource allocation should allow patients to move to the highest level of care available and, ideally, should also avoid excessive and inappropriate expenditure in a time of limited medical resources."

West identified eight essential elements integral to an inclusive trauma system based on criteria from the American College of Surgeons ([123]). These criteria are: (a) the presence of a lead agency with legal authority to designate trauma centers; (b) the use of a formal process for trauma center designation; (c) the use of American College of Surgeons standards for trauma centers; (d) the use of an out-of-area survey team for trauma center designation; (e) limiting the number of designated trauma centers in a community based on assessment of population need; (f) the application of written triage criteria that form the basis for bypassing non-trauma center hospitals; (g) the presence of ongoing monitoring systems for trauma centers; and (h) the state-wide availability of trauma centers.

Regional trauma care systems denote an approach to trauma care which is coordinated at a regional, as opposed to at a local level. These systems involve state, province or region-wide emergency medical system legislation and authority in order to provide funding for, administer and run the system. By coordinating services on a regional basis, costly and specialized resources can be concentrated in fewer areas and injured patients can be treated in centers with greater amounts of experience and resources.

The civilian interest and the move towards regionalization of trauma care in the United States came about secondary to the U.S. military experience with organized trauma care in Korea and Vietnam ([97],[87],[95]). Civilian trauma providers learned about well-trained paramedical personnel providing care in the field, effective pre-hospital, in-hospital and pre- to in-hospital communications, rapid emergency evacuation and transport systems (helicopter evacuations), and specialized "trauma surgeons" working out of specially designed "trauma centers" or MASH units.

The first civilian regionalized trauma system was in established in Illinois in 1971 ([94],[97],[116],[117],[118],[119],[120],[121]). The "team approach" to trauma care was of paramount importance in establishing this system of treating injured patients, which encompassed access to the system through rehabilitation ([113]). Hospital designation, triage and transport guidelines as well as the concept of a "burn center" were put into place. For the first time, a central bed registry and a patient distribution and triage program were established. Regionalization of care in Illinois, led to an eight percent decline in highway mortality in the first 6 months of 1972 (following regionalization) compared to the same six month period in 1971, prior to regionalization ([121]). This decrease in injury related mortality was observed in spite of an increase in highway accidents and injuries during that same period.

Following the success of the Illinois trauma system, the first and landmark study critically evaluating civilian regionalized care for injured patients and comparing a regionalized to a non-regionalized area was published by West, Trunkey and Lim in 1979 ([131,132]). This study was responsible for a new field of healthcare and health services research. It demonstrated that thirty-seven percent (11/30) of non-CNS related deaths in a non-regionalized area (Orange County) were clearly preventable, compared to none in a regionalized area (San Francisco County). Since that time there have been numerous studies evaluating the effects of trauma care systems on mortality. These systems have been repeatedly shown to decrease mortality and improve the outcome of injured patients in the Province of Quebec, Canada ([293,174,42]), as well as in multiple other diverse regions throughout the western world ([662,233,121,135,663,234,272,347,235,236,498,237,238,239,39,40,322,241,242,243,182,275,664,244,308,219,126,41,136]). The regionalized system of trauma care in Quebec, was established in 1992, is highly advanced and has been previously described in detail ([42,665]). In 1992, prior to the commencement of trauma care organization in Quebec, the mortality rate from major trauma was 51.8%. After 10 years of evaluation and change, the rate has decreased to 8.6% in 2002 ([665]).

Regionalized trauma care incorporates several different elements, which together make up the trauma "system". These systems as a whole have been shown to improve the outcome of injured patients, however, the building blocks required for these systems have been based largely on expert opinion ([25]). Furthermore, these systems have been shown to improve outcome as a whole, however, we do not have evidence regarding which components making up a system contribute to superior outcome and to what degree. There are also no studies assessing whether the US model for trauma care systems is appropriate for all regions. To date, there is no available data enabling us to discern which components of the system are essential and which could be omitted, without affecting patient outcome. Further questions include the assessment of variables that affect the component-outcome association which may include: injury epidemiology, case-mix, geography, accessibility, resource availability and their potential impact on the requirements for residual trauma systems.

We undertook this study in an attempt to identify components of a regionalized trauma care system that are essential in a specific region. We accomplished this by examining the association between distinct independent components of a trauma care system and the morbidity and mortality of trauma patients in an established, contemporary regionalized trauma system.

13.2.2 Methods

13.2.2.1 Study Design

This was an observational database study. The study examined the association between trauma system components and outcome by linking database patients from a regionalized trauma registry with a survey distributed to all contributing hospitals in the region.

13.2.2.2 Data Sources

13.2.2.2.1 Trauma Components Survey

Components of both systematic trauma care regionalization and in-hospital trauma care organization were ascertained from an in-depth review of the available literature regarding trauma system and trauma center effectiveness as well as from guidelines put forth by the American College of Surgeons Committee on Trauma ([153]). The questions were developed by the study authors and were selected so that they adequately represent the important trauma system and trauma center elements in a typical regionalized North American trauma system. Surveys included items concerning in-hospital (14 questions), system-based components (4 questions) and regional demographic variables. Identical surveys were created in both French and English (Table 14) and mailed to the director of trauma services at all 59 trauma centers contributing data to the Quebec Trauma Registry (QTR). At one, two and three months following the initial mailing, trauma directors who had not yet returned the surveys were contacted by both telephone and e-mail requesting completion and return of surveys.

13.2.2.2.2 Quebec Trauma Registry

The QTR is a regional trauma registry for the Province of Quebec, Canada. It was established in 1992. All trauma hospitals throughout the province of Quebec collect data on trauma victims that are then submitted for central processing and verification to the Regie de l'Assurance Maladie du Quebec (RAMQ). At the present time, there are a total of 59 centers in Quebec contributing data to the registry. These consist of: 6 tertiary centers (4 adult, 2 pediatric), 25 secondary and 28 primary centers. Registry inclusion criteria include any one of the following: (1) death as a result of injury; (2) admission with hospital stay ≥ 3 days; (3) admission to the ICU; or (4) interhospital transfers. Exclusion criteria include: (1) all injuries with the primary diagnosis consisting of: intoxication, drowning, electrocution and burns; and (2) admissions secondary to a complication of injury.

Identical data are collected in all participating trauma centers using customized database management software that was specifically designed for the QTR. Data entry is performed by qualified medical archivists at each hospital during the admission and is completed following patient discharge. Patients are identified upon admission through the emergency department records or transfer logs. Eligible patients are tracked prospectively and data are collected prospectively with additional information gathered through chart review within 30 days of discharge.

13.2.2.3 Analysis

The survey database was linked with the QTR database using unique encrypted identifier codes in order to assure hospital anonymity. In order to evaluate the process-outcome associations, processes were defined using variables that describe trauma care system components, including pre-hospital care, in-hospital care, level of regionalization and integration of the system. The primary outcome measure used in this study was death prior to discharge. Secondary outcomes include both hospital and intensive care unit (ICU) length of stay. Stratified analyses for hospital level and Injury Severity Score (ISS) categories were used to determine the association between these covariates and the process-outcome relationships.

Patients were included in the analysis if they were entered into the QTR database between June 1, 1997 and March 30, 2002 and were at least 16 years old at the time of injury. Patients were excluded from analysis if they were transferred from one institution to another following injury; data from the first trauma center where the patient was initially treated or stabilized was included, however all subsequent trauma center data, following transfer, was excluded. Patients were also excluded if they experienced pre-hospital cardiac arrest (defined as non-detectable initial systolic blood pressure in emergency department, or having received pre-hospital cardiopulmonary resuscitation).

Statistical significance for crude associations was assessed using the Chi-Square test and Analysis of Variance for categorical and continuous variables, respectively. Logistic regression models were used in order to control for potential confounding in the assessment of the association between the primary outcome and process-predictor variables. Backwards conditional selection was used to select those variables that defined the model that best described the data with the highest accuracy. A significance level of 5% was set as the maximum for statistical significance.

The dependent variable for the model was survival to hospital discharge or transfer (binary variable: dead = 1, alive = 0). Independent variables included in the final model were: Glasgow Coma Score (GCS)([556]) (continuous variable), Revised Trauma Score (RTS)([263]) (continuous variable), the 1990 revision of the Abbreviated Injury Scale (AIS-90) body regions injured categories ([666]) (categorical variable) and Injury Severity Score (ISS) categories (0-24.0, 24.1-75) (categorical variable). The RTS was calculated based on initial patient status recorded by the trauma team or emergency physician in the trauma bay. Trauma system and in-hospital components were entered into the model as categorical variables.

Adjusted associations between the variables of interest and duration of hospital and ICU stay were estimated using multiple linear regression. Patients who died in hospital prior to discharge were excluded from length of stay analysis. Linear regression was used to adjust for the following associations: age, gender, RTS, GCS, ISS, ISS category, and AIS category. All data was analyzed using the SPSS version 11.0 software package for Windows.

13.2.3 Results

Over 4.8 years, there were 110,924 patients injured in Quebec and included in the QTR. 38,851 patients were excluded secondary to inclusion/exclusion criteria violations. Centers participating in the study are demonstrated geographically by region, by ACS level of in-hospital care and by demographic location in figures 11, 12, and 13 respectively. Thus 72,073 patients were retained in the final study cohort. Of the 59 surveys mailed, 58 trauma centers in Quebec (98.3%) returned the survey. There were 5 tertiary centers (8.6%), 25 secondary centers (43.1%) and 28 primary centers (48.3%) that responded. Crude overall mortality for the sample was 4,446 patients (6.2%). Mean ± standard deviation for age was 55.9 ± 23.4, GCS was 13.1 ± 3.7, RTS was 7.4 ± 1.0 and ISS was 11.9 ± 9.7. Sample demographics are described in table 15. AIS body regions for the sample are described in table 16.

Crude, unadjusted mortality rates for individual trauma system and trauma center components are described in tables 17 and 18, respectively. Final logistic regression model parameter estimates and accuracy statistics are outlined in table 19. Table 20 describes the adjusted odds of mortality for each system component and table 8 describes the adjusted odds of death by in-hospital components. All patients were treated in hospitals where cooperation between trauma centers was established and therefore this component was removed from the trauma systems model. Only pre-hospital notification (system component) (O.R. = 0.608, 95% CI = 0.394-0.938) and the presence of a performance improvement program (in-hospital component) (O.R. = 0.436, 95% CI = 0.202-0.940) were associated with improved survival following injury severity adjustment. Increased trauma patient volume was associated with a significant reduction in adjusted mortality (O.R. = 0.980, 95% CI = 0.969-0.991). Additional components which in multivariate analysis trended towards statistical significance and which are believed by the authors to be clinically important were: the presence of pre-hospital triage protocols in the area served (system component), the presence of a dedicated trauma service within the trauma center, centers which were possessed university affiliation and the presence of general surgery residents in the trauma center (in-hospital components).

13.2.3.1 ISS Categories

Stratified analysis by ISS categories demonstrated that pre-hospital notification was only associated with lower odds of death in patients who sustained mild injuries (ISS ≤ 12) (O.R. = 0.600, 95% CI = 0.386-0.932). This element on its own did not impact on survival in patients with ISS between 12.1 and 24 or with ISS between 24.1 and 75. With regards to in-hospital elements, presence of in-house radiology residents (O.R. = 2.926, 95% CI = 0.935-9.153) and the availability of rehabilitation facilities (O.R. = 2.320, 95% CI = 1.177-4.575) were associated with increased risk of mortality, whereas university affiliation was associated with reduced risk of death (O.R. = 0.297, 95% CI = 0.102-

0.859) in the ISS ≤ 12 category. Performance improvement programs were associated with increased survival in the ISS 12.1 – 24 category (O.R. = 0.080, 95% CI = 0.007-0.970) and the presence of rehabilitation facilities were associated with reduced survival (O.R. = 9.660, 95% CI = 1.094-85.264) in the same ISS category of injury severity.

13.2.3.2 Level of Trauma Center Designation

When the data were analyzed separately by trauma center designation levels (I, II, or III), performance improvement programs were associated with higher survival in tertiary centers (O.R. = 0.706, 95% CI = 0.553-0.902) and the presence of in-house surgical residents was associated with increased mortality in secondary centers (O.R. = 4.059, 95% CI = 1.220-13.501). Tertiary trauma centers were associated with a significant reduction in risk-adjusted mortality compared to both secondary and primary centers (O.R. = 0.684, 95% CI = 0.475-0.985).

13.2.3.3 Length of Hospital and ICU Stay

Crude and adjusted mean length of hospital and ICU length of stay are described in tables 21 and 22, respectively. The only elements significantly associated with overall hospital length of stay following adjustment for potential confounders were the presence of pre-hospital triage protocols (decreased mean LOS by 2.72 days, p=0.045), presence of a performance improvement program (increased mean LOS by 2.41 days, p=0.025), and the presence of 24-hour in-house radiology residents (increased mean LOS by 1.76 days, p=0.031). ICU length of stay was significantly associated with the presence of a lead hospital identified in the region (decreased mean ICU LOS by 7.38 days, p=0.017), and the presence of rehabilitation corridors (increased mean LOS by 8.58 days, p=0.004).

13.2.4 Discussion

Rigid adherence to the classic "trauma system" model outlined by the American College of Surgeons or any other governing health authority on trauma systems ignores the considerable variation in both the specific population needs for trauma system development and maintenance and is unattainable for some regions due to limitations in available financial or other resources ([625,626,139]). Regions, provinces, states and countries need to develop their own trauma systems based not only on the specific needs of the community served, but also based on the existing hospitals, available and accessible expertise, and available resources ([627,324]). Hackey eloquently points out that "*in some states, participants may regard prehospital communications and training as the most pressing problem, whereas others may emphasize data collection, the creation of standards for classifying and/or designating institutions as trauma centers, or other concerns*" ([110]). Unfortunately, to this date, we do not know which elements making up a regionalized trauma system impact on patient outcome, and to what degree ([25]). Furthermore, designated trauma centers and established trauma systems have been shown to possess extreme variability in terms of available resources and characteristics ([315]). By requiring communities to adhere to the all or none recipe for trauma system creation and maintenance, many may be discouraged from regionalizing trauma care due to both high costs, inability to comply with criteria and non-compatibility of the model to their regional needs.

Integrated trauma systems have been designed to improve the outcome of injured patients and have been repeatedly demonstrated to be effective. They have proven to be one of the most important advances in the care of the injured patient over the last 30 years. These systems have been traditionally based on the United States model of regionalization. The current goal for most regions is to create a system that as closely as possible resembles this model ([31]). However, patient demographics and regional variations in geography, population profile and etiology of injuries differ between regions. Currently there are no evidence-based guidelines for the implementation of local trauma systems tailored to specific regional needs. There are also no modern era studies assessing the impact of trauma care system variations on patient outcomes.

Systems of trauma care have been developed, adapted and improved upon based largely on expert opinion ([629,301]). Mullins explains that: "*we are in transition from an era when trauma systems were designed on the basis of speculation to an era when trauma systems should be revised on the basis of conclusions dependably derived from data analysis*" ([281]). Even though there is good evidence from many systems showing that these systems improve outcome, the elements making up these systems were not fashioned in an evidence-based manner and therefore we lack the understanding of the contribution of individual components on the efficacy of the system ([630]). Rutledge highlights the reality that trauma systems have been mostly developed based on informal consensus development ([26]). Informal consensus development is the oldest and most prevalent approach to the selection of interventions involved in the treatment of disease. Interventions designed, implemented and assessed based on information accrued from informal consensus development are often of poor quality and do not reflect the current state of knowledge. Dynamic processes of evaluation based evolution of medicine allow input and continuous assessment. Therefore, change in the traditional model of trauma care, requires careful analysis and evaluation.

There have been few studies examining the relationship between trauma system and trauma center components and outcome. Melton attempted to study the relationship between motor vehicle collision associated mortality and medical resource availability in the state of Alabama ([667]). He found that counties having 24-hour availability of general surgeons, orthopedic surgeons, neurosurgeons, CT scanners and operating rooms were associated with a lower risk of death compared to counties without those resources. Furthermore, he found that counties with designated trauma centers had lower motor-vehicle related mortality rates. Unfortunately, the study was ecologic and therefore the outcome data consisted of population-based crude mortality rates, unadjusted for injury severity, mechanism of injury, or patient age - factors which have previously been shown to impact on survival following automobile collisions. Another ecologic study using per capita pediatric trauma death rates in North Carolina showed that demographic factors had important associations with pediatric trauma mortality rates ([190]). Advanced life support, however, was the only factor which on its own was significantly associated with superior pediatric outcomes.

Pasquale examined five trauma center specific factors: level of accreditation, volume of trauma admissions, presence of in-house trauma surgeons, presence of a surgical residency program, and presence of an on-site medical school and evaluated the association of these factors with outcome of seriously injured patients in 24 trauma centers in Pennsylvania ([467]). The only factor associated with significantly decreased risk of death was increased institutional patient volume. We have confirmed the lack of association between trauma system components and outcome for three of the four factors: presence of in-house trauma surgeons, presence of a surgical residency program, and presence of an on-site medical school. We have also confirmed the improved outcome associated with treatment in high volume trauma centers. Results of this study differed from those of Pasquale in that tertiary trauma centers in Quebec were associated with improved outcomes in risk-adjusted patients. In the current study, university affiliation and the presence of general surgery residents did not reach statistical significance, however the trend was towards a positive impact on survival and the authors believe these factors to be clinically important.

Regionalization of care and centralization of specialized services in order to pool resources in high volume centers has been previously shown to improve outcomes not only in injured patients, but also in other areas of medicine ([442],[222],[223],[226]). The evaluation and management of severely injured patients requires significant institutional commitment and the commitment of skilled personnel ([17]). Recently, there has been much debate over the American College of Surgeons requirements for minimal trauma center volume in order for designation ([153]). Numerous studies have been published over the last few years with conflicting results regarding the correlation between volume and outcome. Several studies have shown that volume has a positive correlation with survival ([467],[468],[469],[467],[470],[471],[469]), however others have demonstrated a lack of association ([472],[473],[186],[474],[475]). We have observed improvement in risk-adjusted outcome in high volume centers in a regionalized trauma system. By treating injured patients in centers with available resources and a significant commitment to the care of the injured patient, it is intuitive that outcomes should be improved. There is also a volume-performance association for surgical procedures and this will affect the outcome of trauma patients requiring operation.

Within trauma centers, the development of a designated trauma service or "trauma team" in order to appropriately manage injured patients and supervise their overall care has repeatedly been shown to decrease mortality and improve effectiveness ([453],[454],[455]). Dedicated trauma programs and trauma teams have also been shown to significantly improve outcomes in severely injured patients within established centers ([309],[458],[455]). These services are responsible for the overall care of the injured patient from the moment they arrive at the emergency department until discharge or transfer to a long term care or rehabilitation facility. They coordinate the care rendered to the polytraumatized patient from multiple consulting medical, surgical, and allied health services teams. Trauma teams significantly improve the care of the injured patient by providing an organized approach to the care of the multiply injured patient. Surgeons or senior surgical residents are typically in charge of the initial resuscitation of injured patients, however emergency medicine physicians and emergency medicine residents have been shown to produce comparable outcome results ([456]). Although the trauma team is activated for most trauma arrivals in many hospitals with trauma team availability, the appropriateness of team activation in all trauma cases has been questioned in recent years ([457],[179]). Trauma team activation is costly to the system and is a major resource expenditure in terms of equipment usage, infrastructure and personnel. The presence of a designated trauma team was positively associated with improved outcomes in hospitals in Quebec, however, did not reach statistical significance. It is probable that this lack of statistical significance was not due to the lack of efficacy of the in-hospital trauma teams, but rather due to the dedication of the hospitals without these teams to the care of the injured patient and the high standards of care demonstrated by hospitals without the mass resources that are available in centers with specialized trauma teams.

The presence of in-house coverage by a trauma or general surgeon at level I trauma centers has recently received much attention in the literature. The ACS requires a senior surgical resident to be in-house 24-hours a day to evaluate, resuscitate and manage injured patients ([153]). However, many surgeons believe that the presence of in-house staff surgeons improves outcomes and some hospitals have required 24-hour in-house staff surgical coverage. The requirement for this has not been evidence-based, is costly to the system and is difficult to implement due to the requirement for attending staff being in-house 24-hours a day. The new evidence seems to demonstrate that in centers where senior surgical residents initially assess and treat injured patients, and where attending staff is available within minimal delay, there is no negative effect with respect to patient outcome ([459],[460],[461],[462],[668]). However, this contentious issue remains unresolved and is at the center of an ongoing, emotionally-charged debate. A similar debate has begun regarding the evidence for the ACS requirement for level I trauma centers to have residency training programs in general surgery. Offner showed that resident participation in the care of injured patients did not affect outcome, however, it did reduce hospital length of stay and emergency department hours ([463]). We did not observe statistically significant superiority in outcomes in centers with residency programs in general surgery or in hospitals with 24-hour a day in-house senior surgical residents with regards to both survival and length of stay. However, improvement in outcomes in hospitals with general surgery residents trended towards significance. The impact of in-house staff surgeons could not be assessed due to the fact that no trauma centers in Quebec have 24-hour in-house staff surgical coverage. These results are also not generalizeable to hospitals receiving high volumes of penetrating trauma (4.2% penetrating injuries in the current study cohort). In hospitals that see high volumes of penetrating injuries, in-house surgical coverage may be important.

Transfers were excluded from the current analysis due to the fact that in a regionalized trauma system, seriously injured patients should be transported directly to a tertiary center and not transferred between institutions, unless pre-hospital death is imminent (these patients were excluded). Furthermore, the assignment of outcome following injury to the initial hospital or to the receiving hospital is a matter of much contention. Transferred patients in a well-running mature, urban trauma system should not have inferior outcome ([636]), however, many areas of study in the current series of project were from areas with rudimentary or non-existent trauma systems. ISS categories were chosen for use in the logistic regression models based on the distribution of mortality by ISS in the sample and the best fit between ISS and mortality (Figure 10).

Limitations include the retrospective nature of the study as well as the fact that in a highly regionalized trauma system, many important elements of the system were present in many areas. Higher level centers are required to implement many more trauma system components than do lower level centers and also receive a higher proportion of severely injured patients in a regionalized trauma care system due to triage and direct transport protocols. In order to attempt to correct for these variations in admission patterns, patients transferred following stabilization at lower level centers were excluded from analysis and confounding due to injury severity was minimized by using logistic and linear regression modeling. The strengths of the current study include both the completeness of the data in the Quebec Trauma Registry and the high participation rate of centers in the trauma system component survey. Patients treated at 58 out of 59 trauma centers (98.3%) receiving injured patients in a highly regionalized, mature contemporary trauma system were included.

The results of this observational study raise many important issues and areas for further in depth prospective evaluation, however, the most important point observed is that in a highly regionalized trauma system, outcomes are improved based on various components making up a system and that not one single component appears to be a major drive for the benefits that have been observed following trauma system implementation and evolution in Quebec ([293],[42]). Significant decreases in adjusted mortality were associated with both pre-hospital notification protocols and in hospitals with performance improvement programs in use. Pre-hospital notification was associated with the most significant reduction in mortality in tertiary centers and in patients with mild injuries (ISS <12). On sub-analysis performance improvement programs appeared to primarily impact on outcome in tertiary centers and in patients with moderate injury severity (ISS 12-24). Additional components which in multivariate analysis trended towards statistical significance were: the presence of pre-hospital triage protocols in the area served, the presence of a dedicated trauma service within the trauma center, centers which possessed a university affiliation and the presence of general surgery residents in the trauma center.

13.2.5 Conclusions

Improvements in outcome in a highly regionalized trauma system are the result of a combination of trauma system and in-hospital components as well as the interaction of these elements. It is very difficult to attribute better outcomes to specific components in a well functioning system however, pre-hospital notification protocols as well as performance improvement programs appear to be associated with overall decreased risk-adjusted odds of death in our mature regionalized trauma system. This study re-affirms the positive association between tertiary trauma centers on outcome as well as the positive association between hospital volume and survival following trauma.

13.2.6 Connecting Bridge between Studies in Thesis

The second part of the thesis looked at specific components of trauma care regionalization and their association with outcome in a mature regionalized trauma system. In order to understand component-related outcomes and discrepancies in resource availability between urban and rural areas in a highly regionalized area, component-based methodology was applied and compared between urban and rural areas in Quebec, Canada.

13.3 The Impact of Differing Trauma System Resources and In-Hospital Trauma Care Availability in Rural and Urban Trauma Centers

13.3.1 Introduction

The regionalization of trauma care, which has occurred in many areas of both Canada and the United States, has shifted the scope of trauma patient management from hospital-based care to a systems approach. The systematic regionalized approach to trauma care (a regional trauma system) consists of the global care of the injured patient, from the time of injury until the end of rehabilitation and allows for the centralization and pooling of resources in order to improve both outcome and efficiency of the system ([17,18]). These systems provide continuity of care from prevention, to injury, to full rehabilitation and re-integration into the community.

Regionalized trauma care incorporates several components integral to the effective and efficient running of the system. The systematic approach to the care of the injured patient has been repeatedly shown to improve outcome in both urban([42]) and rural([25]) areas. However, the building blocks required to construct and maintain trauma systems have been based largely on expert opinion and are not individualized to either setting. Furthermore, components present in urban areas are often lacking in rural areas. To date, there are no data to generate evidence regarding impact of variations in the resources and process of care between urban and rural trauma centers. This is necessary to determine what components are essential to the establishment of rural trauma centers that are integrated with an urban center within a regionalized trauma care system.

Regionalized trauma systems improve outcomes in urban settings. However, the integration of rural regions has been through satellite centers that transfer patients to urban level I trauma centers. The question is whether some components of urban regionalized trauma systems should be transplanted to rural regions and whether or not this is necessary to improve patient outcomes in outlying regions.

Urban and rural areas significantly differ in terms of patient demographics, injury epidemiology (mechanism, type, severity) and resources available to treat and rehabilitate patients following injury. This study describes the association between injury epidemiology and resource availability with patient outcome in urban and rural areas within a regionalized trauma system in Quebec.

13.3.1.1 Objectives:

The objectives for the current study were:

1. To describe and assess differences between rural and urban trauma patients with respect to patient profile, injury characteristics, patient outcomes and process of care.

2. To identify process of care parameters that are important independent prognostic predictors and contribute to the differences in outcome between urban and rural patients.

13.3.2 Methods

13.3.2.1 Study Design

This was an observational study based on two cohorts of trauma patients; one treated in rural centers and the other in urban centers. The study examined the association between trauma center location, and trauma care component availability with patient outcome. Hospital location was defined as being in either a primarily urban or primarily rural location on the basis of survey of trauma directors at all hospitals. The cohorts were assembled from patient treated at 29 rural and 29 urban trauma centers between 1997 and 2002. Patients were included in the urban group if they were treated in a hospital which resided in an urban area and received primarily patients injured in urban areas. Patients were included in the rural group if they were treated in a hospital which resided in a rural area and received primarily patients injured in rural areas.

Follow-up was to hospital discharge or death. Associations between location and trauma system components was assessed through linkage of patients from a regionalized trauma registry with a survey of trauma system components distributed to all contributing hospitals in the region. The Quebec trauma care system has previously been described in detail ([665]).

Patients were included in the analysis if they were entered into the QTR database between June 1, 1997 and March 30, 2002 and were at least 16 years old at the time of injury. Patients were excluded from analysis if they were transferred from one institution to another following injury or if they experienced pre-hospital cardiac arrest (defined as non-detectable initial systolic blood pressure in emergency department, or having received pre-hospital cardiopulmonary resuscitation). Patients treated at hospitals which did not return the survey were also excluded.

13.3.2.2 Sources of Data

13.3.2.2.1 Trauma Care Components Survey

Individual components of both trauma care systems and in-hospital trauma care organization were identified from an in-depth review of the available literature and the guidelines put forth by the American College of Surgeons Committee on Trauma ([153]). These were used to design a questionnaire-based survey that would facilitate the description of trauma care systems and hospitals with respect to the presence of these individual components. The survey was comprised of 14 questions describing in-hospital organization and resource allocation, and four questions describing the trauma care system of the region. French and English versions of the survey have been created and cross-translated for validation. The questionnaires were mailed to the director of trauma services at all centers contributing data to the Quebec Trauma Registry (QTR) (59 trauma centers). Non-responders to the first mailing were contacted by both telephone and e-mail requesting completion and return of surveys. Survey components are described in table 14.

The QTR is a regional trauma registry for the Province of Quebec, Canada that was established in 1992. All trauma hospitals in the province of Quebec submit data on trauma admitted for treatment for central processing and verification to the Regie de l'Assurance Maladie du Quebec (RAMQ). At the present time, there are a total of 59 centers in Quebec contributing data to the registry. Of these: six are tertiary centers (4 adult, 2 pediatric), 25 are secondary and 28 are primary centers. Inclusion criteria for the QTR are: (1) death as a result of injury; or (2) admission with hospital stay $\geq$ 3 days; or (3) admission to the ICU; or (4) interhospital transfers.

Data from all participating centers are collected using customized database management software that was specifically designed for the QTR. Data entry is performed by qualified medical archivists at each hospital during the admission and is completed following patient discharge. Patients are identified upon admission through the emergency department records or transfer logs. All included patients are tracked prospectively through chart review that is completed within 30 days of discharge.

13.3.2.3 Database Linkage and Data Analysis

The survey responses were linked with the QTR database using unique encrypted identifier codes in order to assure hospital anonymity. The two cohorts were compared with respect to patient demographics, process of care and outcome. Process of care was defined using variables that describe trauma care system components, including pre-hospital care, in-hospital care, and level of regionalization and integration of the system (table 14). The primary outcome measure used in this study was death prior to discharge. Secondary outcomes were duration of hospital and intensive care unit (ICU) stay. Subgroup analyses were performed for Injury Severity Score (ISS) categories.

Descriptive statistics were produced for all variables for each of the two study cohorts. Between-cohort differences with respect to patient demographics and injury characteristics were assessed for clinical significance. Due to the large sample size, statistical significance was used only as a reference when clinically important differences were observed. A difference of 0.25 or more was considered clinically important.

The statistical significance of between-cohort differences with respect to mortality was assessed by the chi-square statistic. The relative risk and ninety-five percent confidence intervals were used to provide an assessment of the relative mortality and precision of the estimate for inference to target populations. Multiple-logistic regression analysis was used to adjust the mortality relative risk estimate for the potential confounding effect of patient demographics and injury characteristics.

Backwards conditional selection was used to select those variables that defined the model that best described the data with the highest accuracy. A significance level of 5% was set as the minimum for entering the variable in the final model. Between cohort differences with respect to secondary outcomes were assessed with the chi-square test for categorical variables and the student's t-test for continuous variables. Multiple logistic analysis and generalized linear models were used to adjust these differences for patient demographics and injury characteristics.

Independent variables included in the final model were: Glasgow Coma Score (GCS)([556]) (continuous variable), Revised Trauma Score (RTS)([263]) (continuous variable), the 1990 revision of the Abbreviated Injury Scale (AIS-90) body regions injured categories ([666]) (categorical variable) and Injury Severity Score (ISS) categories (0-24.0, 24.1-75) (categorical variable). The RTS was calculated based on initial patient status recorded by the trauma team or emergency physician in the trauma bay. Trauma center location was entered into the model as a categorical variable (urban = 0, rural = 1).

Patients who died in hospital prior to discharge were excluded from length of stay analysis. All data was analyzed using the SPSS versions 11.0 and 12.0® software packages for Windows.

13.3.3 Results

Over 4.8 years there were 110,924 patients injured in Quebec and included in the QTR. Of these, 39,587 patients (35.7%) were excluded because they did not fulfill the study inclusion/exclusion criteria. This left 71,337 patients (64.3%) in the final study cohort. Of the 59 trauma centers in Quebec, 58 (98.3%) returned the survey and were included in analysis. Centers participating in the study are demonstrated geographically by ACS level of in-hospital care and by demographic location in figures 12 and 13, respectively. Crude overall mortality for the sample was 4,400 (6.2%). Demographics of patients treated at urban and rural centers are described in table 24. Penetrating injuries were more common in urban areas (4.4% urban, 3.3% rural, $p<0.001$). Crude mortality for severely injured trauma patients in rural centers was 4.5% compared to 6.6% in urban centers ($p<0.001$). Patients treated in rural hospitals were significantly older and had injuries of lower severity than patients treated in urban hospitals. Mean hospital and intensive care unit (ICU) length of stay was also less in rural compared to urban hospitals. Table 25 describes the place of injury for patients treated in urban and rural centers in Quebec.

Table 26 outlines the demographics and hospital bed structure in terms of both numbers of hospitals and numbers of patients treated at the hospital for both urban and rural centers. Rural hospitals had significantly less hospital beds, ICU beds and trauma admissions per year compared to urban centers. Tables 27 and 28 outline the average pre-hospital times and trauma center designation by location.

Tables 29 and 30 describe the differences between trauma system and in-hospital resource components between urban and rural centers. Decreased numbers of rural centers compared to urban centers had university affiliations (31.0% rural, 58.6% urban, $p<0.035$), participated in a surgical residency training program (6.9% rural, 37.9% urban, $p=0.006$), participated in an emergency medicine residency training program (6.9% rural, 31.0% urban, $p=0.020$), had 24-hour in-house radiology residents (0% rural, 13.8% urban, $p=0.035$), had orthopedic surgeons on-call to treat trauma patients 24-hours/day (34.5% rural, 82.8% urban, $p<0.001$), had neurosurgeons available to treat trauma patients 24-hours/day (0% rural, 31.0% urban, $p=0.002$), and participated in trauma related research (10.3% rural, 37.9% urban, $p=0.011$).

Logistic regression showed that there was no difference in adjusted odds of death in rural hospitals compared to urban centers (odds ratio for patients treated in rural centers = 1.207, 95% confidence interval = 0.966-1.508) (table 31). Treatment in a rural center compared to an urban center did also not affect the mean adjusted hospital or ICU length of stay. When the analysis was stratified by injury severity score (ISS) category, patients with mild injuries (ISS = 0-12) had significantly poorer outcomes in rural compared to urban centers (odds ratio = 1.33, 95% confidence interval = 1.025-1.737). No differences were observed in either the ISS = 12-24 or 24-75 groups. Linear regression for both hospital (table 32) and ICU length of stay (table 33) demonstrated that adjusted mean length of stays were similar in both urban and rural centers.

13.3.4 Discussion

This study was undertaken with the goal of understanding the variation between trauma system components and outcomes based on location of injury (urban versus rural). We have used a survey linked with outcome and injury severity measures from a trauma registry to compare both the resource availability and outcomes between urban and rural areas within a regionalized trauma system. There were, as expected, significant differences between available resources and components between urban and rural centers. The lack of components in rural areas was not associated with negative outcomes in terms of mortality and hospital or ICU length of stay. In Scotland, McGuffie examined outcomes in moderately and severely injured patients treated in urban and rural areas ([669]). He found that despite long pre-hospital times in rural areas, there were no differences in mortality or length of stay compared to urban areas.

The results are encouraging and demonstrate that within a regionalized system, with established triage and transport protocols, as well as inter-hospital transfer protocols, patients injured in rural areas have similar outcomes to their urban counterparts. The evidence presented in this manuscript supports the need for the creation of trauma systems based on patient demographics and the importance of the differences between urban and rural areas.

Strengths of the study include the number and percentage of participating centers from a single regionalized system (58/59 hospitals, 98%) as well as the even distribution of rural and urban centers. The fact that all centers included in the study participate in the same regionalized trauma system ensures that there is no confounding due to the differing demographics and effectiveness of dissimilar systems. Weaknesses included the retrospective nature of the study and the lack of a control. Prospective studies evaluating systematic and demographic components of trauma systems are not feasible and therefore we must rely on retrospective database methodology. This enables a large sample size and surmounts the logistic dilemmas with prospective studies of this nature.

Rural communities cannot be expected to fit the urban model of trauma system care and must have systems designed to fit their specific needs ([482],[483]). Patients injured in rural areas have different demographics and injury patterns than their urban counterparts ([242]). Emphasis should therefore be placed on maximizing basic principles needed to save life and limb and creating rapid corridors to definitive care. It is ineffectual to waste resources and time trying to acquire and set up highly sophisticated training programs and equipment installation in rural areas. Most patients who die unnecessarily in rural areas can be saved with relatively straightforward and basic techniques. Waller notes that in rural areas the "*need is not for activities that require more money or scarce personnel, but rather for different organizational patterns*" ([484]). Unfortunately, most of the work regarding trauma systems and trauma centers has been concentrated on urban areas.

The differences between urban and rural trauma patients is highlighted by the fact that in urban areas, initial stabilization at non-trauma centers has been repeatedly shown to poorly impact on outcome ([136],[162],[174],[485]), whereas in rural centers initial stabilization and subsequent transfer is necessary, secondary to long pre-hospital times and low population densities. Furthermore, initial stabilization and subsequent transfer has been shown not to negatively impact on outcome in rural areas ([486]).

Rural trauma centers and trauma care systems face unique problems. These problems are related to the fact that the areas served encompass great land mass, but contain only a minority of the population. This contributes to prolonged transport times, difficult patient access, sparse populations, small hospitals and limited financial and human resources ([373],[477]). All of these hurdles contribute to poor outcomes, however, the common denominator in poor outcome is time to definitive and appropriate surgical care ([478]). Dr. Eastman makes an accurate and important point in his paper from 1992: "Blood in our Streets – The Status and Evolution of Trauma Care Systems" ([18]). He states that the "*grave mistake thus far has been the attempt to impose the "urban model" on the rural area.*" He goes on to write that "*this has led to a sense of defeatism and has impeded the development of rural trauma care systems.*" Dr. Eastman later calls for a "*system that addresses the specific needs of rural America. The critical feature will be the linkage between existing systems and sharing of resources.*"

Rural trauma systems have not received as much attention or funding as urban systems and little is known about the applicability of urban research and data to rural settings ([479]). Rogers has dubbed rural trauma the "neglected disease of the nineties" ([480]), a reference to the white paper's claim that trauma was the neglected disease of the sixties and seventies ([109]). He points out that 21,413 manuscripts were published on trauma related topics since the white paper in 1966, however only 270 of them (1.2%) are specifically related to rural trauma. The lack of investigation of the needs of rural communities with regard to injured patients occurs despite the fact that rural accidents are two-times as likely to result in death compared to accidents occurring in urban areas ([481]).

Regionalized trauma care and trauma center designation has also been shown to prevent mortality in rural areas ([493,494,495,496]) and this beneficial effect occurs irrespective of patient volume ([494]). Esposito studied preventable trauma deaths and inappropriate care in a rural state without regionalized trauma care (Montana) ([252]). He found that the overall preventable death rate (pre- and in-hospital) was 13%, in-hospital preventable death rate was 27% and the overall rate of inappropriate care was 33%. These results are not dissimilar to those reported in other rural ([251]) and urban areas lacking regionalized trauma care ([156,217,136]). Esposito later evaluated the effect of trauma system implementation in the rural state of Montana ([497]). In Montana preventable death rates decreased following implementation of a regionalized trauma care system from 13% to 8%. There was also a reduction in inappropriate care.

Karstead identified 266 severely injured patients in a rural area with regionalized trauma care (North Coast EMS region of California) over 3 years ([498]). Key components of the rural trauma program included: (1) warning of the receiving hospital of the impending arrival of a trauma patient using triage criteria; (2) early mobilization/activation of a pre-organized trauma team in the emergency department; and

(3) improved efficiency by regional hospitals and pre-hospital care providers through system review and modification. Mean pre-hospital time in this rural system was 55 minutes. There was a significant reduction in mortality in the rural trauma system compared to the Major Trauma Outcome Study (MTOS)([259]). This study supports the notion that a systematic approach to a region with limited resources improves outcome for injured patients.

Zulick evaluated the outcomes following trauma in a level II rural trauma center in Cooperstown, New York using TRISS methodology ([495]). Mean transport time for non-transferred patients was 1.6 hours. He found that mortality for patients being treated at a level II trauma center in a rural area was comparable to patients with similar injury severity being treated at level I centers ($Z = -0.9$). Wenneker observed improvements in preventable death rates (42% to 14%, $p<0.025$), surgeon's response time and time to surgery following designation of a level II trauma center in a rural area (Napa County, California) ([496]). These improvements occurred despite increased injury severity scores. Norwood observed similar improvements in outcome following implementation of ACS level II criteria in a rural based hospital in northeastern Texas ([499]). He also demonstrated outcome results that exceeded MTOS standards in a rural-based level I trauma center in Urbana, Illinois ([500]).

Time-distance relationships between injured patients and definitive and appropriate care are vital to any trauma system design ([94]). Systems need to be created with geographic, time-transportation factors and maximum health delivery capabilities of a region in mind ([170]). Boyd appropriately points out that in order to design and implement an effective regional trauma system, focusing on one component of the subsystem will not be as effective as an overall and comprehensive view of the sequence of events as they affect the course and final outcome ([94]).

Rural trauma centers working within a regionalized trauma system play an important role in the care of the communities they serve and in the overall system of trauma care. It appears that in Quebec, these centers are doing an excellent job. They are doing this with limited resources compared to their urban counterparts. Areas requiring further investigation include the impact of specific components of trauma systems in rural areas with the aim of creating evidence-based and cost-effective trauma care systems as well as the evaluation of outcomes of patients transferred from rural to urban centers.

13.3.5 Conclusion

Rural trauma centers function with significantly limited resources compared to urban centers in Quebec. The discrepancy in trauma system component availability and resources was not associated with inferior outcomes in rural as compared to urban areas within the Quebec regionalized trauma system. Interpreting results from this study leads us to conclude that in a well-developed and mature trauma system with appropriate and efficient triage, transport and transfer protocols in place, rural trauma patients received good care and have good outcomes. Additional resources should therefore not be allocated to rural trauma areas in systems such as the one in Quebec.

13.3.6 Connecting Bridge between Studies in Thesis

The previous section of the thesis demonstrated that in a well-developed and mature trauma system, rural trauma patients receive good care and have good outcomes, despite the inequalities in resources favoring urban compared to rural areas. The following portion of the thesis is an examination of trauma system-based components in a large cohort of injured patients from centers throughout North America. Similar methodology as was used in the evaluation of the Quebec trauma system was used (section 13.2), however, patients in this cohort differed due to the highly variable geography, resource availability, level of regionalization of trauma care and sample size. The results of this portion of the thesis are therefore greatly more generalizable to patients in systems of varying levels, with varying resources and maturity.

13.4 The Elements of Regionalization – An Evidence-Based Approach to the Creation and Running of Trauma Systems in North America

13.4.1 Introduction

Regionalized systems of trauma care have been created and improved upon based on expert opinion. These systems have repeatedly been demonstrated to improve outcome in severely injured patients, however, we do not have information regarding the components of these systems and their contribution, or lack thereof to this beneficial effect on mortality. The groundwork and background to this portion of the thesis has been described in detail in previous sections.

This study is a continuation of the work outlined in this thesis examining the components of trauma care systems and their individual impact on outcome within these systems. This specific study examines injured patients throughout North America.

This study differs from the previous studies secondary to the fact that it:

1. Examines a very large cohort of injured patients throughout North America which greatly increases the power of the sample from which to draw important conclusions.
2. Comprises patients from a wide range of geographic and demographic regions.

3. Examines trauma patients treated at hospitals within highly-regionalized, partially-regionalized and non-regionalized areas. This differs from the other studies which examined patients in a relatively homogeneous and highly regionalized system.
4. Examines subsets of patients including:
    - Overall cohort inclusive of all patients excluding transfers
    - Transferred patients
    - Patients with blunt injuries only

13.4.2 Methods

13.4.2.1 Study Design

This was an observational database study. The study examined the association between trauma system components and outcome throughout North America by linking database patients from a three separate trauma registries: the American College of Surgeons National Trauma Databank (ACS-NTDB), the Quebec Trauma Registry (QTR) and the Canadian Institutes of Health Research National Trauma Registry (CIHI-NTR) with a survey distributed to all contributing hospitals contributing data to these databanks.

13.4.2.2 Data Sources

13.4.2.2.1 Trauma Components Survey

Components of both systematic trauma care regionalization and in-hospital trauma care organization were ascertained from an in-depth review of the available literature regarding trauma system and trauma center effectiveness as well as from guidelines put forth by the American College of Surgeons Committee on Trauma ([153]). The questions were developed by the study authors and were selected so that they adequately represent the important trauma system and trauma center elements in a typical regionalized North American trauma system. Surveys included items concerning in-hospital (14 questions), system-based components (4 questions) and regional demographic variables. Identical surveys were created in both French and English (Table 14) and mailed to the director of trauma services at all 59 trauma centers contributing data to the Quebec Trauma Registry (QTR). At one, two and three months following the initial mailing, trauma directors who had not yet returned the surveys were contacted by both telephone and e-mail requesting completion and return of surveys.

13.4.3 Quebec - Quebec Trauma Registry (QTR)

The Quebec Trauma Registry was established in 1993. All trauma centers throughout the province of Quebec collect data on trauma victims that are then submitted to the Registry. The primary goal of the registry is to improve the quality of care for trauma victims. By applying statistical methods to data from the registry, questions to many clinical questions have been answered and new hypotheses formulated. The registry was therefore designed not only to improve quality of care, but to improve the process of care, decrease injury morbidity and mortality and in quality assurance. At the present time, there are a total of 59 centers in Quebec contributing data to the registry. These consist of: 6 tertiary centers (4 adult, 2 pediatric), 25 secondary and 28 primary centers.

<u>Inclusion Criteria</u>:

- Death as a result of injury
- Admission with hospital stay $\geq$ 3 days
- Admission to the ICU
- Interhospital transfers

<u>Exclusion Criteria</u>:

- All injuries with the primary diagnosis consisting of: intoxication, drowning, electrocution and burns

- Admissions secondary to a complication of injury

The Registry database was constructed in Paradox®. There are sixty-seven individual tables with injury data in the database. The same data is collected in all the participating trauma centers. Data entry is performed by qualified personnel at each hospital during the admission and is completed following patient discharge. Medical archivists and specific trauma registry personnel abstract the data from the patient's chart once the entire chart has been completed and all test results and medical summaries are intact. Computerized edit checks are performed on a regular basis to ensure that the data are complete and accurate. Reports are produced on a yearly basis.

13.4.4 Canada - National Trauma Registry – (NTR)

The Canadian Institute of Health Information (CIHI) in conjunction with the Trauma Association of Canada (TAC) launched the Canadian National Trauma Registry (NTR) in 1997. Data are submitted by hospitals in all Canadian Provinces and Territories. Deadline for data submission is the end of June of each year in order to be entered in the CIHI's annual report. The goals of the NTR are to ([547]):

- Contribute to the reduction of injuries and related deaths in Canada by providing data which allow the examination of national injury epidemiology
- Facilitate provincial and international injury comparisons
- Increase awareness of injury as a public health problem in Canada
- Assist injury prevention programs
- Facilitate injury research

The NTR currently contains two separate datasets. The Minimal Data Set (MDS). And the Comprehensive Data Set (CDS). The MDS is created using the Hospital Morbidity Database (HMD) at the CIHI which contains demographic, diagnostic and procedural information on all admissions secondary to injury in Canada. The sources for the MDS include CIHI's Discharge Abstract Database (DAD) for all provinces except Manitoba, Quebec and Saskatchewan, which do not submit all inpatient discharge abstract to CIHI. For these three provinces, data is submitted from hospitals to the provincial Minister of Health, who then submits them to the CIHI. Selection of patients to be included in the MDS is based on specific external cause of injury codes (E-codes). A list of CIHI E-Code inclusions and exclusions can be found in TABLES 5 and 6, respectively. A third dataset, the death data set is currently under development. It will include data on all deaths in Canada as a result of injury, regardless of hospitalization.

The CDS includes data on injured patients with major trauma treated in 23 acute care hospitals throughout Canada. Inclusion criteria for the CDS include ([549]):

- Injury Severity Score > 12
- An appropriate External Cause of Injury Code (E-code) (TABLES 5 and 6)
- Patient was treated at an acute care facility (tertiary care center)
- Admission to hospital is not an inclusion criteria; patients who meet the above inclusion criteria and who are treated in the Emergency Department (ED) and discharged home or transferred to another acute care facility can be included.
- Patients that are Dead on Arrival (DOA) are excluded, whereas patients that Die in Emergency departments (DIE) are included.
- DIE is defined by a patient who dies in the ED following any active treatment or resuscitation by the trauma team or ED physician after the patient enters the ED.

13.4.5 United States - National Trauma Databank (NTDB)

The largest trauma registry in the world is the American College of Surgeons National Trauma Databank (ACS – NTDB). The foundations for this database consisting of data on injured patients from all over the United States were laid down and conceptualized in 1966 in the National Academy of Sciences / National Research Council's "white paper" ([109]). The NTDB is designed to provide national and regional benchmarking for use in trauma center and trauma system performan ce improvement, as well as to provide data for trauma-related clinical research ([670]). It was started in 1989 and now contains over 450,000 cases form 130 trauma centers in 28 US states and territories. These 130 centers represent 25% of the level I and II centers in the United States. The annual call for data goes out in March of each year to all participating trauma centers. Data received by the ACS by July 1 are included in the Annual NTDB Report, distributed every October.

The goals set out by the ACS for the NTDB are to ([551]):

- Improve the quality of patient care
- Provide an established information system for the evaluation of injury care and preparedness
- Develop better injury scoring and outcome measures
- Provide a rich source of data for clinical benchmarking, process improvement, and patient safety

Inclusion criteria required for patient entry into NTDB include ([552]):

- Patients with at least one injury ICD-9 diagnosis code in the range of 800-959.9 (injury code as a result of a traumatic event, excluding poisonings and drownings), excluding 905-909 (late effects of injury), 930-939 (foreign bodies), and 958 (early complications of trauma).
- At least one of the following:
    - Admission > 24 hours
    - Dead on arrival (DOA)
    - Patients who die after receiving any treatment while on hospital premises
    - Patients who are transferred into or out of the hospital

The American College of Surgeons Committee on Trauma's NTDB utilizes NATIONAL TRACS® software for the collection, storage, analysis and reporting of data concerning injured patients throughout the United States. Work on TRACS commenced in 1991 and it was unveiled in 1992. It is a commercial microcomputer-based software package providing data capable of supporting and with its main goals to facilitate:

- Treatment and prevention of injury
- Quality assurance
- Cost effectiveness of care
- Trauma reimbursement
- Outcome-based trauma care research

NATIONAL TRACS software was developed at the request of the Committee on Trauma by the Software Development Group, which is comprised of a group of interested trauma surgeons, coordinators and registrars, and is funded by the ACS. It allows individual hospitals to enter data into hospital-based computerized trauma registries, which then is easily submitted to the NTDB for compilation of the National Trauma Registry.

13.4.5.1 Linkage Procedures

Linkage procedures for all three databases are described in detail in section 12.6 - Linkage Procedures.

13.4.5.2 Analysis

The survey database was linked with the three databases using unique encrypted identifier codes in order to assure hospital anonymity. In order to evaluate the process-outcome associations, processes were defined using variables that describe trauma care system components, including pre-hospital care, in-hospital care, level of regionalization, and integration of the system. The primary outcome measure used in this study was death prior to hospital discharge.

Patients were included in the analysis if they were entered into the QTR database between June 1, 1997 and March 30, 2002 and were at least 16 years old at the time of injury. Patients were included in the analysis if they were entered into the NTDB between January 1, 1994 and March 30, 2002 and were at least 16 years old at the time of injury.

Data from the CIHI-NTR database was excluded from analysis due to the inconsistencies between the CIHI database and the other two databases (QTR and NTDB). Linkage proved to be unreliable and difficult and analysis even more difficult due to the paucity of severity indicators in the analysis as well as well as the large amount of missing data.

Patients were excluded from primary analysis if they were transferred from one institution to another following injury; data from the first trauma center where the patient was initially treated or stabilized was included, however all subsequent trauma center data, following transfer, was excluded. Patients were also excluded if they experienced pre-hospital cardiac arrest (defined as non-detectable initial systolic blood pressure in emergency department, or having received pre-hospital cardiopulmonary resuscitation). Patients who were treated in hospitals where linkage was not possible were excluded from analysis. A total of 1,551,271 patients were included in the North American database, 1,246,940 were excluded secondary to exclusion / exclusion criteria leaving 304,331 in the final database.

Three separate analyses were performed in this part of the research program (North American Analysis). The primary analysis included all patients following the aforementioned exclusions (N = 219,575). Secondary sub-analyses were performed for a cohort of transferred patients (N = 82,504) and for a cohort of patients injured in motor vehicle collisions (N = 191,451) (Table 34).

Statistical significance for crude associations was assessed using the Chi-Square test and Analysis of Variance for categorical and continuous variables, respectively. Logistic regression models were used in order to control for potential confounding in the assessment of the association between the primary outcome and process-predictor variables. Backwards conditional selection was used to select those variables that defined the model that best described the data with the highest accuracy. A significance level of 5% was set as the maximum for statistical significance.

The dependent variable for the model was survival to hospital discharge or transfer (binary variable: dead = 1, alive = 0). Independent variables included in the final model included: Glasgow Coma Score (GCS)([556]) (continuous variable), Revised Trauma Score (RTS)([263]) (continuous variable), age (continuous variable), systolic blood pressure in the Emergency Department (continuous variable), Injury Severity Score (ISS) categories (0-24.0, 24.1-75) (categorical variable), and blunt versus penetrating injury (categorical variable). The RTS was calculated based on initial patient status recorded by the trauma team or emergency physician in the trauma bay. Trauma system and in-hospital components were entered into the model as categorical variables. Variables used in logistic regression models were chosen based on fit within the model.

13.4.6 Results

Centers participating in the study are demonstrated geographically by ACS level of in-hospital care and by demographic location in figures 14 and 15, respectively. A total of 1,551,271 patients made up the final North American Database prior to exclusions (Table 35). Over 8 years 360,810 patients were matched and 304,331 were included in the study (after inclusion / exclusion criteria were applied) (Table 34). Of these patients 219,575 were included in the overall analysis, 82,504 were included in the analysis of transferred patient and 191,451 were included in the motor vehicle collision cohort.

Frequency and percentage of patients by year following exclusion for the overall North American Database are described in Table 36. Sample demographics for the entire cohort are outlined in tables 37 and 38. The North American Database possessed a good case mix which included 41.7% of patients injured in rural areas and 58.3% of patients injured in urban areas as well as 10.8% of patients with penetrating mechanism of injury (compared to 4.2% in Quebec). Overall unadjusted mortality for the sample was 4.8%.

13.4.6.1 Overall Analysis

Patients included in the overall North American analysis are described based on their hospital descriptors in table 39. 43.1% of patients were treated in tertiary centers

(ACS level I centers), 21.5% in secondary centers (ACS level II) and 2.2% in primary centers (ACS level III). Crude elements of in-hospital care by patient in the North American cohort are described in table 40. 93% of patients were treated in hospitals which utilized dedicated trauma services (mostly ACS level I centers) and 60.1% of patients were treated in hospitals that had a university affiliation. Crude elements of systematic trauma care by patient in the North American cohort are described in table 41. Almost all patients were treated in systems with pr-hospital notification programs (97.4%) and 72.2% of patients were treated in regions utilizing helicopters for the pre-hospital transport of injured patients. Cooperation between centers was also present for 92.3% of patients.

Univariate analysis of in-hospital care elements (table 42) demonstrated that all elements with the exception of two (performance improvement programs and 24-hour in-house surgeons) were significantly associated with increased mortality. Univariate analysis of systematic trauma care elements (table 43) demonstrated that all elements except one (helicopter systems) were significantly associated with increased mortality. The fact that most elements which were put into place to decrease mortality, morbidity and increase efficiency were associated with significantly increased mortality is not surprising and in fact validates the database. The reason for this is that these statistics are without any attempt at injury severity stratification and therefore sicker or more severely injured patients are transported directly to higher level centers (possessing more in-hospital and systematic components). These patients therefore have increased mortality because they are more critical and injury severity adjustment is required in order to make sense of the true effect of systematic components on outcome.

The multivariate logistic regression model constructed in order to adjust for injury severity and control for case mix. Variables chosen for the overall analysis are outlined in table 44. Model construction consisted of: GCS (continuous variable), RTS (continuous variable), age (continuous variable), systolic blood pressure in the Emergency Department (continuous variable), ISS category (categorical variable – 0-24.0, 24.1-75), and blunt injury (categorical variable).

Table 45 outlines the results of regression analysis for systematic elements of trauma care. A trauma system being present (O.R. = 0.722, C.I. = 0.607-0.859) and trauma being regionalized in the area (O.R. = 0.649, C.I. = 0.530-0.795) were the only elements which, following injury severity adjustment, were demonstrated to be associated with improved survival. Having a helicopter system in place was associated with increased mortality (O.R. = 1.126, C.I. = 1.027-1.234).

Table 46 outlines the results of regression analysis for in-hospital elements of trauma care. Components of in-hospital trauma care associated with improved risk-adjusted survival included: performance improvement programs (O.R. = 0.677, C.I. = 0.518-0.886), residency program in general surgery (O.R. = 0.765, C.I. = 0.587-0.997), and 24-hour availability of neurosurgery (O.R. = 0.697, C.I. = 0.569-0.855). Components of in-hospital trauma care associated with increased risk-adjusted mortality included:

accreditation process (O.R. = 1.127, C.I. = 1.030-1.233), residency program in emergency medicine (O.R. = 1.174, C.I. = 1.057-1.305), 24-hour in-house surgical residents (O.R. = 1.324, C.I. = 1.030-1.552), and 24-hour availability of orthopedic surgery (O.R. = 1.392, C.I. = 1.096-1.767).

13.4.6.2 Transfer Cohort

Sample demographics for the transfer cohort are outlined in tables 47 and 48. Overall unadjusted mortality for the sample was 6.1%. These patients have increased injury severity (mean ISS = 13.0 versus 10.2 in overall cohort) and therefore mortality compared to the overall cohort (mortality rate = 4.8%) secondary to the fact that they were too severely injured to be cared for at their initial hospital and therefore were transferred to a higher level center.

Patients included in the transfer analysis are described based on their hospital descriptors in table 49. 51.2% of patients were treated in tertiary centers (ACS level I centers), 17.6% in secondary centers (ACS level II) and 0.5% in primary centers (ACS level III). Crude elements of in-hospital care by patient in the transfer cohort are described in table 50. 96% of patients were treated in hospitals which utilized dedicated trauma services (mostly ACS level I centers) compared to 93% in the overall, non-transferred cohort and 76.5% of patients were treated in hospitals that had a university affiliation (versus 60.1% in non-transferred cohort). Crude elements of systematic trauma care by patient in the transfer cohort are described in table 51. Almost all patients were treated in systems with pre-hospital notification programs (98.8%). Cooperation between centers was also present for 97.1% of patients.

Univariate analysis of in-hospital care elements (table 52) demonstrated that all elements with the exception of one (24-hour in-house radiologist) were significantly associated with increased mortality. Univariate analysis of systematic trauma care elements (table 53) demonstrated that all elements except two (pre-hospital notification and cooperation between centers – both elements did not reach statistical significance) were significantly associated with increased mortality.

The multivariate logistic regression model constructed in order to adjust for injury severity and control for case mix. Variables chosen for the overall analysis are outlined in table 54. Model construction consisted of: GCS (continuous variable), RTS (continuous variable), age (continuous variable), systolic blood pressure in the Emergency Department (continuous variable), ISS category (categorical variable – 0-24.0, 24.1-75), and blunt injury (categorical variable).

Table 55 outlines the results of regression analysis for systematic elements of trauma care. A helicopter system being present (O.R. = 0.744, C.I. = 0.656-0.844) was the only element which, following injury severity adjustment, was demonstrated to be associated with improved survival. Triage protocols were associated with increased mortality (O.R. = 1.205, C.I. = 1.046-1.388).

Table 56 outlines the results of regression analysis for in-hospital elements of trauma care. Components of in-hospital trauma care associated with improved risk-adjusted survival included: residency program in emergency medicine (O.R. = 0.853, C.I. = 0.732-0.993), and 24-hour in-house surgeons (O.R. = 0.696, C.I. = 0.605-0.802). The only component of in-hospital trauma care associated with increased risk-adjusted mortality was the presence of a 24-hour in-house anesthesiologist (O.R. = 1.492, C.I. = 1.146-1.944).

13.4.6.3 Motor Vehicle Collision Cohort

Sample demographics for the motor vehicle collision cohort are outlined in tables 57 and 58. Overall unadjusted mortality for the sample was 4.5%.

Patients included in the motor vehicle collision analysis are described based on their hospital descriptors in table 59. 41.9% of patients were treated in tertiary centers (ACS level I centers), 23.4% in secondary centers (ACS level II) and 2.4% in primary centers (ACS level III). Crude elements of in-hospital care by patient in the motor vehicle collision cohort are described in table 60. 92% of patients were treated in hospitals which utilized dedicated trauma services (mostly ACS level I centers) compared to 93% in the overall North American cohort (blunt and penetrating) and 58.7% of patients were treated in hospitals that had a university affiliation (versus 60.1% in overall cohort). Crude elements of systematic trauma care by patient in the motor vehicle collision cohort are described in table 61.

Univariate analysis of in-hospital care elements is outlined in table 62. Univariate analysis of systematic trauma care elements is outlined in table 63.

The multivariate logistic regression model constructed in order to adjust for injury severity and control for case mix. Model construction consisted of: GCS (continuous variable), RTS (continuous variable), age (continuous variable), systolic blood pressure in the Emergency Department (continuous variable), ISS category (categorical variable – 0-24.0, 24.1-75), and blunt injury (categorical variable).

Table 64 outlines the results of regression analysis for systematic elements of trauma care. Table 65 outlines the results of regression analysis for in-hospital elements of trauma care.

13.4.7 Discussion

Regionalized trauma systems and trauma centers improve efficiency and patient outcome ([628],[631],[671]). However, we do not have evidence regarding why these systems work and nor do we have evidence examining which components are important to the positive impact these systems of care have had and to what degree. Access to trauma systems throughout North America is variable ([672]) and the discrepancy in areas with highly regionalized trauma systems, moderately regionalized trauma systems or no trauma system whatsoever is based on the cost of these systems, regional differences in resources and geography and the lack of evidence as to which elements of the these systems impact on outcome and to what degree. Mann demonstrated that in the United States, economic issues, recruitment and retention of medical personnel are threatening the viability of current trauma systems ([673]).

In an attempt to define evidence-based components of trauma care systems, a study was conducted which compared available system and in-hospital components of regionalized trauma care with patient survival. Injury severity was controlled for using well-studied and accepted indicators. The methodology for this study has been reported and published previously ([674]). This study differs from the previous studies performed in this body of work secondary to the fact that it examines trauma care throughout North America. This significantly differs from the studies performed looking at patients treated in the Province of Quebec where all patients are treated in a highly regionalized, well-established, improved upon, and mature trauma care system ([665]). Patients in the current study were treated in the full range of trauma care abilities; ranging from completely non-regionalized care areas to the most highly regionalized and well-tuned systems. Even in areas with advanced regionalized trauma systems, a large proportion of patients with serious injuries are not treated at designated trauma centers. In California, only 56% of seriously injured patients were treated at designated trauma centers over 2 years ([675]). Patients in non-regionalized rural areas can have equivalent outcomes whether treated in community hospitals or designated trauma centers ([501]), again raising the question of components in non-regionalized areas that may be able to be put in place to further improve outcomes.

Strengths of the current study include the fact that the study examines a very large sample size which decreases the bias and increases the confidence in the sample. Drawing from a wide-range of systems of trauma care over a large geographic area increases the generalizability of the results to a broader range of communities, as opposed to the Quebec data which is more applicable to well-established regionalized systems of trauma care.

Weaknesses include the retrospective nature of the data as well as the inherent weaknesses in all database studies. Furthermore, selection bias is introduced in any study looking at trauma patients from various non-inclusive registries. The reason for this is because trauma centers agreeing to participate in voluntary trauma registries inherently are those that are committed to trauma care and hence often, but not always, have more trauma system components than those that do not participate in these registries.

A trauma system being present (O.R. = 0.722, C.I. = 0.607-0.859) and trauma being regionalized in the area (O.R. = 0.649, C.I. = 0.530-0.795) were the only system-based elements which, following injury severity adjustment, were demonstrated to be associated with improved survival. This does not necessarily indicate that other components of regionalized trauma care are inconsequential, however, it signifies that the two most important components following injury severity adjustment and control for other components of trauma care were a "system" being present and regionalized care.

A "system" is hard to define. Some areas have a fully functional and regionalized process which is inclusive and incorporates all aspects of pre-, in-, and post-hospital trauma care as well as all ancillary services and programs relating to it. These all inclusive systems more often than not incorporate trauma care research, injury prevention research, injury prevention programs and trauma care education and training program at all levels. However, there are other areas that have a "system" in place which is less comprehensive. Hospitals in this study were left to designate whether a system present or not without strict guidelines as to what a criteria were necessary in order to be designated as an area with a system present. This was done in order to capture areas where there was any semblance of organized trauma care, regardless of what components made up the "system". The reason this was done was because the specific components of the system thought to be important in terms of trauma outcomes (based on available literature) were evaluated separately as system components through the other, more unambiguous elements, studied in this research. However, in this analysis, none of the specific components, when separated out, had a positive impact on patient outcome following injury. The "regionalized system" bore out as the most important factor – demonstrating that in trauma care; the whole is more than the sum of its parts.

Interestingly, having a helicopter system in place was associated with increased mortality (O.R. = 1.126, C.I. = 1.027-1.234). The increased mortality in patients treated and transported from the scene by helicopter cannot be explained solely by the fact that these patients were more severely injured than those transported by ground because data was adjusted for injury severity. Increased mortality could be due to the prolonged distance from the scene to the hospital and therefore possibly increased pre-hospital times which has been shown to negatively impact on outcome by increasing time to definitive care ([28]). However, more importantly, advanced life support procedures performed on-scene and en-route by paramedics and by physicians (who typically staff the helicopters) have been repeatedly shown to increase time to definitive care and to be deleterious to patient outcome ([292,374,376,378,386,430,433,660,661,676,677]).

Components of in-hospital trauma care associated with improved risk-adjusted survival included: performance improvement programs (O.R. = 0.677, C.I. = 0.518-0.886), residency program in general surgery (O.R. = 0.765, C.I. = 0.587-0.997), and 24-hour availability of neurosurgery (O.R. = 0.697, C.I. = 0.569-0.855). Performance improvement programs were also shown to impact positively on survival in the Quebec study. These programs allow for constant re-evaluation of care and allow for improvements on deficiencies as well as reinforcement of properly functioning components.

Residency programs in general surgery are an indicator of a hospital's commitment to surgical education and therefore can be associated with higher level care of injured patients and a more up-to-date staff. Surgeons in hospitals with training programs in general surgery are constantly challenged and required to keep up with current literature and new developments in patient care. Severely injured patients often require intensive surgical and post-surgical care and institutions with general surgery residency programs in place are well-equipped to provide these services and are the probable explanation for the improved outcomes in patients treated in centers with these programs present.

Neurosurgical availability is a key resource for patients with severe head injury. These injuries are often time-sensitive and rapid evaluation, surgical decompression and invasive monitoring is necessary to assure good outcomes in these patients. In the current study, 24-hour neurosurgical coverage was associated with improved outcome for injured patients. The cohort included both head injured and non-head injured patients. Esposito et al. recently reported a study using NTDB data which demonstrated that the immediate availability of neurosurgery was not essential if a properly trained and credentialed trauma surgeon or other health care provider could appropriately monitor injured patients for neurologic demise and effect early transfer should this be required ([678]). This study, however, did not look at mortality. It looked at rates of neurosurgical interventions and timing of interventions and therefore ignores the immeasurable decision-making process that a neurosurgeon often is critical to in deciding who gets these interventions and when.

Components of in-hospital trauma care associated with increased risk-adjusted mortality included: accreditation process (O.R. = 1.127, C.I. = 1.030-1.233), residency program in emergency medicine (O.R. = 1.174, C.I. = 1.057-1.305), 24-hour in-house surgical residents (O.R. = 1.324, C.I. = 1.030-1.552), and 24-hour availability of orthopedic surgery (O.R. = 1.392, C.I. = 1.096-1.767). Possible explanations for these findings include the opinion that having a emergency medicine residents treating trauma patients removes surgical decision making by another level from the time of injury and detracts from the surgical care of the trauma patient which should include triage, initial assessment and management and operative decision-making. The presence of 24-hour in house general surgery residents may contribute to decreased attending staff involvement in the care of the most serious injured patients – those that arrive at night. Hospitals that have 24-hour orthopedic programs are often overburdened by low impact, low injury severity musculoskeletal injuries which can crowd emergency rooms and lead to the tying up of valuable physical, economic and man-power resources making them less available for the care of severely injured patients ([176]). Arabi showed that high patient load at a level I trauma center in Seattle, Washington (one of the largest trauma centers in the country) was not associated with inferior outcomes ([679]), however we do not have data regarding the effect of patient load at lower volume centers.

Due to the fact that data from patients transferred or referred to trauma centers from other hospitals has been shown to introduce bias into data sets, these patients were removed from the primary analysis ([635]). Transferred patients are typically more severely injured thatn directly transported patients and have higher mortalities ([680]). Severely injured transferred patients in some areas have been shown to have significantly inferior outcomes compared to those transported directly to level I centers ([174,681]). However, transferred patients in a well-running, mature, urban trauma system should not have inferior outcome ([636]), however, many areas of study in the current series of projects were from areas with rudimentary or non-existent trauma systems.

The question of what to do with transferred patients in trauma system research is a large area of contention. By including transfers in the cohort, a selection bias is introduced into the sample. It is possible that certain patients would be included in the cohort twice; once from the initial hospital and once from the receiving hospital (for example in the case of a patient stabilized at a level II or III center and then transferred to a level I trauma center for definitive care). Furthermore, the inclusion of transfers makes the allocation of outcome between the initial and secondary hospital difficult. For example, a severely injured patient initially transported to a level II center could be deemed too severely injured to be appropriately treated at the level II center or could be inappropriately treated at the level II hospital and then transferred to a level I center. If this patient was to die in the second hospital (level I), the mortality would be attributed to the level I center and a positive outcome would be attributed to the level II center for the same patient. This inherent risk in including transferred patients in the cohort would make the interpretation of results difficult. Furthermore, by including transfers, multiple outcomes can be attributed to one patient (one outcome at each center the patient is treated in) which would further bias results.

A subanalysis was completed for transferred patients in order to assess the effects of trauma system elements on this specific subset of injured patients. However, the results from these analyses must be carefully interpreted with the aforementioned biases in mind.

Overall unadjusted mortality for the transfer cohort sample was 6.1%. These patients have increased injury severity (mean ISS = 13.0 versus 10.2 in overall cohort) and therefore mortality compared to the overall cohort (mortality rate = 6.1% vs. 4.8%) secondary to the fact that they were too severely injured to be cared for at their initial hospital and therefore were transferred to a higher level center.

51.2% of transferred patients were treated in tertiary centers (ACS level I centers), 17.6% in secondary centers (ACS level II) and 0.5% in primary centers (ACS level III). 96% of transferred patients were treated in hospitals which utilized dedicated trauma services (mostly ACS level I centers) compared to 93% in the overall, non-transferred cohort and 76.5% of patients were treated in hospitals that had a university affiliation (versus 60.1% in non-transferred cohort). Almost all transferred patients were treated in systems with pre-hospital notification programs (98.8%). Cooperation between centers was also present for 97.1% of patients.

A helicopter system being present (O.R. = 0.744, C.I. = 0.656-0.844) was the only system element which, following injury severity adjustment, was demonstrated to be associated with improved survival. Possible explanations for this improved survival compared to the non-transferred cohort is due to the fact that the initial stabilization had already been performed by the time of transfer and that the most expedited mode possible for transport is by air. Also, on-scene time is not a factor in helicopter transfer as opposed to helicopter transport. Patients are taken directly from one hospital to another and little is done en-route; which removes the ALS controversy discussed preciously.

Components of in-hospital trauma care associated with improved risk-adjusted survival in the transfer cohort included: residency program in emergency medicine (O.R. = 0.853, C.I. = 0.732-0.993), and 24-hour in-house surgeons (O.R. = 0.696, C.I. = 0.605-0.802). By definition, transferred patients are very sick on arrival and therefore often require dedicated, specialized care as soon as they arrive at the transferred hospital. These two components demonstrate readiness to respond to these needs as soon as the patient arrived at the door.

13.4.8 Conclusion

From the current analysis of trauma patients throughout North America, we can make generalizations regarding systems of trauma care ranging from those that are not regionalized whatsoever to the highest organization of regionalized trauma care. The presence of an organized trauma system, regionalization of care, performance improvement programs, general surgery programs, and the 24-hour availability of neurosurgery appear to be associated with improved outcome. It is in these components that resources should be concentrated and efforts should be made at improvements. When devising a new trauma system for an area without one, these elements are probably a good place to begin.

13.4.9 Connecting Bridge between Studies in Thesis

The first four sections of the thesis form the bulk of the data to which we have and will draw conclusions in order to make recommendations for improvements to current systems and the establishment and design of new systems. Trauma systems have been designed based on expert panels and opinion. In the final section of the thesis we examine the ability of expert opinion to correctly predict the essential components of trauma care regionalization with regards to their effect on outcome.

13.5 A Comparison between Expert Opinion Regarding Trauma System Element Significance and Outcome–Based Effectiveness of Trauma System Elements

13.5.1 Introduction

Trauma systems have been designed based on expert panels and opinion. Most of the guidelines for trauma system creation were developed in the 1980's and early 1990s([157],[161]). In order to assess the relative importance of specific trauma system components, a survey was created and administered to world-renowned leaders in trauma system development and evaluation. The responses of these experts were then compared with objective evidence accrued through the series of studies in this project.

13.5.2 Methods

Components of both systematic trauma care regionalization and in-hospital trauma care organization were ascertained from an in-depth review of the available literature regarding trauma system and trauma center effectiveness as well as from guidelines put forth by the American College of Surgeons Committee on Trauma ([153]). Surveys were designed by the study authors and were felt to adequately represent important trauma system and trauma center elements in a regionalized North American trauma system. Surveys included in-hospital (21 elements), system-based components (17 elements) and demographic variables. The expert panel surveys (Figure 16) were created based on the trauma systems component survey used in other parts of this manuscript (Table 14).

Expert panel surveys were mailed to 17 trauma system experts across the United States and Canada. An expert was defined as an individual who has either been involved in the creation and/or running of a trauma system in North America, or an individual who has published peer-reviewed manuscripts looking at trauma system effectiveness. In order to assure anonymity, once expert survey scoring systems were received, the points related to each question were entered into a blinded database and the surveys were destroyed.

Experts were asked to fill in a score from 0 to 10 for each element in the survey. They were instructed as follows: "***Could you please fill in a <u>score from 0 to 10</u> for each of the elements on the next two pages. If you believe that an element is not important, please assign a 0 to it. Also, please be aware that a score of X in one category is equivalent to a score of X in another category, therefore please score elements while keeping in mind the rest of the survey. For YES/NO questions, please indicate the points for the YES response only, NO will be taken as zero.***"

13.5.3 Results

Expert surveys were completed and returned by 9 of the 17 (53%) experts surveyed. Trauma system experts agreeing to participate in the survey are listed in table 66. Mean (with standard deviation) scores for both the level of trauma care regionalization and level of in-hospital care are shown in tables 67 and 68, respectively. Figures 17 and 18 show the mean responses in a diagrammatic comparison format.

Trauma system components that were scored highest by trauma system experts included: regionalized trauma care (mean answer = 9.44 ± 1.01), pre-hospital triage guidelines (mean score = 9.44 ± 1.33) dedicated trauma services (mean answer = 9.67 ± 0.71), performance improvement programs (mean answer = 9.89 ± 0.33) and cooperation between centers in the region (mean answer = 9.00 ± 1.80).

In-hospital trauma care elements scored highest by trauma system experts included: the 24-hour availability of an orthopedic surgeon (mean answer = 9.22 ± 2.33) and the 24-hour availability of a neurosurgeon (mean answer = 9.22 ± 2.33).

As previously described, components objectively assessed to be associated with improved outcomes in the Quebec study included: pre-hospital notification (system component) (O.R. = 0.608, 95% CI = 0.394-0.938) and the presence of a performance improvement program (in-hospital component) (O.R. = 0.436, 95% CI = 0.202-0.940).

Increased trauma patient volume was associated with a significant reduction in adjusted mortality (O.R. = 0.980, 95% CI = 0.969-0.991). Additional components which in multivariate analysis trended towards statistical significance were: the presence of pre-hospital triage protocols in the area served, the presence of a dedicated trauma service within the trauma center, centers which possessed university affiliation and the presence of general surgery residents in the trauma center.

In-hospital elements objectively assessed to be associated with improved outcomes in the North American study included: performance improvement programs (O.R. = 0.677, C.I. = 0.518-0.886), residency program in general surgery (O.R. = 0.765, C.I. = 0.587-0.997), and 24-hour availability of neurosurgery (O.R. = 0.697, C.I. = 0.569-0.855). A trauma system being present (O.R. = 0.722, C.I. = 0.607-0.859) and trauma being regionalized in the area (O.R. = 0.649, C.I. = 0.530-0.795) were the only system-based elements which, following injury severity adjustment, were demonstrated to be associated with improved survival.

13.5.4 Discussion

Trauma systems have been designed to improve the outcome for injured patients and have been repeatedly demonstrated to be effective ([628]). They have proven to be one of the most important advances in the care of the injured patient over the last 30 years. These systems have been traditionally based on the United States model of trauma care regionalization. The current goal for most regions is to create a system that as closely as possible resembles this model ([31]). However, patient demographics and regional variations in geography, population profile and etiology of injuries differ between regions. Currently there are no guidelines for the implementation of local trauma systems tailored to specific regional needs. There are also no modern era studies assessing the impact of trauma care system variations on patient outcomes.

Systems of trauma care have been developed, adapted and improved upon based largely on expert opinion ([629],[301]). Mullins explains that: "*we are in transition from an era when trauma systems were designed on the basis of speculation to an era when trauma systems should be revised on the basis of conclusions dependably derived from data analysis*" ([281]). Even though there is good evidence from many systems showing that these systems improve outcome, the elements making up these systems were not fashioned in an evidence-based manner and therefore we do understand the contribution of individual elements to the efficacy of the system ([630]). Rutledge highlights the reality that trauma systems have been mostly developed based on informal consensus development ([26]). Informal consensus development is the oldest and most prevalent approach to the selection of interventions involved in the treatment of injuries. Rutledge further points out that interventions designed, implemented and assessed based upon information gained from informal consensus development are often of poor quality and may be far less effective than initially thought. This is well highlighted by the decades of use of MAST pants for the treatment of patients in shock. These devices were introduced and implemented secondary to expert consensus panels, however, years later were scientifically evaluated and shown to be detrimental to injured patient outcome ([443],[386]). Rutledge explains:

> *"The days of opinion-based and data-free decision making should be over. A growing emphasis on careful analyses of trauma-related data sources is the wave of the future in informed decision making in health care in general and in trauma in particular."* ([26])

Expert responses to our survey did correctly identify some elements proven to be important by objective evidence-based analyses of trauma system components in North America. However, experts also put much emphasis on many components which did not bear out in our analyses. This is not to say that the expert opinion was or is incorrect, but merely points out that it is expert estimation is imperfect and if there is objective evidence available it should be valued above expert opinion. In reality, the experts are correct in attributing high scores to multiple components and they appreciate, better than any research that improved outcomes in systems of care are secondary to the interplay of multiple elements which is impossible to demonstrate with studies such as the ones described in this series of projects.

13.5.5 Conclusion

Trauma systems and the components which comprise them were originally devised based on expert opinion. They have subsequently been shown to significantly improve the outcome of injured patients in many systems throughout the world over the last thirty years. This study demonstrates that expert estimation is imperfect at allocating relevance to various components making-up trauma systems throughout North America. However, the interplay of various components on the positive outcome attributed to regionalized systems of trauma care is probably better appreciated by experts than by models which separate these components out.

14. Summary

The series of projects which comprise this thesis have attempted to dissect trauma systems into their basic components and then attribute specific outcomes to each element in order to enable the creation of evidence-based, cost-effective trauma systems for the future. The goals of the project were accomplished. To our knowledge, this is the first study to ever look at trauma systems in this way and hence creates benchmarks for future research in this area.

Data from this study will hopefully:

- Improve trauma systems in place based on evidence-based components.
- Enable the ability to concentrate efforts and funding.
- Allow systems to prioritize system-based components.
- Allow the design of cost-effective systems for areas without systems currently in place.
- Enable areas with limited funds to implement bare-bones trauma systems based on the proven-components.
- Methods used can be applied to systems in place to compare component based-outcomes to "North-American Benchmarks" which have been defined through this research.
- Be used to identify deficiencies and hopefully improve outcomes in current systems.

- De-mystify the trauma system design which has been traditionally based on expert opinion, rather than evidence and systematic research.

Trauma systems were designed based on expert opinion and experience. The elements that make up these systems were not put together in an evidence-based manner. Until now, we therefore, did not understand the benefits of the specific elements, which make up each of these categories. By elucidating the elements which contribute to improved trauma patient survival and decreased morbidity, we can now design cost-effective trauma systems.

By understanding the elements that are beneficial in areas with differing demographics, we can begin to design tailor-made trauma systems, which can respond to the needs of the community served. Regions contemplating establishing new trauma systems can design these new systems using evidence-based criteria. This will avoid the blanket usage and advocacy among many communities of the American model of regionalization which has been applied by many areas, even though the individual components of the system have not been subjected to critical evaluation ([633],[634]).

14.1 Primary Aim

Regionalized trauma systems have repeatedly been shown to improve outcomes. However, until now, we did not know which elements of these systems and to what degree these elements improve outcome. Our primary objective was to bring an evidence-based approach to the creation and running of trauma systems, based on “outcomes” related to specific elements which make up the “structure” of the systems and contribute to the “process” of care which make up these systems.

14.2 Main Findings

- Constant critical evaluation and change is vital in order to further decrease trauma mortality in a trauma care system.

- Improvements in outcome in a highly regionalized trauma system are the result of a combination of trauma system and in-hospital components as well as the interaction of these elements. It is very difficult to attribute better outcomes to specific components in a well functioning system however; pre-hospital notification protocols as well as performance improvement programs appear to be associated with overall decreased risk-adjusted odds of death in a mature regionalized trauma system.

- Rural trauma centers function with significantly limited resources compared to urban centers in highly regionalized trauma systems. The discrepancy in trauma system component availability and resources is not associated with inferior outcomes in rural as compared to urban areas. In a well-developed and mature trauma system with appropriate and efficient triage, transport and transfer protocols in place, rural trauma patients received good care and experience good outcomes.

- From the analysis of trauma patients throughout North America, we can make generalizations regarding systems of trauma care ranging from those that are not regionalized whatsoever to the highest organization of regionalized trauma care. The presence of an organized trauma system, regionalization of care, performance improvement programs, general surgery programs, and the 24-hour availability of neurosurgery appear to be associated with improved outcome. It is in these components that resources should be concentrated and efforts should be made at improvements. When devising a new trauma system for an area without one, resources should be concentrated on these elements.

- Trauma systems and the components which comprise them were originally devised based on expert opinion. They have subsequently been shown to significantly improve the outcome of injured patients in many systems throughout the world over the last thirty years. We have shown that expert estimation is imperfect at allocating relevance to various components making-up trauma systems throughout North America.

14.3 Conclusions

This is the first study to evaluate the specific elements which go into building a trauma system / trauma center. These elements were created by committees based on their experience in treating trauma patients in urban hospitals and in war-time scenarios. The creation of these systems was not evidence-based and although these systems have been shown to work and improve outcomes, we now understand which elements of these systems are responsible for the improvement in outcome, to what degree these elements contribute to improved outcome, and which elements do not.

14.4 Strength of Evidence

The strength of evidence for the program of research which comprise this thesis is strong. The use of a combination of databases which comprise the majority of trauma data from areas throughout North America as well as the fact that the final analysis is based on a very large sample contribute to the strength of evidence. The limitation of retrospective database studies such as this study is overpowered by the extremely large sample size of the cohort. Weaknesses include the requirement for linkage in the North American cohort to protect confidentiality as well as the heterogeneity in trauma care throughout different regions in the study sample. This heterogeneity, however, improves the generalizability of the results to areas with different geography, resources, trauma epidemiology, and maturity of systems.

We have been able to study and obtain important results for components of trauma care in a highly regionalized and mature system, in rural versus urban areas, in areas with varying levels of trauma care regionalization and for separate cohorts of patients (direct admissions, motor vehicle collisions, transfers). These analyses have improved the ability of the results and conclusions to be applied to different settings and cohorts of patients.

14.5 Final Conclusion

Evidence-based, component-oriented analysis can be successfully applied to the evaluation of trauma care systems. Results from these analyses can be used to define variables which impact positively on outcome for injured patients and to what degree. The results of this study can be used to create new systems and update current systems in an evidence-based manner which will lead to improved outcomes and cost-efficiency in these systems.

14.6 Implications / Impact

The series of studies comprising this project aimed to examine the individual elements or components of a trauma system and their effect on patient outcome. By examining the relationship between individual elements making up a trauma system and their relationship to patient outcome, the project will help to define policy guidelines that can be implemented at the regional level in order to create efficient and evidence-based trauma systems. This thesis provides the information required to define the important elements of a trauma system as well as their degree of importance and will have implications on the treatment of trauma patients throughout North America.

14.7 Future Research

Future research stemming from this thesis will include examining trauma care systems throughout the entire world (research already in progress) as well as short and long-term quality of life issues following injury (research already in progress). Evidence-based component analysis will also be used to evaluate other (non-North American) systems as well as individual systems which comprised part of the overall database for this thesis and areas which were not included in this analysis.

14.8 Final Statement

This is the first study to evaluate the specific elements which go into building a trauma system / trauma center. These elements were created by committees based on their experience in treating trauma patients in urban hospitals and in war-time scenarios. The creation of these systems was not evidence-based and although these systems have been shown to work and improve outcomes, we now understand which elements of these systems are responsible for the improvement in outcome, to what degree these elements contribute to improved outcome, and which elements do not.

15. Appendix

15.1 Tables

Table 1 – American College of Surgeons Trauma Center Designation Structure

Level I Trauma Center Structure

- Tertiary care facility central to the trauma care system
- All patients who require access to the center should have access to it
- Provides leadership and total care for every aspect of injury (from prevention to rehabilitation)
- Adequate depth of resources and personnel
- Usually university-based
- Leadership in research, education and system planning in trauma
- Medical education programs for residents, physicians, nurses, pre-hospital care providers

Level II Trauma Center Structure

- Expected to provide initial definitive trauma care, regardless of severity of injury
- May not have the ability to provide same comprehensive care as level I center due to location, resources, staff, facilities
- Patients with injuries too complex to be managed should be transferred to level I centers
- Level II centers may be the most prevalent centers in a community, managing the majority of trauma patients
- Can be academic, public or private facilities and can be located in urban, suburban, or rural areas
- In areas where level I centers do not exist, level II centers should take on the responsibility for education and system leadership

Level III Trauma Center Structure

- *Serves communities that do not have immediate access to a level I or II institution*
- Provide prompt assessment, resuscitation, emergency operations, and stabilization for trauma patients
- Arrange transfer to centers that can provide definitive care
- Generally are not appropriate in urban or suburban areas with level I and/or level II resources

Level IV Trauma Center Structure

- Provide advanced trauma life support (ATLS) prior to patient transfer in remote areas where no higher level of care is available
- May be a clinic rather than a hospital
- May or may not have a physician available
- Due to the isolated location, the level IV center is the defacto primary care provider
- If willing to make commitment to provide optimal trauma care, given its resources, level IV facility should be an integral part of the inclusive trauma care system
- Must have a good working relationship with nearest level I, II, or III center in order to assure prompt and appropriate transfer
- Involvement of a committed health care professional who can provide leadership and sustain the affiliation with other centers is essential

Table 2 – American College of Surgeons Trauma Center Requirements by Designation Level

The following table shows levels of categorization and their essential (E) or desirable (D) criteria.

	Levels I	II	III	IV
INSTITUTIONAL ORGANIZATION (see Chapter 5)				
Trauma program	E	E	E	E
Trauma service	E	E	E	—
Trauma team	E	E	E	E
Trauma program medical director	E	E	E	D
Trauma multidisciplinary committee	E	E	E	D
Trauma coordinator/TPM	E	E	E	E
HOSPITAL DEPARTMENTS/DIVISIONS/SECTIONS				
Surgery	E	E	E	—
Neurological surgery	E	E	—	—
Neurosurgical trauma liaison	E	E	—	—
Orthopaedic surgery	E	E	E	—
Orthopaedic trauma liaison	E	E	E	—
Emergency medicine	E	E	E	—
Anesthesia	E	E	E	—
CLINICAL CAPABILITIES (Specialty Immediately Available 24 hours/day)				
Published on-call schedule	E	E	E	E
General surgery	E	E	E	D
Published back-up schedule	E	E	D	—
Dedicated to single hospital when on-call	E	E	D	—
Anesthesia (see Chapter 11)	E	E	E	D
Emergency medicine[1]	E	E	E	—
On-call and promptly available 24 hours/day				
Cardiac surgery	E	D	—	—
Hand surgery	E	E	D	—
Microvascular/replant surgery	E	D	—	—
Neurologic surgery	E	E	D	—
Dedicated to one hospital or back-up call (see Chapter 8)	E	E	D	—
Obstetrics/gynecologic surgery	E	E	D	—
Ophthalmic surgery	E	E	D	—
Oral/maxillofacial surgery	E	E	D	—
Orthopaedic surgery	E	E	E	D
Dedicated to one hospital or back-up call (see Chapter 9)	E	E	D	—
Plastic surgery	E	E	E	D
Critical care medicine	E	E	D	—
Radiology	E	E	E	D
Thoracic surgery	E	E	D	—
CLINICAL QUALIFICATIONS				
General/trauma surgeon (see Chapter 6)				
Current board certification	E	E	E	—
16 hours CME/year	E	E	D	D
ATLS completion	E	E	E	E
Peer review committee attendance >50%	E	E	E	—
Multidisciplinary committee attendance	E	E	E	—
Emergency medicine (see Chapter 7)				
Board certification	E	E	D	—

	Levels I	II	III	IV
Trauma education: 16 hours CME/year	E	E	D	—
ATLS completion	E	E	E	E
Peer review committee attendance >50%	E	E	E	—
Multidisciplinary committee attendance	E	E	E	—
Neurosurgery (see Chapter 8)				
Current board certification	E	E		—
16 hours CME/year	E	E	D	D
ATLS completion	D	D	D	D
Peer review committee attendance >50%	E	E	E	—
Multidisciplinary committee attendance	E	E	E	—
Orthopaedic surgery (see Chapter 9)				
Board certification	E	E	D	—
16 hours CME in skeletal trauma	E	E	D	D
ATLS completion	D	D	D	D
Peer review committee attendance >50%	E	E	E	D
Multidisciplinary committee attendance	E	E	E	—
FACILITIES/RESOURCES/CAPABILITIES				
Volume Performance				
Trauma admissions 1,200/year	E	—	—	—
Patients with ISS >15 (240 total or 35 patients/surgeon)[2]	E	—	—	—
Presence of surgeon at resuscitation	E	E	E	D
Presence of surgeon at operative procedures	E	E	E	E
Emergency Department (ED)				
Personnel				
Designated physician director	E	E	E	D
Equipment for resuscitation for patients of all ages				
Airway control and ventilation equipment	E	E	E	E
Pulse oximetry	E	E	E	E
Suction devices	E	E	E	E

	Levels I	II	III	IV
Electrocardiograph-oscilloscope-defibrillator	E	E	E	E
Internal paddles	E	E	E	—
CVP monitoring equipment	E	E	E	D
Standard IV fluids and administration sets	E	E	E	E
Large-bore intravenous catheters	E	E	E	E
Sterile surgical sets for				
Airway control/ cricothyrotomy	E	E	E	E
Thoracostomy	E	E	E	E
Venous cutdown	E	E	E	E
Central line insertion	E	E	E	—
Thoracotomy	E	E	E	—
Peritoneal lavage	E	E	E	D
Arterial catheters	E	E	D	D
Ultrasound	D	D	D	D
Drugs necessary for emergency care	E	E	E	E
X ray availability 24 hours/day	E	E	E	D
Cervical traction devices	E	E	E	D
Broselow tape	E	E	E	E
Thermal control equipment				
For patient	E	E	E	E
For fluids and blood	E	E	E	D
Rapid infuser system	E	E	E	D
Qualitative end-tidal CO_2 determination	E	E	E	E
Communication with EMS vehicles	E	E	E	E
Operating Room				
Immediately available 24 hours/day	E	D[3]	D	D
Personnel				
In-house 24 hours/day	E	D[3]	—	—
Available 24 hours/day	—	E	E	E
Age-specific equipment				
Cardiopulmonary bypass	E	D	—	—
Operating microscope	E	D	D	—

	Levels I	II	III	IV
Thermal control equipment				
For patient	E	E	E	E
For fluids and blood	E	E	E	E
X ray capability, including c-arm image intensifier	E	E	E	E
Endoscopes, bronchoscope	E	E	E	D
Craniotomy instruments	E	E	D	—
Equipment for long bone and pelvic fixation	E	E	E	D
Rapid infuser system	E	E	E	D
Postanesthetic Recovery Room (SICU is acceptable)				
Registered nurses available 24 hours/day	E	E	E	—
Equipment for monitoring and resuscitation	E	E	E	E
Intracranial pressure monitoring equipment	E	E	D	—
Pulse oximetry	E	E	E	E
Thermal control	E	E	E	E
Intensive or Critical Care Unit for Injured Patients				
Registered nurses with trauma education	E	E	E	—
Designated surgical director or surgical co-director	E	E	E	D
Surgical ICU service physician in-house 24 hours/day (see Chapter 11)	E	D	D	—
Surgically directed and staffed ICU service	E	D	D	—
Equipment for monitoring and resuscitation	E	E	E	—
Intracranial monitoring equipment	E	E	—	—
Pulmonary artery monitoring equipment	E	E	E	—
Respiratory Therapy Services				
Available in-house 24 hours/day	E	E	D	D
On call 24 hours/day	—	—	E	D
Radiological Services (Available 24 hours/day)				
In-house radiology technologist	E	E	D	D
Angiography	E	E	D	—
Sonography	E	E	E	D

	Levels I	II	III	IV
Computed tomography	E	E	E	D
In-house CT technician	E	D	—	—
Magnetic resonance imaging	E	D	D	—
Clinical Laboratory Service (Available 24 hours/day)				
Standard analyses of blood, urine, and other body fluids, including microsampling when appropriate	E	E	E	E
Blood typing and cross-matching	E	E	E	E
Coagulation studies	E	E	E	E
Comprehensive blood bank or access to a community central blood bank and adequate storage facilities	E	E	E	E
Blood gases and pH determinations	E	E	E	E
Microbiology	E	E	E	E
Acute Hemodialysis				
In-house	E	D	—	—
Transfer agreement	—	E	E	E
Burn Care—Organized				
In-house or transfer agreement with Burn Center	E	E	E	E
Acute Spinal Cord Management				
In-house or transfer agreement with Regional Acute Spinal Cord Injury Rehabilitation Center	E	E	E	E
REHABILITATION SERVICES				
Transfer agreement to an approved rehabilitation facility	E	E	E	E
Physical therapy	E	E	E	D
Occupational therapy	E	E	D	D
Speech therapy	E	E	D	—
Social Service	E	E	E	D
PERFORMANCE IMPROVEMENT				
Performance improvement programs	E	E	E	E
Trauma registry				
In-house	E	E	E	D
Participation in state, local, or regional registry	E	E	E	E
Orthopaedic database	D	D	—	—
Audit of all trauma deaths	E	E	E	E

	Levels I	II	III	IV
Morbidity and mortality review	E	E	E	E
Trauma conference multidisciplinary	E	E	E	D
Medical nursing audit	E	E	E	E
Review of prehospital trauma care	E	E	E	D
Review of times and reasons for trauma-related bypass	E	E	D	D
Review of times and reasons for transfer of injured patients	E	E	D	D
Performance improvement personnel dedicated to care of injured patients	E	E	D	D
CONTINUING EDUCATION/OUTREACH				
General surgery residency program (see Chapter 17)	E	D	—	—
ATLS provide/participate	E	D	D	D
Programs provided by hospital for:				
Staff/community physicians (CME)	E	E	E[4]	D
Nurses	E	E	E	D
Allied health personnel	E	E	E	—
Prehospital personnel provision/participation	E	E	E	D
PREVENTION				
Injury control studies	E	D	—	—
Collaboration with other institutions	E	D	D	D
Monitor progress/effect of prevention programs	E	D	D	D
Designated prevention coordinator-spokesperson for injury control	E	E	D	—
Outreach activities	E	E	D	D
Information resources for public	E	E	D	—
Collaboration with existing national, regional, and state programs	E	E	D	—
Coordination and/or participation in community prevention activities	E	E	E	D
RESEARCH				
Trauma registry performance improvement activities	E	E	E	—
Research committee	E	D	—	—
Identifiable IRB process	E	D	—	—
Extramural educational presentations	E[3]	D	D	—
Number of scientific publications	E[4]	D	—	—

[1] When emergency medicine specialists are not involved with the care of the injured patient, these criteria are not required.

[2] The mechanism to calculate ISS should be through use of AIS 90 and handcoding.

[3] An operating room must be adequately staffed and immediately available in a Level I trauma center. This is met by having a complete operating room team in the hospital at all times, so if an injured patient requires operative care, the patient can receive it in the most expeditious manner. These criteria cannot be met by individuals who are also dedicated to other functions within the institution. Their primary function must be the operating room.

An operating room must be adequately staffed and available when needed in a timely fashion in a Level II trauma center. The need to have an in-house OR team will depend on a number of things, including patient population served, ability to share responsibility for OR coverage with other hospital staff, prehospital communication, and the size of the community served by the institution. If an out-of-house OR team is used, then this aspect of care must be monitored by the performance improvement program.

Brasel KJ, Akason J, Weigelt JA: The dedicated operating room for trauma: A costly recommendation. *J Trauma* 1998; 14: 832-838.

[4] In areas where the Level III hospital is the lead institution, these educational activities are an essential criteria. When the Level III is in an area that contains other hospital resources, such as a Level I or II, then this criteria is no longer essential.

[5] Four Educational Presentations per year for the program. These presentations must be given outside the academically affiliated institutions of the Trauma Center.

[6] Publications should appear in peer-reviewed journals. *Index Medicus* listing is preferable. In a three-year cycle, the minimum acceptable number is 10 for the entire trauma program. This must include a minimal activity of one publication (per review cycle) from the physicians representing each of the four following specialties: emergency medicine, general surgery, orthopaedic surgery, and neurosurgery.

Table 3 – Trauma System Effectiveness

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalized Mortality	Regionalized Mortality	Change
Abernathy JH[682]	2002	Level I TC, University of Alabama at Birmingham (pre- and post-regionalization)	Hospital-based Trauma Registry	Injured patients	1306 pre 1718 post	5.9% crude mortality	3.8% crude mortality	Adjusted Odds of death post regionalization = 0.48
Nathens AB[illegible]	2000	United States (22 regionalized states versus non-regionalized states)	National Vital Statistics Database	All injury deaths	67,429 deaths	29.2/100,000	26.5/100,000	9% lower crude injury mortality rate in regionalize states
Nathens AB[illegible]	2000	United States (comparison between pre-regionalization and post-regionalization in 22 states with trauma systems)	Fatality Analysis Reporting System	MVC mortality	439,195 deaths	16.9 deaths per 100,000 person-years	14.3 deaths per 100,000 person-years	MRR = 0.87 (pre- vs post-regionalization)
Özgüc H[illegible]	2000	Uldağ University Medical School, Bursa, Turkey (pre- versus post-in-hospital trauma integration)	Medical Records Review	Seriously injured patients	242 pre 137 post	32.5% crude mortality	23.3% crude mortality	9.2% improvement in crude mortality
Nathens AB[illegible]	1999	United States (comparison between pre-regionalization and post-regionalization in 22 states with trauma systems)	Fatality Analysis Reporting System	MVC mortality		17.3 deaths per 100,000 person-years	14.2 deaths per 100,000 person-years	Adjusted Mortality Rate Ratio = 0.91 (pre- vs post-regionalization)
Sampalis JS[illegible]	1999	Montreal and Quebec City, Quebec (pre- and post-regionalization)	Regional Trauma Database Analysis	Seriously injured patients	1,884 pre 2,107 post	51.8% crude mortality	17.7% crude mortality	34.1%% improvement in crude mortality (O.R.=0.147 post regionalization)
Mullins RJ[illegible]	1998	Oregon (pre- and post-regionalization) and Washington State (non-regionalized)	Hospital Discharge Data Analysis	Seriously injured patients	30,757 pre (OR + WA) 11,879 post (OR only)	R.R. for death = 1.0	R.R. for death = 0.91	9% decreased risk of death post regionalization
Hulka F[illegible]	1997	Oregon (regionalization) and Washington State (non-regionalized)	Hospital Discharge Data Analysis	Seriously injured children (<19 years)	12,991 non-regionalized 8,981 regionalized	O.R. for death = 1.0	O.R. for death = 0.68	32% adjusted risk-reduction for death in regionalized area
Mullins RJ[illegible]	1997	Oregon (pre- and post-regionalization) and Washington State (non-regionalized)	Hospital Discharge Data Analysis	Seriously injured patients	10,496 pre 10,629 post	O.R. for death = 0.92	O.R. for death = 0.80	8% decreased odds of death post regionalization
Rogers FB[illegible]	1997	San Diego County(urban regionalized trauma system) compared to Vermont(rural non-regionalized system)	State Medical Examiner's Database and Autopsy Database	On-scene deaths	103 non-regionalized 248 regionalized	72% crude mortality	40.5% crude mortality	Rural/non-regionalized areas have significantly higher proportion of on-scene deaths
Nichol J[illegible]	1997	North Staffordshire Royal Infirmary and 5 district general hospitals in North West Midlands (regionalized) vs Lancashire and Humberside, England (non-regionalized)	Medical Records Review	Seriously injured patients	1503 non-regionalized 1143 regionalized	45% crude mortality	43% crude mortality	No difference in either crude or adjusted mortality
Mullins RJ[236]	1996	State of Oregon (pre- and post-regionalization)	Hospital Discharge Data Analysis	Injured patients	14,694 pre 13,654 post	O.R. for death = 1.0	O.R. for death = 0.82	18% decreased odds of death post regionalization
Sampalis JS[illegible]	1995	Montreal, Quebec (pre- and post-trauma center designation)	Regional Trauma Database Analysis	Seriously injured patients	158 pre 288 post	20% crude mortality	10% crude mortality	Mortality pre-regionalization significantly greater than MTOS, post-regionalization no change
Stewart TC[illegible]	1995	Victoria Hospital, London, Ontario (pre- and post-regionalization)	Hospital-based Trauma Registry (TRISS)	MVC patients, ISS>12	156 pre 189 post	Z = -0.40	Z = +0.72	6 more survivors per 100 patients post regionalization
Mullins RJ[237]	1994	Four Counties in Portland, Oregon (pre- and post-regionalization)	Hospital Discharge Data Analysis	Injured patients	25,145 pre 21,806 post	O.R. for death in Level I centers = 1.0		

Table 4 – Trauma System Effectiveness

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalized Mortality	Regionalized Mortality	Change
Karsteadt LL([436])	1994	North Coast EMS Region of California (rural trauma system post-regionalization compared to MTOS)	Regional Trauma Registry	Seriously injured patients	266 patients	MTOS Ps = 23.6%	Observed Survival = 20.3%	Z = -2.33 indicating lower mortality in study group compared to MTOS
Rutledge R([182])	1993	North Carolina Counties With Trauma Centers versus Counties Without Trauma Centers	State Medical Examiner's Database	Per capita trauma death rates	309 (TC counties) 78 (non-TC counties)	5.0 deaths per 10,000 population	4.0 deaths per 10,000 population	Decrease in 1 death per 10,000 population
Hill DA([347])	1993	Royal Prince Alfred Hospital, Sydney, Australia (pre- versus post-in-hospital trauma integration)	Hospital-based Trauma Registry	Seriously injured patients	70 pre 51 post	28% crude mortality	11% crude mortality	17% improvement in crude mortality (no significant change in PDR)
Thoburn E([413])	1993	Hillsborough County, Florida (pre- and post-regionalization)	Medical Audit – PDA	Non-CNS Trauma Deaths	452 pre 504 post	PDR = 23%	PDR = 7%	16% improvement in PDR
Kane G([232])	1992	Los Angeles County (pre- and post-regionalization)	Hospital Chart Review	MVC with multiple serious injuries	658 pre 766 post	Odds of survival = 1.0	Odds of survival = 1.455	45% increased odds of survival post-regionalization
Rutledge R([243])	1992	North Carolina Counties With Trauma Centers versus Counties Without Trauma Centers	State Medical Examiner's Database	Per capita trauma death rates	309 (TC counties) 78 (non-TC counties)	5.0 deaths per 10,000 population	4.0 deaths per 10,000 population	Decrease in 1 death per 10,000 population
Champion HR([663])	1992	Washington Hospital Center (pre- and post-trauma center designation and system implementation)	Hospital-based Trauma Registry (TRISS)	Trauma with blunt mechanism	467 pre 214 post	Z = -2.17	Z = +1.78	4.34 more survivors per 100 patients post designation
Smith JS([244])	1990	Western Pennsylvania and Maryland (Trauma Centers versus Non-Trauma Centers)	Hospital Discharge Data Analysis	Patients with femoral shaft fracture requiring operation	718 non-trauma center 614 trauma center	2.2% crude mortality	1.0% crude mortality	1.2% improvement in crude mortality (Non Significant)
Guss DA([272])	1989	San Diego County, California (pre- and post-regionalization)	Medical Audit – PDA	All injury deaths	177 pre 211 post	PDR = 11.4%	PDR = 1%	10.4% improvement in PDR
Shackford SR([664])	1987	San Diego County (post-regionalization compared to MTOS)	Medical Audit – PDA	Trauma Score ≤ 8	189 patients	MTOS Ps = 18%	Observed Survival = 29%	11% reduction in mortality compared to MTOS
Shackford SR([275])	1986	San Diego County (pre- and post-regionalization)	Medical Audit – PDA	Seriously injured patients	591 pre 1,366 post	PDR = 13.6%	PDR = 2.7%	10.9% improvement in PDR
Clemmer TP([234])	1985	Salt Lake County, Utah (level I centers vs community hospitals)	Hospital Discharge Data Analysis	CRAMS ≤ 6	56 LI 24 community	46% crude mortality	75% crude mortality	29% improvement in crude mortality
Ornato JP([241])	1985	Nebraska (pre- and post-regionalization)	Dept of Health Database	All injury deaths	474 pre 349 post			23.9% improvement in crude mortality
Cales RH([135])	1984	Orange County, California (pre- and post-regionalization)	Medical Audit – PDA	MVC Deaths	58 pre 60 post	PDR = 34%	PDR = 15%	20% improvement in PDR
Alexander RH([233])	1984	Florida (comparison of counties with level I equivalent hospitals to those without)	Highway Patrol Database	Mileage Population Death Index (MPDI)		MPDI = 24.5	MPDI = 0.82	Reduction in MPDI = 23.7
West JG([136])	1983	Orange County, California (pre- and post-regionalization)	Medical Audit – PDA	Non-CNS MVC TC Deaths	21 pre 23 post	PDR = 71%	PDR = 9%	62% improvement in PDR
West JG([41])	1979	Orange County, California (non-regionalized) vs San Francisco County, California (regionalized)	Medical Audit – PDA	Non-CNS MVC related deaths	30 non-regionalized 16 regionalized	PDR = 73%	PDR = 6%	67% improvement in PDR
Waters JM([126])	1973	Jacksonville, Florida (pre- and post-regionalization)		All traffic accidents	16,035 pre 22,494 post	8.4 deaths per 1000 accidents	5.2 deaths per 1000 accidents	38% reduction in mortality from traffic accidents
Boyd DR([125])	1973	State of Illinois (pre- and post-regionalization)	Highway Death Rate Analysis	All highway injuries		2.8% mortality rate	2.1% mortality rate	Decline in highway fatalities of 8%

Table 5 – CIHI E-Code Inclusion Criteria

E-Code Category	Definition
E800-807	Railway incidents
E810-819	Motor vehicle traffic incidents
E820-825	Motor vehicle non-traffic incidents
E826	Pedal cycle incidents
E827-829	Other road vehicle incidents
E830-838	Water transport incidents
E840-845	Air and space transport incidents
E846-848	Vehicle incidents not elsewhere classifiable
E880-888	Unintentional falls
E890-899	Incidents caused by fire and flame
E900-902, E906-909	Incidents due to natural and environmental factors
E910, E913	Incidents caused by drowning and suffocation
E314-915	Foreign bodies (excluding choking)
E916-928	Other incidents
E953-958	Suicide and self-inflicted injury (excluding poisoning)
E960-961	Homicide and injury purposely inflicted by other persons
E970-976, E978	Legal interventions
E983-988	Injury undetermined whether unintentionally or purposefully inflicted
E990-998	Injury resulting from operations of war

Table 6 – CIHI E-Code Exclusion Criteria

E-Code Category	Definition
E850-858	Poisonings by drugs
E860-869	Poisonings by gases
E870-876	Misadventures
E878-879	Complications
E903	Travel and motion
E904	Huger, thirst, exposure, neglect
E905	Venomous animals and plants
E911	Inhalation and ingestion of food causing obstruction
E912	Inhalation and ingestion of other objects causing obstruction
E929	Late effects
E930-949	Drugs, medicinal and biological substances causing adverse effects
E950-952	Suicide and self inflicted injury
E959	Late effects of self inflicted injury
E962	Assault by poisoning
E969	Late effects of injury purposely inflicted by other persons
E977	Injury due to legal intervention
E980-982	Poisoning undetermined whether unintentionally or purposefully inflicted
E989	Late effects of injury, undetermined whether accidentally or purposely inflicted
E999	Late effects due to war

Table 7 - Glasgow Coma Scale (GCS)

Assessment Element	Score
Eye Opening (E)	
Spontaneous	4
To Speech	3
To Pain	2
None	1
Verbal Response (V)	
Oriented	5
Confused Conversation	4
Inappropriate Words	3
Incomprehensible Sounds	2
None	1
Best Motor Response (M)	
Obeys Commands	6
Localizes Pain	5
Normal Flexion (withdrawal)	4
Abnormal Flexion (decorticate)	3
Abnormal Extension (decerebrate)	2
None (flaccid)	1

GCS = (E + V + M). Best possible score = 15, worst possible score = 3.

Table 8 – Triage Index

Variable	Definition	Score
Respiratory Expansion	Normal Shallow Retractive None	0 2 2 3
Capillary Refill	Immediate (less than 2 sec) Delayed (more than 2 sec)	0 2
Eye Opening	Spontaneous To voice To Pain None	0 1 2 3
Verbal Response	Oriented Confused Inappropriate Words Incomprehensible Sounds None	0 1 2 3 4
Motor Response	Obedience Withdrawal Flexion Extension None	0 1 2 3 4

Table 9 – Trauma Score

Trauma Score	Value	Points
A. **Respiratory Rate** Number of respirations in 15 sec, multiply by four	10-24 25-35 >35 <10 0	4 3 2 1 0
B. **Respiratory Effort**	Normal Shallow or Retractive	1 0
C. **Systolic Blood Pressure**	>90 70-90 50-69 <50 0	4 3 2 1 0
D. **Capillary Refill**	Normal Delayed None	2 1 0
E. **Glasgow Coma Scale** Eye Opening	Spontaneous To Voice To pain None	4 3 2 1
Verbal Response	Oriented Confused Inappropriate Words Incomprehensible Words None	5 4 3 2 1
Motor Response	Obeys Commands Purposeful Movement (pain) Withdraws (pain) Flexion (pain) Extension (pain) None	6 5 4 3 2 1

Trauma Score = A + B + C + D + E

Table 10 - Revised Trauma Score

GCS	Systolic BP	Respiratory Rate	Points
13-15	>89	10-29	4
9-12	76-89	>29	3
6-8	50-75	6-9	2
4-5	1-49	1-5	1
3	0	0	0

Total RTS = 0.9368 GCS(c) + 0.7326 SBP(c) + 0.2908 RR(c), where (c) corresponds to the coded value in the table

Table 11 – CRAMS Scale

Components	Score
Circulation	
Normal Capillary Refill and BP > 100	2
Delayed Capillary Refill or 85 < BP > 100	1
No Capillary Refill or BP < 85	0
Respirations	
Normal	2
Abnormal (laboured or shallow)	1
Absent	0
Abdomen	
Abdomen and Thorax Nontender	2
Abdomen or Thorax Tender	1
Abdomen Rigid or Flail Chest	0
Motor	
Normal	2
Responds Only to Pain (other than decerebrate)	1
No Response (or decerebrate)	0
Speech	
Normal	2
Confused	1
No Intelligible Words	0

Table 12 – NTDB Linkage Table

NTDB Datapoinrs	SKA Quickdisk Datapoints	Survey Datapoints
Facility Key (FAC_KEY) [0-128]	Hospital Name	Hospital Name
ACS Verification Level (ACS_VERIFI)		ACS Verification Level
State Designation (STATE_DESI)		
Number of Adult Hospital Beds (NO_ADU_BED)	Beds set up and staffed total facility (H_BEDFAC)	Number of hospital beds
Number of Pediatric Hospital Beds (NO_PED_BED)	Pediatric beds (H_BEDPEDIATRICMSC)	
Number of Burn Hospital Beds (NO_BUR_BED)	Number of burn care beds (H_BEDBURNCARE)	
Number of ICU Beds Available for Trauma (NO_TRA_ICU)	Number of ICU Beds	Number of ICU Beds
Number of ICU Beds Available for Burns(NO_BUR_ICU)		
Hospital Teaching Status (TEAC_STATU) [university, community, non-teaching]		University affiliated
Hospital Type (TEACH_TYPE) [public, private]		

Table 13 - Trauma Mortality Rates in Quebec (1992-2002)

Year	Number of Patients	Deaths	Percent
1992-93	1,884	976	51.8%
1993-94	1,953	789	40.4%
1994-95	2,188	536	24.5%
1995-96	2,107	420	19.9%
1996-97	1,969	360	18.3%
1997-98	2,107	372	17.7%
1998-99	3,010	153	5.1%
1999-2000	4,731	381	8.1%
2000-01	4,607	377	8.2%
2001-02	3,823	328	8.6%

Table 14 – Trauma System Survey Components

Elements of Systematic Trauma Care (Yes / No Variables)
Triage Protocols
Pre-Hospital Notification
Lead Hospital Identified
Cooperation Between Centers
Elements of In-Hospital Care (Yes / No Variables)
Dedicated Trauma Service
Accreditation Process
Performance Improvement Program
Rehabilitation Facilities Present
Rehabilitation Transfer Corridors
University Affiliation
Trauma Research
Residency Programs
• General Surgery
• Emergency Medicine
24-hour In-House:
• Surgical Resident
• Anesthesiologist
• Radiology Resident
24-hour Availability of:
• Orthopedic Surgery
• Neurosurgery
Demographics
Number of Years Participating in Trauma System
Patient Demographics (primarily urban versus primarily rural)
Hospital Location (urban versus rural)
Average Pre-hospital Time
Number of Tertiary, Secondary, Primary Centers in Region
Population Served (number of people)
Level of Center (primary, secondary, tertiary)
Number of Hospital Beds
Number of ICU Beds
Number of Trauma Admissions Per Year
Number of Physicians Treating Trauma Patients
Type of Physicians Primarily Treating Trauma Patients
Type of Physician Acting as Trauma Director
Type of Physicians Acting as Trauma Team Leader

Table 15 - Sample Demographics - Entire Cohort

	Frequency	Percent
Patient Number	72,073	
Sex		
• Male	40,534	56.2
• Female	31,539	43.8
Age		
• < 65	41,159	57.1
• 65 +	29,783	41.3
Place of Accident		
• Home	18,383	25.5
• Farm	361	0.5
• Mine / Quarry	71	0.1
• Industrial Area	3,307	4.6
• Recreation / Sports	3,335	4.6
• Street / Highway	20,781	28.8
• Public Building	2,326	3.2
• Residential Institution	4,771	6.6
• Other	2,634	3.7
Patient Demographics		
• Urban	34,526	47.9
• Rural	36,815	51.1
Mechanism of Injury		
• Blunt	69,072	95.8
• Penetrating	3,001	4.2
Discharge Disposition		
• Home	39,886	55.3
• Transfer	21,295	29.5
• Dead	4,446	6.2
• Other	5,396	7.5
Outcome		
• Alive	66,577	92.3
• Dead	4,446	6.2

Table 16 – Sample Demographics

AIS Body Region Injured	Frequency	Percent of Patients with Injury
Head	20,611	28.6
Face	15,607	21.6
Neck	1,179	1.6
Thorax	13,667	19.0
Abdomen	7,069	9.8
Spine	10,714	14.9
Extremity	53,418	74.1

Table 17 - Univariate Analysis: Elements of Systematic Trauma Care

Trauma System Element	Element Present Mortality (N)	Element Present Percent Mortality	Element Absent Mortality (N)	Element Absent Percent Mortality	P-Value
Triage Protocols	4,330	6.2	1,427	4.2	<0.001
Pre-Hospital Notification	4,299	6.2	101	5.7	<0.001
Lead Hospital Identified	4,323	6.3	77	3.3	<0.001

Table 18 - Univariate Analysis: Elements of In-Hospital Care

In-Hospital Element	Element Present Mortality (N)	Element Present Percent Mortality	Element Absent Mortality (N)	Element Absent Percent Mortality	P-Value
Dedicated Trauma Service	3,713	6.4	668	5.1	<0.001
Accreditation Process	4,384	6.2	11	2.4	0.001
Performance Improvement Program	3,772	6.1	628	7.0	<0.001
Rehabilitation Facilities Present	3,480	6.3	912	5.8	0.006
Rehabilitation Transfer Corridors	4,219	6.2	84	7.4	<0.001
University Affiliation	3,148	6.4	1,252	5.6	<0.001
Trauma Research	3,228	6.8	1,071	4.8	<0.001
Residency Programs					
• General Surgery	3,154	6.9	1,216	5.1	<0.001
• Emergency Medicine	3,167	7.0	1,203	5.0	<0.001
24-hour In-House:					
• Surgical Resident	1,124	7.2	3,235	5.9	<0.001
• Anesthesiologist	2,768	6.5	1,632	5.6	<0.001
• Radiology Resident	2,359	7.0	2,000	5.4	<0.001
24-hour Availability of:					
• Orthopedic Surgery	4,187	6.3	213	4.2	<0.001
• Neurosurgery	3,140	7.1	1,242	4.7	<0.001

Table 19 – Multivariable Logistic Regression Model Construction

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.078	0.029	0.925	0.873-0.980
RTS	-0.355	0.090	0.701	0.588-0.837
ISS Category*	-1.990	0.101	0.137	0.112-0.166
Body Region Injured (Head)**	0.712	0.111	2.038	1.641-2.532
Body Region Injured (Face)**	0.721	0.086	2.056	1.737-2.433
Body Region Injured (Neck)**	-0.151	0.231	0.860	0.547-1.351
Body Region Injured (Thorax)**	0.146	0.084	1.158	0.981-1.366
Body Region Injured (Abdomen)**	0.312	0.108	1.366	1.104-1.688
Body Region Injured (Spine)**	0.843	0.102	2.323	1.900-2.839
Body Region Injured (Extremity)**	-0.050	0.078	0.952	0.817-1.109

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**Body Region Injured; Injury Present = 1, Injury Absent = 0
Dead = 1, Alive = 0
Hosmer and Lemeshow Chi-Square Statistic = 12.738, P-value = 0.079

Table 20 - Multivariable Logistic Regression Model – Systems of Trauma Care Components

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.076	0.030	0.927	0.875-0.982
RTS	-0.361	0.090	0.697	0.584-0.832
ISS Category*	-2.005	0.102	0.135	0.110-0.165
Body Region Injured (Head)**	0.686	0.113	1.985	1.591-2.476
Body Region Injured (Face)**	0.715	0.086	2.043	1.725-2.421
Body Region Injured (Neck)**	-0.176	0.232	0.838	0.532-1.320
Body Region Injured (Thorax)**	0.127	0.086	1.136	0.960-1.343
Body Region Injured (Abdomen)**	0.279	0.109	1.322	1.068-1.638
Body Region Injured (Spine)**	0.838	0.103	2.311	1.888-2.830
Body Region Injured (Extremity)**	-0.019	0.079	0.981	0.840-1.145
Triage Protocols	-0.210	0.247	0.811	0.500-1.316
Pre-Hospital Notification	-0.498	0.222	0.608	0.394-0.938
Lead Hospital Identified	0.323	0.469	1.381	0.551-3.463

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**Body Region Injured; Injury Present = 1, Injury Absent = 0
Dead = 1, Alive = 0

Table 21 - Multivariable Logistic Regression Model – In-Hospital Trauma Care Components

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.086	0.030	0.918	0.865-0.974
RTS	-0.352	0.092	0.703	0.587-0.843
ISS Category*	-2.059	0.106	0.128	0.104-0.157
Body Region Injured (Head)**	0.623	0.120	1.865	1.475-2.358
Body Region Injured (Face)**	0.740	0.089	2.095	1.761-2.492
Body Region Injured (Neck)**	-0.163	0.238	0.849	0.533-1.354
Body Region Injured (Thorax)**	0.087	0.088	1.090	0.918-1.295
Body Region Injured (Abdomen)**	0.279	0.111	1.322	1.063-1.644
Body Region Injured (Spine)**	0.805	0.106	2.238	1.820-2.752
Body Region Injured (Extremity)**	0.033	0.082	1.033	0.880-1.213
Dedicated Trauma Service	-0.231	0.275	0.793	0.463-1.360
Accreditation Process	0.303	1.101	1.354	0.157-11.711
Performance Improvement Program	-0.830	0.392	0.436	0.202-0.940
Rehabilitation Facilities Present	0.527	0.273	1.694	0.922-2.892
Rehabilitation Transfer Corridors	-0.073	0.479	0.930	0.364-2.375
University Affiliation	-0.285	0.338	0.752	0.387-1.460
Trauma Research	-0.362	0.553	0.696	0.236-2.056
Residency in Surgery	-0.499	0.463	0.607	0.245-1.504
Residency in ER	0.212	0.399	1.236	0.565-2.703
In-House Surgical Residents	0.095	0.399	1.100	0.503-2.406
In-House Anesthesiologist	0.014	0.505	1.014	0.377-2.728
In-House Radiology Resident	0.113	0.279	1.119	0.648-1.932
Ortho available 24-hours/day	0.599	0.334	1.820	0.946-3.502
Neurosurgery available 24-hours/day	0.127	0.617	1.135	0.339-3.800

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**Body Region Injured; Injury Present = 1, Injury Absent = 0
Dead = 1, Alive = 0

Table 22 – Multiple Linear Regression for Adjusted Hospital Length of Stay

System Element	Element Present Unadjusted Mean (SD)	Element Absent Unadjusted Mean (SD)	Adjusted Change with Element Present	Standard Error	p-value
Triage Protocols in Place	14.6 (18.9)	11.6 (15.7)	-2.721	1.355	.045
Pre-Hospital Notification Guidelines	14.6 (19.0)	14.6 (13.3)	-.533	1.687	.752
Lead Hospital Present	14.6 (19.0)	12.2 (15.1)	-1.144	2.215	.606
Dedicated Trauma Service in Hospital	14.8 (19.4)	13.6 (16.3)	1.277	1.319	.333
Accreditation Process	14.6 (18.9)	10.2 (8.9)	-1.189	3.101	.701
Performance Improvement Program	14.5 (18.9)	14.9 (18.5)	2.413	1.077	.025
Rehabilitation Facilities Present	14.7 (19.2)	14.1 (17.8)	-.519	1.005	.605
Rehabilitation Transfer Corridors	14.5 (19.0)	16.0 (17.0)	-2.937	1.853	.113
University Affiliated	14.4 (19.4)	14.9 (17.7)	-2.053	1.170	.079
Residency in Surgery	14.7 (19.4)	14.7 (17.7)	-.601	1.796	.738
Residency in Emergency Medicine	14.7 (19.3)	14.6 (17.9)	.105	1.532	.945
24-hour surgical resident in-house	15.0 (17.5)	14.4 (19.2)	.966	.736	.189
24-hour anesthesia in-house	14.4 (19.0)	14.8 (18.7)	1.570	.834	.060
24-hour radiology resident in-house	14.7 (20.0)	14.4 (17.7)	1.763	.819	.031
24-hour availability of orthopedic surgery	14.6 (18.8)	14.2 (20.2)	2.858	1.608	.076
24-hour availability of neurosurgery	14.9 (19.5)	14.0 (17.8)	-.417	2.100	.843
Trauma research at hospital	14.8 (19.1)	13.9 (18.2)	.499	1.648	.762

Linear regression adjusted for: age, sex, RTS, GCS, ISS, ISS category, and AIS category.

Table 23 – Multiple Linear Regression for Adjusted ICU Length of Stay

System Element	Element Present Unadjusted Mean (SD)	Element Absent Unadjusted Mean (SD)	Adjusted Change with Element Present	Standard Error	p-value
Triage Protocols in Place	6.3 (12.7)	2.0 (2.8)	-4.298	2.310	.063
Pre-Hospital Notification Guidelines	6.3 (12.6)	1.7 (2.4)	-3.692	3.060	.228
Lead Hospital Present	6.4 (12.7)	2.1 (3.2)	-7.383	3.098	.017
Dedicated Trauma Service in Hospital	6.6 (13.0)	3.1 (5.6)	-1.344	2.054	.513
Accreditation Process	6.3 (12.6)	2.3 (3.1)	-.566	4.264	.894
Performance Improvement Program	6.4 (12.5)	4.7 (13.7)	2.691	1.845	.145
Rehabilitation Facilities Present	6.6 (13.1)	3.9 (6.6)	-1.913	1.921	.320
Rehabilitation Transfer Corridors	6.4 (12.3)	6.0 (30.0)	8.575	2.968	.004
University Affiliated	6.8 (12.9)	3.7 (10.0)	-1.492	1.672	.372
Residency in Surgery	7.0 (13.1)	3.6 (9.7)	-.398	2.633	.880
Residency in Emergency Medicine	7.0 (13.2)	3.5 (9.5)	3.669	2.116	.083
24-hour surgical resident in-house	4.2 (6.4)	6.8 (13.6)	1.146	.936	.221
24-hour anesthesia in-house	6.9 (13.2)	4.0 (9.8)	-1.223	1.213	.313
24-hour radiology resident in-house	7.6 (13.6)	3.9 (10.1)	-1.248	1.035	.228
24-hour availability of orthopedic surgery	6.4 (11.8)	5.1 (21.7)	.644	2.491	.796
24-hour availability of neurosurgery	7.0 (12.6)	3.6 (12.0)	1.574	3.077	.609
Trauma research at hospital	6.8 (12.4)	3.7 (13.4)	1.228	2.514	.625

Linear regression adjusted for: age, sex, RTS, GCS, ISS, ISS category, and AIS category.

Table 24 - Sample Demographics

	Urban	Rural	P-Value
Number of Centers (%)	29 (50)	29 (50)	
Number of Patients (%)	57,004 (79.9)	14,333 (20.1)	
Males (%)	32,750 (57.5)	7,447 (52.0)	
Females (%)	24,354 (42.5)	6,886 (48.0)	<0.001
Mechanism of Injury			
Blunt (%)	54,492 (95.6)	13,855 (96.7)	
Penetrating (%)	2,512 (4.4)	478 (3.3)	<0.001
Mean Age (SD)	55.10 (23.44)	58.87 (22.87)	<0.001
Mean ISS (SD)	12.76 (10.18)	8.58 (6.76)	<0.001
Mean GCS (SD)	12.75 (3.93)	14.41 (2.19)	<0.001
Mean RTS (SD)	7.35 (1.06)	7.75 (0.49)	<0.001
Mean LOS (SD)	14.92 (19.46)	13.09 (16.37)	<0.001
Mean ICU LOS (SD)	6.61 (12.61)	3.42 (11.84)	<0.001
Discharge Disposition			
Home (%)	31,098 (54.6)	8,289 (57.8)	<0.001
Transfer (%)	18,252 (32.0)	2,906 (20.3)	<0.001
Other (%)	3,169 (5.6)	2,176 (15.2)	<0.001
Unknown (%)	729 (1.3)	312 (2.2)	<0.001
Deaths	**3,750 (6.6)**	**650 (4.5)**	**<0.001**

Table 25 – Place of Injury

	Urban (%)	Rural (%)
Home	14,166 (24.9)	3,935 (27.5)
Street / Highway	17,603 (30.9)	3,046 (21.3)
Residential Institution	3,360 (5.9)	1,363 (9.5)
Farm	268 (0.5)	90 (0.6)
Mine/Quarry	13 (0.0)	55 (0.4)
Industrial Site	2,823 (5.0)	468 (3.3)
Recreation / Sports	2,610 (4.6)	706 (4.9)
Public Building	2,040 (3.6)	275 (1.9)
Other	2,138 (3.8)	486 (3.4)
Unknown	11,983 (21.0)	3,909 (27.3)

Table 26 – Hospital Demographics and Bed Structure by Location

	Urban Centers		Rural Centers		
	Number of Hospitals (%)	Number of Patients (%)	Number of Hospitals (%)	Number of Patients (%)	**P-Value** (patient N)
Catchment Area					
<50,000	4 (13.8)	1,195 (2.1)	16 (55.2)	1,451 (10.1)	
50-100,000	6 (20.7)	2,531 (4.4)	4 (13.8)	1,601 (11.2)	
100-500,000	9 (31.0)	7,790 (13.7)	9 (31.0)	11,281 (78.7)	
500,000-1 million	4 (13.8)	8,078 (14.2)	0	0	
1-5 million	6 (20.7)	3,7410 (65.6)	0	0	<0.001
Number of Hospital Beds					
0-50	2 (6.9)	63 (0.1)	13 (44.8)	692 (4.8)	
51-100	3 (10.3)	704 (1.2)	9 (31.0)	2,804 (19.6)	
101-200	9 (31.0)	5,139 (9.0)	3 (10.3)	1,621 (11.3)	
201-400	8 (27.6)	7,579 (13.3)	3 (10.3)	7,563 (52.8)	
401-600	5 (17.2)	33,698 (59.1)	1 (3.4)	1,653 (11.5)	
>600	2 (6.9)	9,821 (17.2)	0	0	<0.001
Number of ICU Beds					
0	0	0	1 (3.4)	114 (0.8)	
1-5	4 (13.8)	719 (1.3)	20 (69.0)	1,656 (11.6)	
6-10	13 (44.8)	8,320 (14.6)	6 (20.7)	6,198 (43.2)	
11-20	7 (24.1)	13,643 (23.9)	2 (6.9)	6,365 (44.4)	
21-40	5 (17.2)	34,322 (60.2)	0	0	<0.001
Trauma Admissions per Year					
<100	11 (37.9)	3,214 (5.6)	22 (75.9)	2,275 (15.9)	
101-1000	14 (48.3)	16,724 (29.3)	7 (24.1)	11,735 (81.9)	
1001-3000	4 (13.8)	37,066 (65.0)	0	0	<0.001

Table 27 – Approximate Pre-Hospital Ground Time by Hospital Location

Ground Time	Urban Centers (%) Number of Hospitals (%)	Urban Centers (%) Number of Patients (%)	Rural Centers (%) Number of Hospitals (%)	Rural Centers (%) Number of Patients (%)	P-Value (patient N)
< 30 minutes	7 (24.1)	21,686 (38.0)	1 (3.4)	4,712 (32.9)	
30-60 minutes	8 (27.6)	11,562 (20.3)	6 (20.7)	4,191 (29.2)	
>60 minutes	11 (37.9)	8,585 (15.1)	22 (75.9)	5,430 (37.9)	<0.001

Table 28 – Trauma Center Level by Hospital Location

Hospital Designation	Urban Centers (%)		Rural Centers (%)		P-Value (patient N)
	Number of Hospitals (%)	Number of Patients (%)	Number of Hospitals (%)	Number of Patients (%)	
Tertiary	5 (17.4)	37,203 (65.3)	0	0	
Secondary	19 (65.5)	19,607 (34.4)	6 (20.7)	11,186 (78.0)	
Primary	5 (17.2)	194 (0.3)	23 (79.3)	3,147 (22.0)	<0.001

Table 29 – Hospitals with Trauma System Component Availability

	Urban Centers (%)	Rural Centers (%)	P-Value
Triage Protocols in Place	26 (89.7)	24 (82.8)	0.543
Pre-Hospital Notification Guidelines	28 (96.6)	29 (100)	0.313
Lead Hospital Present	25 (86.2)	23 (79.3)	0.550
Level of Lead Hospital			
Tertiary	14 (48.3)	8 (27.6)	
Secondary	12 (41.4)	9 (31.0)	
Primary	0	0	0.017
Dedicated Trauma Service in Hospital	19 (65.5)	15 (51.7)	0.107
Accreditation Process	29 (100)	26 (89.7)	0.206
Performance Improvement Program	26 (89.7)	25 (86.2)	0.687
Rehabilitation Facilities Present	24 (82.8)	22 (75.9)	0.555
Rehabilitation Transfer Corridors	23 (79.3)	19 (65.5)	0.240
University Affiliated	17 (58.6)	9 (31.0)	0.035
Residency in Surgery	11 (37.9)	2 (6.9)	0.006
Residency in Emergency Medicine	9 (31.0)	2 (6.9)	0.020
24-hour surgical resident in-house	3 (10.3)	1 (3.4)	0.191
24-hour anesthesia in-house	15 (51.7)	19 (65.5)	0.286
24-hour radiology resident in-house	4 (13.8)	0	0.035
24-hour availability of orthopedic surgery	24 (82.8)	10 (34.5)	<0.001
24-hour availability of neurosurgery	9 (31.0)	0	0.002
Trauma research at hospital	11 (37.9)	3 (10.3)	0.011

Table 30 – Patients Treated in Areas with Trauma System Components Present

	Urban (%)	Rural (%)	P-Value
Triage Protocols in Place	55,610 (97.6)	14,090 (99.0)	<0.001
Pre-Hospital Notification Guidelines	55,234 (96.9)	14,333 (100)	<0.001
Lead Hospital Present	55,232 (96.9)	13,703 (95.9)	<0.001
Level of Lead Hospital			
Tertiary	43,616 (78.5)	1,487 (10.5)	
Secondary	11,981 (21.5)	11,392 (80.8)	
Primary	0	1,223 (8.7)	<0.001
Dedicated Trauma Service in Hospital	52,434 (92.0)	5,341 (38.6)	<0.001
Accreditation Process	57,004 (100)	13,787 (96.8)	<0.001
Performance Improvement Program	48,294 (84.7)	14,049 (98.0)	<0.001
Rehabilitation Facilities Present	46,776 (82.1)	8,721 (61.4)	<0.001
Rehabilitation Transfer Corridors	54,801 (98.8)	13,234 (96.4)	<0.001
University Affiliated	45,210 (79.3)	3,839 (26.8)	<0.001
Residency in Surgery	43,123 (75.6)	2,269 (18.5)	<0.001
Residency in Emergency Medicine	41,377 (72.6)	3,787 (30.8)	<0.001
24-hour surgical resident in-house	14,888 (26.5)	769 (5.6)	<0.001
24-hour anesthesia in-house	34,743 (60.9)	7,674 (53.5)	<0.001
24-hour radiology resident in-house	33,650 (59.8)	0	<0.001
24-hour availability of orthopedic surgery	54,220 (95.1)	12,102 (84.4)	<0.001
24-hour availability of neurosurgery	44,123 (78.2)	0	<0.001
Trauma research at hospital	46,375 (82.4)	1,922 (13.4)	<0.001

Table 31 – Multivariable Logistic Regression

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.079	0.030	0.924	0.872-0.979
RTS	-0.354	0.090	0.702	0.588-0.837
ISS Category*	-2.018	0.102	0.133	0.109-0.162
AIS (Head)**	0.685	0.113	1.985	1.589-2.478
AIS (Face)**	0.709	0.086	2.032	1.716-2.407
AIS (Neck)**	-0.180	0.232	0.835	0.530-1.315
AIS (Thorax)**	0.146	0.085	1.157	0.980-1.368
AIS (Abdomen)**	0.292	0.109	1.339	1.082-1.657
AIS (Spine)**	0.838	0.103	2.311	1.888-2.829
AIS (Extremity)**	-0.023	0.079	0.977	0.837-1.139
Rural versus Urban	0.188	0.113	1.207	0.966-1.508

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**AIS Body Region Injured; Injury Present = 1, Injury Absent = 0
Dead = 1, Alive = 0
Rural = 1, Urban = 0
Hosmer and Lemeshow Chi-Square Statistic = 16.732, P-value = 0.033

Table 32 – Multiple Linear Regression for Adjusted Hospital Length of Stay

	B	Standard Error	p-value	95% Confidence Interval
Age	.185	.007	.000	0.171-0.199
Sex	.054	.007	.865	-0.570-0.678
ISS	.426	.031	.000	0.365-0.486
GCS	-.428	.163	.009	-0.748--0.108
RTS	.185	.007	.000	-4.914--2.740
ISS Category	.054	.318	.000	2.955-5.508
AIS (Head)**	.426	.031	.000	-3.220--1.722
AIS (Face)**	-.428	.007	.545	-0.862-0.455
AIS (Neck)**	-3.827	.555	.433	-2.679-1.149
AIS (Thorax)**	4.232	.651	.000	-2.711--1.309
AIS (Abdomen)**	-2.471	.382	.000	1.567-3.309
AIS (Spine)**	-.204	.336	.000	2.023-3.446
AIS (Extremity)**	-.765	.977	.000	2.115-3.364
Rural versus Urban	-2.010	.358	.566	-0.977-0.535

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**AIS Body Region Injured; Injury Present = 1, Injury Absent = 0
Rural = 1, Urban = 0

Table 33 – Multiple Linear Regression for Adjusted ICU Length of Stay

	B	Standard Error	p-value	95% Confidence Interval
Age	.063	.009	.000	0.045-0.080
Sex	-1.572	.389	.000	-2.334-0.045
ISS	.172	.033	.000	0.107-0.237
GCS	-.087	.141	.539	-0.364-0.190
RTS	-1.566	.469	.001	-2.487--0.646
ISS Category	1.993	.623	.001	0.771-3.215
AIS (Head)**	-1.573	.009	.001	-2.464--0.681
AIS (Face)**	1.149	.368	.002	0.427-1.871
AIS (Neck)**	.603	.937	.520	-1.233-2.439
AIS (Thorax)**	.396	.395	.316	-0.378-1.170
AIS (Abdomen)**	1.394	.445	.002	0.521-2.267
AIS (Spine)**	1.135	.404	.005	0.343-1.926
AIS (Extremity)**	.195	.368	.596	-0.526-0.915
Rural versus Urban	-.285	.617	.644	-1.494-0.925

*ISS Category 0-24.0 = 1, 24.1-75 = 0
**AIS Body Region Injured; Injury Present = 1, Injury Absent = 0
Rural = 1, Urban = 0

Table 34 - Final Analysis – Whole North American Database

	Patients	Hospitals	Matched Patients
QTR	110,887	• Survey Sent – 59 • Survey Returned – 58 (98%) • Survey Matched – 58 (100%)	110,808
NTDB	474,814	• Survey Sent – 221 • Survey Returned – 119 (54%) • Survey Matched – 64 (54%)	250,002
Total	585,701	• Survey Sent – 306 • Survey Returned – 203 (66%) • Survey Matched – 122 (60%)	360,810

A. Inclusion Criteria:	**Excluded**	**Included**
1. START		585,701
2. Surveys matched to DB	224,891	360,810
3. Greater or equal to 16 years old (missing values excluded)	46,686	314,124
4. Pre-Hospital Cardiac Arrest	3,901	310,223
5. Years (1994-2002)	5,892	304,331
6. ***Direct Admission***	84,756(transfers or missing)	219,575
Total Direct Admissions:		***219,575***

B. Inclusion Criteria:	**Excluded**	**Included**
1. START (A)		304,331
*2. **Transfers***	221,827(direct admits or missing)	82,504
Total Transfers:		***82,504***

Table 35 - Sample Size – Individual Cohorts (North American Analysis)

Total Patients in Database	1,551,271
Entire Cohort (After Inclusion / Exclusion Criteria Applied)	304,331
Direct Admission Cohort	219,575
Transfer Cohort	82,504
Motor Vehicle Collision Cohort	191,451

Table 36 - PATIENTS BY YEAR (North American Analysis)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1994	8598	2.8	2.8	2.8
	1995	14024	4.6	4.6	7.4
	1996	22057	7.2	7.2	14.7
	1997	20792	6.8	6.8	21.5
	1998	48731	16.0	16.0	37.5
	1999	59891	19.7	19.7	57.2
	2000	71576	23.5	23.5	80.7
	2001	55195	18.1	18.1	98.9
	2002	3467	1.1	1.1	100.0
	Total	304331	100.0	100.0	

Table 37 - Sample Demographics (North American Analysis)

	Frequency	Percent
Patient Number		
Sex		
• Male	131,615	59.9%
• Female	87,872	40.0%
Age		
• Mean	48.98	
• < 65	155,165 (mean = 36.2)	70.7%
• 65 +	64,322 (mean = 79.7)	29.3%
Place of Accident		
• Home	17,826	32.8%
• Farm	350	0.6%
• Mine / Quarry	74	0.1%
• Industrial Area	3,232	5.9%
• Recreation / Sports	3,167	5.8%
• Street / Highway	20,469	37.6%
• Public Building	2,242	4.1%
• Residential Institution	4,426	8.1%
• Other	2,600	4.8%
Patient Demographics		
• Urban	127,585	58.3%
• Rural	91,347	41.7%
Mechanism of Injury		
• Blunt	191,451	87.2%
• Penetrating	23,814	10.8%
Alcohol Intoxication		
• Positive	28,901	29.8%
• Negative	32,527	33.5%
• Suspected	2,277	2.3%
• Not Done	33,121	34.1%
• Not Available	180	0.2%
Drug Intoxication		
• Positive	19,604	18.8%
• Negative	47,330	45.3%
• Suspected	412	0.4%
• Not Done	37,081	35.5%
• Not Available	114	0.1%
Pre-hospital Interventions		
• ETI	222 / 55,103	0.4%
• MAST	6,589 / 54,873	12.0%
• I.V.	50,386 / 55,460	90.9%
Emergency Department ETI	7,783	3.5%
Discharge Disposition		
• Home	138,031	62.9%
• Transfer	59,975	27.3%
• Dead	10,443	4.8%
• Other	5,774	2.6%
Outcome		
• Alive	207,165	94.3%
• Dead	10,504	4.8%

Table 38 – Sample Demographics (North American Analysis)

	Mean	Standard Deviation
AGE	48.98	23.17
Length of Stay (LOS)	8.28	13.88
ICU LOS	1.67	6.20
Ventilator Days	1.3	16.0
SBP in ER	133.3	39.3
Temp in ER	36.3	2.0
GCS (Eye Component)	3.4	1.1
GCS (Verbal Component)	4.2	1.5
GCS (Motor Component)	5.1	1.8
Total GCS	13.8	3.1
RTS	7.4	1.5
ISS	10.2	9.6

Table 39 – Patients by Hospital Descriptors (North American Analysis)

	Number of Patients	Percent of Patients
Hospital Location		
• Urban (72 centers – 62.1%)	127,585	58.1%
• Rural (44 centers – 37.9%)	91,347	41.6%
Catchment Area		
• <50,000	6,798	3.1%
• 50-100,000	26,448	12.1%
• 100-500,000	59,736	27.3%
• 500,000-1 Million	40,933	18.7%
• 1-5 Million	82,589	37.7%
Trauma Center Designation		
• Tertiary	94,331	43.1%
• Secondary	47,118	21.5%
• Primary	4,808	2.2%
Number of Beds		
• 0-50	4,739	2.2%
• 51-100	6,658	3.0%
• 101-200	16,198	7.4%
• 201-400	73,126	33.4%
• 401-600	48,646	22.2%
• >600	68,722	31.4%
Number of ICU Beds		
• 0	3,143	1.4%
• 1-5	4,699	2.1%
• 6-10	16,065	7.3%
• 11-20	46,109	21.1%
• 21-40	72,719	33.2%
• 41-60	30,844	14.1%
• >60	45,353	20.7%
Trauma Admissions per Year		
• <100	9,767	4.5%
• 101-1000	74,821	34.2%
• 1001-3000	123,509	56.4%
• 3001-6000	9,039	4.1%
Pre-Hospital Ground Time		
• < 30 minutes	90,312	41.3%
• 30-60 minutes	29,315	13.4%
• > 60 minutes	54,255	24.8%
Trauma Director		
• ED Physician	25,272	24.4%
• Surgeon	76,710	74.2%
• Both	1,433	1.4%
Trauma Team Leader		
• ED Physician	32,652	16.1%
• Surgeon	134,678	66.6%
• Both	34,922	17.3%

Table 40 - Elements of In-Hospital Care - (North American Analysis)

	Element Present		Element Absent	
In-Hospital Care Element	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Dedicated Trauma Service	203,564	93.0%	14,837	6.8%
Accreditation Process	157,649	72.0%	58,315	26.6%
Performance Improvement Program	209,966	95.9%	8,966	4.1%
Rehabilitation Facilities Present	159,071	72.7%	58,066	26.5%
Rehabilitation Transfer Corridors	187,864	85.8%	21,065	9.6%
University Affiliation	131,586	60.1%	87,346	39.9%
Trauma Research	154,163	70.4%	64,134	29.3%
• Basic Science	6194	2.8%	-	-
• Clinical	39925	18.2%	-	-
• Both	100983	46.1%	-	-
Residency Programs				
• General Surgery	133,388	60.9%	81,109	37.0%
• Emergency Medicine	110,154	50.3%	104,343	47.7%
24-hour In-House:				
• Surgeon	87,561	40.0%	130,449	59.6%
• Surgical Resident	107,125	48.9%	108,226	49.4%
• Anesthesiologist	154,318	70.5%	64,614	29.5%
• Radiologist	69,640	31.8%	149,292	68.2%
• Radiology Resident	104,871	47.95	112,866	51.6%
24-hour Availability of:				
• Orthopedic Surgery	200,061	91.4%	18,311	8.4%
• Neurosurgery	177,637	81.1%	40,790	18.6%

Table 41 - Elements of Systematic Trauma Care - (North American Analysis)

	Element Present		Element Absent	
Trauma System Element	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Triage Protocols	180,383	82.4%	29,427	13.4%
Pre-Hospital Notification	213,275	97.4%	5,657	2.6%
Helicopter System	158,026	72.2%	60,906	27.8%
Lead Hospital Identified	171,775	78.5%	44,909	20.5%
Lead Hospital Level				
• Tertiary	123,288	56.3%	-	-
• Secondary	44,227	20.2%	-	-
• Primary	2,631	1.2%	-	-
Cooperation between Centers	201,992	92.3%	16,782	7.7%
• Teaching (TE)	12,783	5.8%	-	-
• Transfer (TR)	41,970	19.2%	-	-
• TR / Performance Improvement (PI)	2,281	1.0%	-	-
• TR / TE	49,036	22.4%	-	-
• TR / TE / PI	99,684	45.5%	-	-

Table 42 - Univariate Analysis: Elements of In-Hospital Care - (North American Analysis)

In-Hospital Element	Element Present Mortality (N)	Element Present Percent Mortality	Element Absent Mortality (N)	Element Absent Percent Mortality	P-Value
Dedicated Trauma Service	9817	4.8%	628	4.2%	<0.001
Accreditation Process	7900	5.0%	2441	4.2%	<0.001
Performance Improvement Program	9831	4.7%	633	7.1%	<0.001
Rehabilitation Facilities Present	8157	5.1%	2265	4.1%	<0.001
Rehabilitation Transfer Corridors	9121	4.9%	863	4.1%	<0.001
University Affiliation	6916	5.3%	3548	4.1%	<0.001
Trauma Research	7971	5.2%	2458	3.8%	<0.001
Residency Programs					
• General Surgery	7164	5.4%	3204	4.0%	<0.001
• Emergency Medicine	6043	5.5%	4325	4.1%	<0.001
24-hour In-House:					
• Surgeon	4053	4.6%	6375	4.9%	<0.001
• Surgical Resident	5318	5.0%	5031	4.6%	<0.001
• Anesthesiologist	7684	5.0%	2780	4.3%	<0.001
• Radiologist	3254	4.7%	7210	4.8%	<0.001
• Radiology Resident	5748	5.5%	4667	4.1%	<0.001
24-hour Availability of:					
• Orthopedic Surgery	9931	5.0%	519	2.8%	<0.001
• Neurosurgery	8959	5.0%	1493	3.7%	<0.001

Table 43 - Univariate Analysis: Elements of Systematic Trauma Care - (North American Analysis)

Trauma System Element	Element Present		Element Absent		P-Value
	Mortality (N)	Percent Mortality	Mortality (N)	Percent Mortality	
Trauma System Present	8248	4.9%	2182	4.3%	<0.001
Trauma Regionalized	8590	4.9%	1866	4.3%	<0.001
Triage Protocols	8911	4.9%	1210	4.1%	<0.001
Helicopter System	7143	4.5%	3321	5.5	<0.001
Pre-Hospital Notification	10213	4.8%	251	4.4%	<0.001
Lead Hospital Identified	8582	5.0%	1820	4.1%	<0.001
Cooperation between Centers	9804	4.9%	652	3.9%	<0.001

Table 44 - Multivariable Logistic Regression Analysis - (North American Analysis)

Multivariable Logistic Regression Model Construction

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.151	0.010	0.860	0.843-0.877
RTS	-0.255	0.017	0.775	0.749-0.802
Age	0.051	0.001	1.052	1.050-1.054
SBP in ER	-0.010	0.000	0.990	0.989-0.991
ISS Category*	-0.233	0.041	0.097	0.090-0.105
Blunt Injury	-1.109	0.052	0.330	0.298-0.366

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Hosmer and Lemeshow Chi-Square Statistic = 157.4, P-value = 0.000

Table 45 - Multivariable Logistic Regression Model – Systems of Trauma Care Elements (North American Analysis)

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.158	0.011	0.854	0.836-0.872
RTS	-0.241	0.019	0.786	0.758-0.815
Age	0.051	0.001	1.052	1.050-1.054
SBP in ER	-0.010	0.000	0.990	0.989-0.991
ISS Category*	-2.313	0.042	0.099	0.091-0.108
Blunt Injury	-1.114	0.053	0.328	0.296-0.364
Trauma System Present	-0.326	0.088	0.722	0.607-0.859
Trauma Regionalized	-0.432	0.103	0.649	0.530-0.795
Triage Protocols	-0.034	0.065	0.966	0.851-1.097
Helicopter System	0.119	0.047	1.126	1.027-1.234
Pre-Hospital Notification	0.053	0.128	1.054	0.821-1.354
Lead Hospital Identified	0.015	0.055	1.015	0.912-1.130
Cooperation between Centers	0.141	0.082	1.152	0.981-1.353

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Table 46 - Multivariable Logistic Regression Model – In-Hospital Trauma Care Elements (North American Analysis)

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.153	0.013	0.858	0.838-0.880
RTS	-0.253	0.022	0.776	0.744-0.810
Age	0.050	0.001	1.052	1.049-1.054
SBP in ER	-0.010	0.001	0.990	0.989-1.054
ISS Category*	-2.343	0.044	0.096	0.088-0.105
Blunt Injury	-1.110	0.056	0.330	0.295-0.368
Dedicated Trauma Service	-0.187	0.111	0.829	0.667-1.031
Accreditation Process	0.119	0.046	1.127	1.030-1.233
Performance Improvement Program	-0.390	0.137	0.677	0.517-0.886
Rehabilitation Facilities Present	0.057	0.057	1.058	0.946-1.183
Rehabilitation Transfer Corridors	0.015	0.075	1.015	0.875-1.177
University Affiliation	-0.193	0.105	0.825	0.671-1.013
Trauma Research	-0.008	0.077	0.992	0.854-1.153
Residency Programs				
• General Surgery	-0.268	0.135	0.765	0.587-0.997
• Emergency Medicine	0.161	0.054	1.174	1.057-1.305
24-hour In-House:				
• Surgeon	0.029	0.058	1.029	0.918-1.154
• Surgical Resident	0.281	0.081	1.324	1.130-1.552
• Anesthesiologist	0.091	0.076	1.095	0.943-1.272
• Radiologist	-0.002	0.055	0.998	0.896-1.112
• Radiology Resident	0.081	0.065	1.085	0.956-1.232
24-hour Availability of:				
• Orthopedic Surgery	0.330	0.122	1.392	1.096-1.767
• Neurosurgery	-0.361	0.104	0.697	0.569-0.855

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Table 47 - Sample Demographics - Transfer Cohort

	Frequency	Percent
Patient Number	82,504	-
Sex		
• Male	56,099	68.0%
• Female	26,386	32.0%
Age		
• < 65		
• 65 +		
Patient Demographics		
• Urban	42,164	51.1%
• Rural	40,300	48.8%
Mechanism of Injury		
• Blunt	71,038	86.1%
• Penetrating	7,497	9.1%
Alcohol Intoxication		
• Positive	8,930	10.8%
• Negative	13,741	16.7%
• Suspected	1,191	1.4%
• Not Done	8,228	10.0%
• Not Available	48	0.1%
Drug Intoxication		
• Positive	5,957	7.2%
• Negative	16,925	20.5%
• Suspected	221	0.3%
• Not Done	9,060	11.0%
• Not Available	25	0.0%
Pre-hospital Interventions		
• ETI	309	0.4%
• MAST	1,776	2.2%
• I.V.	8,499	10.3%
Emergency Department ETI	1,131	1.4%
Discharge Disposition		
• Home	50,160	60.8%
• Transfer	24,081	29.2%
• Dead	4,990	6.0%
• Other	1,871	2.3%
Outcome		
• Alive	77,341	93.7%
• Dead	4,996	6.1%

Table 48 – Sample Demographics –Transfer Cohort

	Mean	Standard Deviation
AGE	45.2	21.3
Length of Stay (LOS)	9.4	15.3
ICU LOS	1.5	13.9
GCS (Eye Component)	3.3	1.3
GCS (Verbal Component)	3.9	1.7
GCS (Motor Component)	4.8	2.1
Total GCS	13.0	4.1
RTS	7.0	2.1
ISS	13.0	10.7

Table 49 – Patients by Hospital Descriptors – Transfer Cohort

	Number of Patients	Percent of Patients
Hospital Location		
• Urban	67,991	82.4%
• Rural	14,473	17.5%
Catchment Area		
• <50,000	785	1.0%
• 50-100,000	6,228	7.5%
• 100-500,000	17,641	21.4%
• 500,000-1 Million	13,650	16.5%
• 1-5 Million	43,231	52.4%
Trauma Center Designation		
• Tertiary	42,210	51.2%
• Secondary	14,496	17.6%
• Primary	412	0.5%
Number of Beds		
• 0-50	524	0.6%
• 51-100	2,206	2.7%
• 101-200	2,652	3.2%
• 201-400	21,086	25.6%
• 401-600	26,970	32.7%
• >600	28,377	34.4%
Number of ICU Beds		
• 0	187	0.2%
• 1-5	836	1.0%
• 6-10	4,227	5.1%
• 11-20	13,460	16.3%
• 21-40	32,511	39.4%
• 41-60	10,743	13.0%
• >60	20,500	24.8%
Trauma Admissions per Year		
• <100	1,092	1.3%
• 101-1000	18,003	21.8%
• 1001-3000	59,165	71.7%
• 3001-6000	3,211	3.9%
Pre-Hospital Ground Time		
• < 30 minutes	35,504	58.2%
• 30-60 minutes	13,889	22.8%
• > 60 minutes	11,649	19.1%
Trauma Director		
• ED Physician	13,126	20.4%
• Surgeon	51,023	79.5%
• Both	61	0.0%
Trauma Team Leader		
• ED Physician	14,707	19.1%
• Surgeon	53,299	69.3%
• Both	8,871	11.5%

Table 50 - Elements of In-Hospital Care - Transfer Cohort

	Element Present		Element Absent	
In-Hospital Care Element	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Dedicated Trauma Service	79,164	96.0%	3,210	3.9%
Accreditation Process	60,914	73.8%	2,382	2.9%
Performance Improvement Program	80,082	97.1%	2,382	2.9%
Rehabilitation Facilities Present	61,780	74.9%	20,670	25.0%
Rehabilitation Transfer Corridors	73,823	89.5%	8,612	10.4%
University Affiliation	63,091	76.5%	19,373	23.5%
Trauma Research	66,889	81.1%	15,459	18.7%
Residency Programs				
• General Surgery	64,527	78.2%	16,098	19.5%
• Emergency Medicine	46,482	56.3%	34,143	41.4%
24-hour In-House:				
• Surgeon	36,534	44.3%	45,756	55.5%
• Surgical Resident	47,791	57.9%	34,144	41.4%
• Anesthesiologist	69,232	83.9%	13,232	16.0%
• Radiologist	25,935	31.4%	56,529	68.5%
• Radiology Resident	50,734	61.5%	31,554	38.2%
24-hour Availability of:				
• Orthopedic Surgery	79,221	96.0%	3,183	3.9%
• Neurosurgery	74,566	90.4%	7,788	9.4%

Table 51 - Elements of Systematic Trauma Care - Transfer Cohort

	Element Present		Element Absent	
Trauma System Element	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Triage Protocols	72,154	87.5%	6,463	7.8%
Pre-Hospital Notification	81,504	98.8%	960	1.2%
Lead Hospital Identified	68,837	83.4%	11,988	14.5%
Lead Hospital Level				
• Tertiary	53,141	64.4%	-	-
• Secondary	14,168	17.2%	-	-
• Primary	99	0.1%	-	-
Cooperation between Centers	80,073	97.1%	2,391	2.9%

Table 52 - Univariate Analysis: Elements of In-Hospital Care - Transfer Cohort

In-Hospital Element	Element Present		Element Absent		P-Value
	Mortality (N)	Percent Mortality	Mortality (N)	Percent Mortality	
Dedicated Trauma Service	4,859	6.1%	131	4.1%	<0.001
Accreditation Process	3,819	6.3%	1,155	5.4%	<0.001
Performance Improvement Program	4,889	6.1%	106	4.5%	0.015
Rehabilitation Facilities Present	3,918	6.3%	1,077	5.2%	<0.001
Rehabilitation Transfer Corridors	4,501	6.1%	492	5.7%	<0.001
University Affiliation	4,093	6.5%	902	4.7%	<0.001
Trauma Research	4,266	6.4%	726	4.7%	<0.001
Residency Programs					
• General Surgery	4,207	6.5%	759	4.7%	<0.001
• Emergency Medicine	3,036	6.5%	1,930	5.7%	<0.001
24-hour In-House:					
• Surgeon	2,274	6.2%	2,709	5.9%	<0.001
• Surgical Resident	2,939	6.1%	2,042	6.0%	<0.001
• Anesthesiologist	4,372	6.3%	623	4.7%	<0.001
• Radiologist	1,463	5.6%	3,532	6.2%	<0.001
• Radiology Resident	3,286	6.5%	1,705	5.4%	<0.001
24-hour Availability of:					
• Orthopedic Surgery	4,847	6.1%	147	4.6%	0.002
• Neurosurgery	4,724	6.3%	269	3.5%	<0.001

Table 53 - Univariate Analysis: Elements of Systematic Trauma Care - Transfer Cohort

Trauma System Element	Element Present		Element Absent		P-Value
	Mortality (N)	Percent Mortality	Mortality (N)	Percent Mortality	
Trauma System Present	3,938	6.2%	1,057	5.6%	<0.001
Trauma Regionalized	4,187	6.2%	808	5.4%	<0.001
Triage Protocols	4,442	6.2%	372	5.8%	<0.001
Helicopter System	3,480	6.2%	1,515	5.7%	0.001
Pre-Hospital Notification	4,940	6.1%	55	5.7%	0.534
Lead Hospital Identified	4,345	6.3%	567	4.7%	<0.001
Cooperation between Centers	4,860	6.1%	135	5.6%	0.150

Table 54 - Multivariable Logistic Regression Analysis – Transfer Cohort

Multivariable Logistic Regression Model Construction

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	0.184	0.012	1.202	1.174-1.230
RTS	0.104	0.020	1.110	1.068-1.153
Age	-0.047	0.001	0.954	0.952-0.957
SBP in ER	1.012	0.001	1.102	1.011-1.014
ISS Category*	1.969	0.054	7.164	6.448-7.960
Blunt Injury	1.124	0.120	3.076	2.431-3.893

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Hosmer and Lemeshow Chi-Square Statistic = 80.0, P-value = 0.000

Table 55 - Multivariable Logistic Regression Model – Systems of Trauma Care Elements – Transfer Cohort

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	0.205	0.013	1.228	1.196-1.260
RTS	0.069	0.022	1.072	1.026-1.119
Age	-0.047	0.001	0.954	0.952-0.957
SBP in ER	0.012	0.001	1.012	1.011-1.014
ISS Category*	1.990	0.054	7.312	6.574-8.132
Blunt Injury	1.049	0.122	2.855	2.249-3.624
Trauma System Present	0.051	0.114	1.053	0.842-1.316
Trauma Regionalized	-0.228	0.135	0.796	0.611-1.037
Triage Protocols	0.186	0.072	1.205	1.046-1.388
Helicopter System	-0.269	0.064	0.744	0.656-0.844
Lead Hospital Identified	-0.091	0.064	0.913	0.806-1.034

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Table 56 - Multivariable Logistic Regression Model – In-Hospital Trauma Care Elements –Transfer Cohort

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	0.210	0.015	1.234	1.198-1.270
RTS	0.064	0.025	1.066	1.015-1.120
Age	0.012	0.001	0.954	0.954-0.957
SBP in ER	2.017	0.055	1.012	1.011-1.013
ISS Category*	1.072	0.123	7.512	6.746-8.365
Blunt Injury	-0.043	0.140	2.920	2.296-3.713
Dedicated Trauma Service	-0.025	0.189	0.958	0.661-1.386
Accreditation Process	-0.025	0.061	0.976	0.865-1.100
Performance Improvement Program	-0.354	0.338	0.702	0.362-1.360
Rehabilitation Facilities Present	-0.047	0.072	0.954	0.828-1.099
Rehabilitation Transfer Corridors	-0.067	0.097	0.935	0.772-1.131
University Affiliation	-0.101	0.142	0.904	0.684-1.195
Trauma Research	0.083	0.108	1.087	0.880-1.342
Residency Programs				
• General Surgery	0.269	0.190	1.308	0.902-1.898
• Emergency Medicine	-0.159	0.078	0.853	0.732-0.993
24-hour In-House:				
• Surgeon	-0.362	0.072	0.696	0.605-0.802
• Surgical Resident	-0.159	0.112	0.853	0.684-1.062
• Anesthesiologist	0.400	0.135	1.492	1.146-1.944
• Radiologist	-0.24	0.076	0.976	0.841-1.133
• Radiology Resident	-0.094	0.088	0.910	0.767-1.080
24-hour Availability of:				
• Orthopedic Surgery	0.187	0.243	1.206	0.749-1.942
• Neurosurgery	0.164	0.205	1.178	0.788-1.762

*ISS Category 0-24.0 = 1, 24.1-75 = 0

Table 57 - Sample Demographics - Motor Vehicle Collision Cohort

	Frequency	Percent
Patient Number	191,451	
Sex		
• Male	108,360	56.6
• Female	83,022	43.4
Age		
• < 65	128,568	67.2
• 65 +	62,883	32.8
Patient Demographics		
• Urban	110,215	57.6
• Rural	80,600	42.1
Alcohol Intoxication		
• Positive	22,792	11.9
• Negative	27,958	14.6
• Suspected	2,150	1.1
• Not Done	31,994	16.7
• Not Available	167	0.1
Drug Intoxication		
• Positive	14,909	7.8
• Negative	39,519	20.6
• Suspected	349	0.2
• Not Done	35,657	18.6
• Not Available	95	0.0
Pre-hospital Interventions		
• ETI	171	0.1
• MAST	5,788	3.0
• I.V.	41,296	21.6
Emergency Department ETI	6,541	3.4
Discharge Disposition		
• Home	116,851	61.0
• Transfer	56,734	29.6
• Dead	8,672	4.5
• Other	5,317	2.8
Outcome		
• Alive	8,700	94.6
• Dead	181,084	4.5

Table 58 - Sample Demographics - Motor Vehicle Collision Cohort

	Mean	Standard Deviation
AGE	51.0	23.5
Length of Stay (LOS)	8.7	14.2
ICU LOS	1.7	6.1
GCS (Eye Component)	3.4	1.2
GCS (Verbal Component)	4.1	1.6
GCS (Motor Component)	5.0	1.9
Total GCS	13.8	3.0
RTS	7.4	1.5
ISS	10.5	9.4
Ventilator Days	1.3	16.3
SBP in ED	135	38.3

Table 59 – Patients by Hospital Descriptors – Motor Vehicle Collision Cohort

	Number of Patients	Percent of Patients
Hospital Location		
• Urban	149,322	78.0
• Rural	41,493	21.7
Catchment Area		
• <50,000	5,724	3.0
• 50-100,000	22,678	11.8
• 100-500,000	53,527	28.0
• 500,000-1 Million	33,749	17.6
• 1-5 Million	73,176	38.2
Trauma Center Designation		
• Tertiary	80,215	41.9
• Secondary	44,796	23.4
• Primary	4,514	2.4
Number of Beds		
• 0-50	3,781	2.0
• 51-100	6,042	3.2
• 101-200	15,069	7.9
• 201-400	62,423	32.6
• 401-600	44,575	23.3
• >600	58,146	30.4
Number of ICU Beds		
• 0	2,294	1.2
• 1-5	4,308	2.3
• 6-10	15,294	8.0
• 11-20	42,827	22.4
• 21-40	63,970	33.4
• 41-60	25,031	13.1
• >60	37,091	19.4
Trauma Admissions per Year		
• <100	8,628	4.5
• 101-1000	68,294	35.7
• 1001-3000	104,970	54.8
• 3001-6000	7,247	3.8
Pre-Hospital Ground Time		
• < 30 minutes	76,500	40.0
• 30-60 minutes	26,484	13.8
• > 60 minutes	54,526	28.5
Trauma Director		
• ED Physician	23,551	12.3
• Surgeon	137,681	71.9
• Both	1,344	0.7
Trauma Team Leader		
• ED Physician	30,609	16.0
• Surgeon	113,169	59.1
• Both	31,719	16.6

Table 60 - Elements of In-Hospital Care - Motor Vehicle Collision Cohort

In-Hospital Care Element	Element Present		Element Absent	
	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Dedicated Trauma Service	176,164	92.0	14,154	7.4
Accreditation Process	138,911	72.6	49,203	72.6
Performance Improvement Program	182,600	95.4	8,215	4.3
Rehabilitation Facilities Present	138,682	72.4	50,616	26.4
Rehabilitation Transfer Corridors	165,529	86.5	16,836	8.8
University Affiliation	112,335	58.7	78,480	41.0
Trauma Research	133,040	69.5	57,165	29.9
Residency Programs				
• General Surgery	112,749	58.9	73,875	38.6
• Emergency Medicine	94,892	49.6	91,732	47.9
24-hour In-House:				
• Surgeon	74,457	38.9	115,474	60.3
• Surgical Resident	87,694	45.8	99,743	52.1
• Anesthesiologist	131,483	68.7	59,332	31.0
• Radiologist	58,756	30.7	132,059	69.0
• Radiology Resident	88,703	46.3	101,008	52.8
24-hour Availability of:				
• Orthopedic Surgery	174,157	91.0	16,164	8.4
• Neurosurgery	152,593	79.7	37,741	19.7

Table 61 - Elements of Systematic Trauma Care - Motor Vehicle Collision Cohort

	Element Present		Element Absent	
Trauma System Element	Number of Patients	Percent of Patients	Number of Patients	Percent of Patients
Triage Protocols	156,702	81.8	25,823	13.5
Pre-Hospital Notification	185,672	97.0	5,143	2.7
Lead Hospital Identified	150,353	78.5	38,344	20.0
Lead Hospital Level				
• Tertiary	107,150	56.0		
• Secondary	39,654	20.7		
• Primary	2,411	1.3		
Cooperation between Centers	176,330	92.1	14,345	7.5

Table 62 - Univariate Analysis: Elements of In-Hospital Care - Motor Vehicle Collision Cohort

In-Hospital Element	Element Present		Element Absent		P-Value
	Mortality (N)	Percent Mortality	Mortality (N)	Percent Mortality	
Dedicated Trauma Service	8,034	4.6	607	4.3	<0.001
Accreditation Process	6,734	4.8	1,826	3.7	<0.001
Performance Improvement Program	8,065	4.4	595	7.2	<0.001
Rehabilitation Facilities Present	6,698	4.8	1927	3.9	<0.001
Rehabilitation Transfer Corridors	7,740	4.7	581	3.5	<0.001
University Affiliation	5,641	5.0	3,019	3.8	<0.001
Trauma Research	6,489	4.9	2,136	3.7	<0.001
Residency Programs					
• General Surgery	5,725	5.1	2,847	3.9	<0.001
• Emergency Medicine	4,995	3.5	3,577	3.9	<0.001
24-hour In-House:					
• Surgeon	3,187	4.3	5,438	4.7	<0.001
• Surgical Resident	3,994	4.6	4,564	4.6	<0.001
• Anesthesiologist	6,104	4.6	2,556	4.3	<0.001
• Radiologist	2,523	4.3	6,137	4.6	<0.001
• Radiology Resident	4,544	5.1	4,073	4.0	<0.001
24-hour Availability of:					
• Orthopedic Surgery	8,183	4.7	469	2.9	<0.001
• Neurosurgery	7,227	4.7	1,421	3.8	<0.001

Table 63 - Univariate Analysis: Elements of Systematic Trauma Care - Motor Vehicle Collision Cohort

	Element Present		Element Absent		P-Value
Trauma System Element	Mortality (N)	Percent Mortality	Mortality (N)	Percent Mortality	
Triage Protocols	7,391	4.7	955	3.7	<0.001
Pre-Hospital Notification	8,442	4.5	218	4.2	<0.001
Lead Hospital Identified	7,225	4.8	1,373	3.6	<0.001
Cooperation between Centers	8,144	4.6	508	3.5	<0.001

Table 64 - Multivariable Logistic Regression Analysis – Systems of Trauma Care Elements – Motor Vehicle Collision Cohort

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.154	0.010	0.858	0.840-0.876
RTS	-0.239	0.019	0.788	0.760-0.817
Age	0.051	0.001	1.052	1.050-1.054
SBP in ER	-0.010	0.000	0.990	0.989-0.991
ISS Category*	-2.359	0.042	0.095	0.087-0.103
Blunt Injury	-1.208	0.108	0.299	0.242-0.369
Trauma System Present	-0.290	0.088	0.748	0.630-0.889
Trauma Regionalized	0.429	0.103	1.535	1.256-1.877
Triage Protocols	-0.012	0.064	0.988	0.871-1.120
Helicopter System	0.141	0.046	1.152	1.052-1.262
Pre-Hospital Notification	0.002	0.127	1.002	0.781-1.284
Lead Hospital Identified	0.017	0.055	1.017	0.914-1.132
Cooperation between Centers	0.161	0.081	1.175	1.002-1.377

Table 65 - Multivariable Logistic Regression Model – In-Hospital Trauma Care Elements – Motor Vehicle Collision Cohort

Variable	Parameter Estimate	Parameter Estimate Standard Error	Odds Ratio	95% Confidence Interval
GCS	-0.153	0.013	0.858	0.838-0.880
RTS	-0.253	0.022	0.776	0.744-0.810
Age	0.050	0.001	1.052	1.049-1.054
SBP in ER	-0.010	0.001	0.990	0.989-0.991
ISS Category*	-2.343	0.044	0.096	0.088-0.105
Blunt Injury	-1.110	0.056	0.330	0.295-0.368
Dedicated Trauma Service	-0.187	0.111	0.829	0.667-1.031
Accreditation Process	0.119	0.046	1.127	1.030-1.233
Performance Improvement Program	-0.390	0.137	0.677	0.517-0.886
Rehabilitation Facilities Present	0.057	0.057	1.058	0.946-1.183
Rehabilitation Transfer Corridors	0.015	0.075	1.015	0.875-1.177
University Affiliation	-0.193	0.105	0.825	0.671-1.013
Trauma Research	-0.008	0.077	0.992	0.854-1.153
Residency Programs				
• General Surgery	-0.268	0.135	0.765	0.587-0.997
• Emergency Medicine	0.161	0.054	1.174	1.057-1.305
24-hour In-House:				
• Surgeon	0.029	0.058	1.029	0.918-1.154
• Surgical Resident	0.281	0.081	1.324	1.130-1.552
• Anesthesiologist	0.091	0.076	1.095	0.943-1.272
• Radiologist	-0.002	0.055	0.998	0.896-1.112
• Radiology Resident	0.081	0.065	1.085	0.956-1.232
24-hour Availability of:				
• Orthopedic Surgery	0.330	0.122	1.392	1.096-1.767
• Neurosurgery	-0.361	0.104	0.697	0.569-0.855

Table 66 – Expert Survey Panel Respondents

Expert Panel

- **Dr. AB Nathens** University of Washington, Seattle, Washington
- **Dr. RV Maier** University of Washington, Seattle, Washington
- **Dr. RJ Mullins** Oregon Health Sciences University, Portland, Oregon
- **Dr. GV Velmahos** University of Southern California, LA, California
- **Dr. TJ Esposito** Loyola University Medical Center, Maywood, Illinois
- **Dr. DB Hoyt** UCSD Medical Center, San Diego, California
- **Dr. SR Shakford** University of Vermont, Burlington, Vermont
- **Dr. W Meredith** Wake Forest University, North Carolina
- **Dr. RL Coscia** Brackenridge Hospital, Boise, Idaho

Table 67 – Expert Survey Responses – Level of Trauma Care Regionalization

Level of Trauma Care Regionalization	Responses	Mean	Standard Deviation
Trauma system operating in region	YES, NO	8.44	3.32
Trauma care regionalization in your area	YES, NO	9.44	1.01
Years of regionalization	Please Indicate number of points / year	7.14	3.93
Are there prehospital triage guidelines in region	YES, NO	9.44	1.33
Does pre-hospital system notify hospital regarding patient status	YES, NO	8.67	1.94
Is there a lead hospital in region	YES, NO	6.78	3.80
Level of lead hospital	LI, LII, LIII, LIV (points per level)	4.00	3.61
Dedicated trauma service in hospital	YES, NO	9.67	0.71
Participation in trauma registry	YES, NO	7.89	2.71
Trauma center accreditation/audit program mandatory in region	YES, NO	8.00	3.35
Performance improvement program used in hospital	YES, NO	9.89	0.33
Cooperation with other centers in region	YES, NO	9.00	1.80
Cooperation with other centers in region (type of cooperation)	TRANSFER	8.33	2.18
Cooperation with other centers in region (type of cooperation)	TEACHING	8.00	2.40
Cooperation with other centers in region (type of cooperation)	PERFORMANCE IMPROVEMENT	8.67	1.50
Are there rehabilitation facilities available in center	YES, NO	7.56	3.32
Are transfer agreements in place with a rehab facility	YES, NO	7.89	2.57

Table 68 – Expert Survey Responses – Level of In-Hospital Trauma Care

Level of Trauma Care in Hospital	Responses	Mean	Standard Deviation
Helicopter pre-hospital system in use	YES, NO	7.78	3.07
Catchment area	<50000, 50-100000, 100-500000, 500000-1M, 1-5M, >5M (points per category)	4.88	4.09
ACS Verification Level	I, II, III, IV (points per level)	2.31	3.15
Number of hospital beds	0-50, 51-100, 101-200, 201-400, 401-600, >600 (points per category)	4.44	3.59
Trauma patient admissions/year	<100, 101-1000, 1001-3000, 3001-6000, >6000 (points per category)	5.67	3.33
Number of ICU Beds	0, 1-5, 6-10, 11-20, 21-40, 41-60, >60 (points per category)	4.37	2.82
Number of MDs dealing primarily with trauma	## (number of points per MD)	5.78	2.59
University affiliated	YES, NO	6.28	3.96
Residency training program - Surgery	YES, NO	7.44	3.84
Residency training program - Emergency Medicine	YES, NO	6.00	4.36
Director of trauma	ED, GS, TS, GP, OTHER (Please indicate points per type of MD)	7.75	3.58
Physician treating trauma patietns	TS, GS, TS+GS, ED, GP (Please indicate points per type of MD)	7.29	3.82
Trauma team leader	GS, ER (Please indicate points per type of MD)	8.00	3.61
24-hour in house trauma/general surgeon	YES, NO	4.56	3.88
24-hour in house senior surgery resident/fellow	YES, NO	7.22	3.87
24-hour in house anesthesiologist	YES, NO	7.67	3.39
24-hour in house radiologist	YES, NO	4.28	4.02
24-hour in house radiology resident	YES, NO	6.39	4.03
24-hour available orthopedic surgeon	YES, NO	9.22	2.33
24-hour available neurosurgeon	YES, NO	9.22	2.33
Trauma research at institution	YES, NO	8.22	3.19

ED = Emergency Department physician, GS = General Surgeon, TS = Trauma Surgeon, GP = General Practitioner

15.2 Figures

Figure 1 – Trauma System History Time Line

5th Century B.C.	100 A.D.	1800's	1861-65	1914-18	1939-45	1950-53	1965-75	1960's	1966	1971	1972	1973	1977
Ancient Greece Injured patients transported to specialized treatment centers.	**Roman Legions** Organize on-site first aid stations and ambulances.	**Larrey (Napoleonic Army)** Organizes "flying ambulance" and military hospitals.	**Civil War** Hospitals organized based on proximity to battlefield and resources.	**WWI** Echelons of treatment facilities improve care for injured soldiers.	**WWII** British organize levels of hospital care. US army develops specialized "AUX" units composed of specialized teams which traveled to front lines.	**Korean War** MASH units enabled injured soldiers to reach definitive care within the "golden hour".	**Vietnam War** Helicopter transport used rampantly to evacuate injured soldiers from front lines.	Excess civilian mortality following trauma secondary to inappropriate care observed in the US.	US NRC publishes "*Accidental Death and Disability*" calling for improved, organized trauma care. US Congress passes "*National Highway Safety Act*" calling for pre-hospital coordination and communication. First civilian trauma centers established in San Francisco and Chicago.	Trauma care system established in Illinois.	8% decline in highway mortality in Illinois in the 6 months following regionalization of trauma care.	US Congress passes "*Emergency Medical Services Act*" enabling regional, comprehensive EMS systems.	Levels of civilian trauma care centers established.

1979	1980	1984
West, Trunkey and Lim compare outcome in a regionalized (San Francisco County) compared to a non-regionalized area (Orange County) and find decreased preventable mortality in regionalized area.	ATLS course established.	Cales shows that preventable death rate in Orange County decreases from 34% to 15% following regionalization of trauma care.

Figure 2 – Studies Demonstrating Trauma System Effectiveness by Year

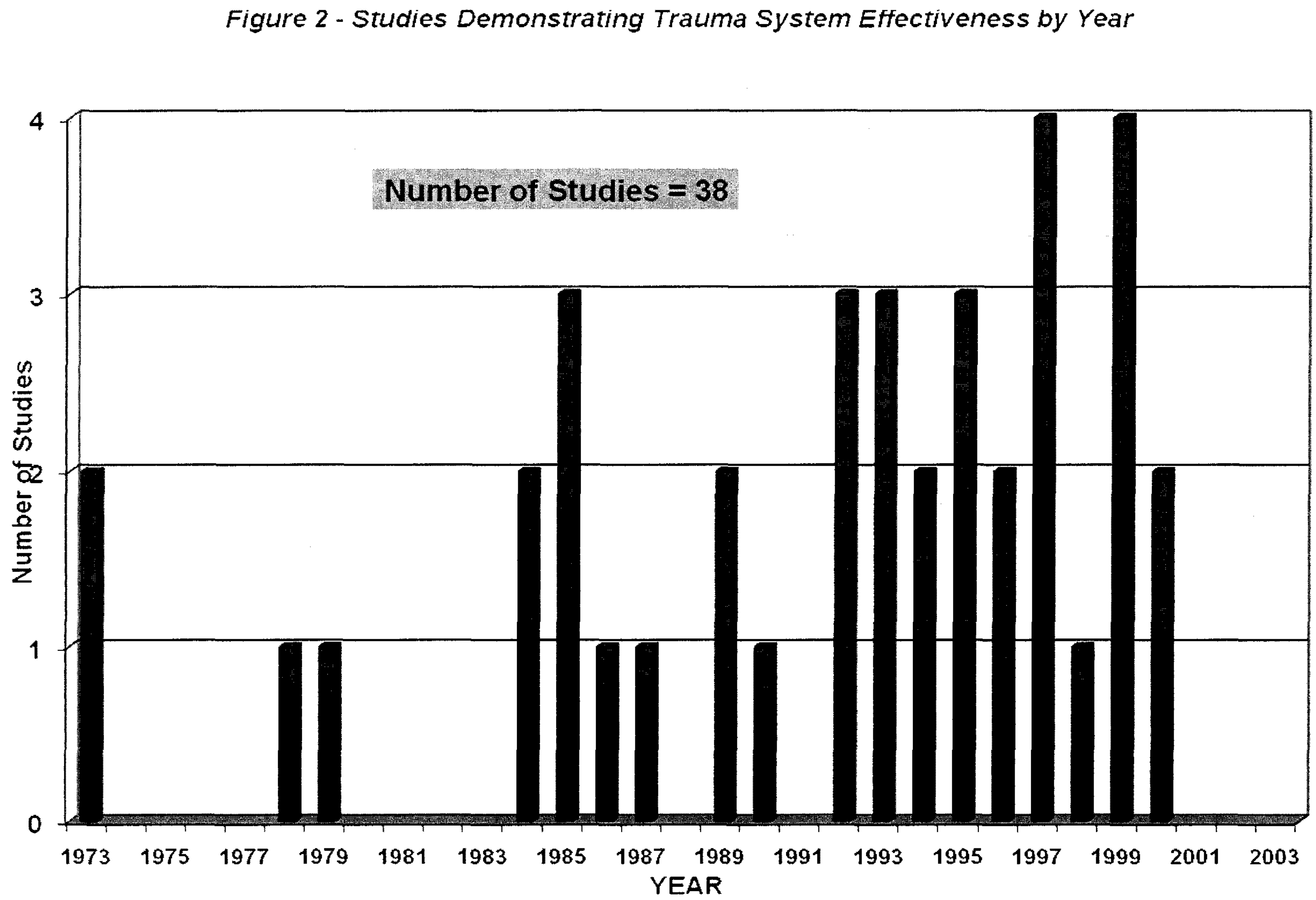

Figure 3 – Percent Mortality of Severely Injured Patients by Year in Quebec

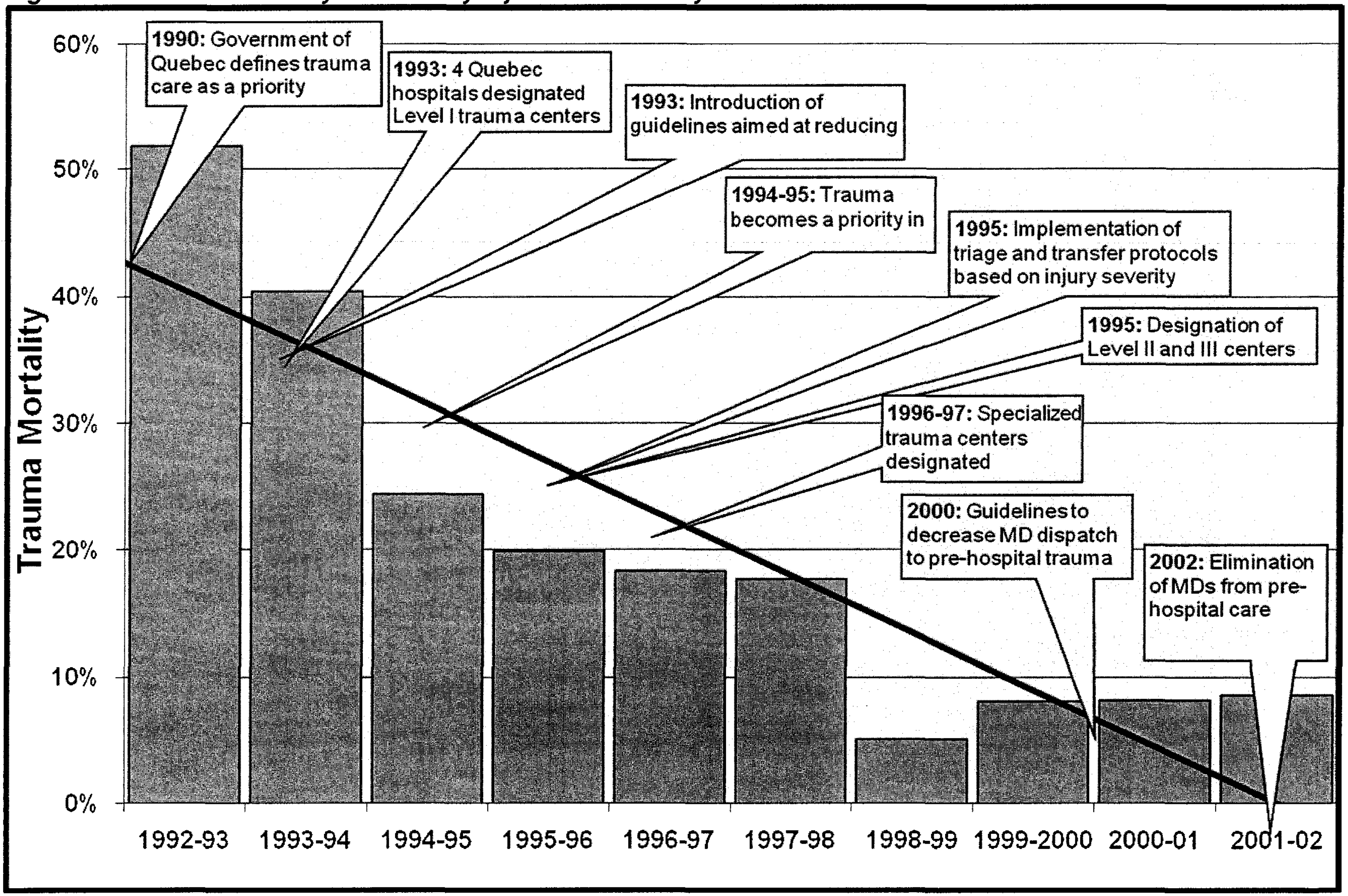

Figure 4 - Trauma System Variability Survey - English

Is there a trauma system operating in your region? YES □ NO □

Is trauma care regionalized in your area? YES □ NO □

In which year did trauma care become regionalized in your region? ________

Are there pre-hospital triage guidelines for trauma in your region? YES □ NO □

Does pre-hospital system notify hospital regarding patient status prior to arrival? YES□ NO□

Is there a lead hospital in region? YES □ NO □
If yes, LI (tertiary center) □ LII (secondary center) □ LIII (primary center) □

Dedicated trauma service in your hospital YES □ NO □

Participation in a trauma registry YES □ NO □

Mandatory trauma center accreditation/audit program in your region YES □ NO □

Performance improvement program used in hospital YES □ NO □

Cooperation with other centers in region YES □ NO □
If yes, for: Transfer □
Teaching / Learning □
Performance Improvement Program □

Are there rehabilitation facilities available at your center? YES □ NO □

Are there transfer agreements in place with a rehabilitation facility? YES □ NO □

Patient demographics Primarily Rural □ Primarily Urban □

Hospital location Rural □ Urban □

Helicopter pre-hospital system in use YES□ NO □

Approximate time by ground to Level I hospital (minutes) <10 □ 11-20 □ 21-30 □
31-40 □ 41-50 □ 51-60 □
61-120 □ 121-180 □ >180 □

Number of Level I (tertiary) trauma centers in region ________

Number of Level II (secondary) trauma centers in region ________

Number of Level III (primary) trauma centers in region ________

Number of Level IV (stabilization) trauma centers in region ________

Catchment Area <50,000 people □ 50-100,000 □ 100-500,000 □
500,000-1 million □ 1-5 million □ >5 million □

ACS verification level I □ II □ III □ IV □ N/A □

Number of hospital beds 0-50 □ 51-100 □ 101-200 □ 201-400 □
401-600 □ >600 □

Trauma patient admissions/year <100 □ 101-1000 □ 1001-3000 □
3001-6000 □ >6000 □

Number of ICU beds 0 □ 1-5 □ 6-10 □ 11-20 □
21-40 □ 41-60 □ >60 □

Number of physicians dealing primarily with trauma ________

University affiliated YES □ NO □

Residency training program Surgery □ Emergency Medicine □Neither □

Director of trauma ED Physician □ General Surgeon □
Trauma Surgeon □ General Practitioner □
Other □ ______________________________

Physicians treating trauma patients Trauma Surgeons □ General Surgeons □
Both Trauma and General Surgeons □
Emergency Medicine Physicians □
General Practitioners □

Trauma team leader General/Trauma Surgeon (resident or fellow included) □
Emergency Medicine Physician (resident or fellow included) □

24-Hour <u>in-house</u> trauma/general surgeon YES □ NO □

24-Hour <u>in-house</u> senior surgery resident/fellow YES □ NO □

24-Hour <u>in-house</u> anesthesiologist YES □ NO □

24-Hour <u>in-house</u> radiologist YES □ NO □

24-Hour <u>in-house</u> radiology resident YES □ NO □

24-Hour <u>available</u> orthopedic surgeon YES □ NO □

24-Hour <u>available</u> neurosurgeon YES □ NO □

Trauma research (undertaken at Institution) YES □ NO □
If yes: Clinical □ Basic Science □ Both □

Figure 5 - Questionnaire sur la variation des systèmes de trauma - French

Y a t-il un système de traumatologie en place dans votre région? OUI □ NON □

Est-ce que la traumatologie est régionalisée dans votre milieu? OUI □ NON □

En quelle année furent régionalisés les soins de traumatologie dans votre région?

____

Y a t-il des protocoles de triage préhospitalier pour les traumatisés dans votre région?
OUI □ NON □

Est-ce que le système préhospitalier avertit l'hôpital concernant le statut du patient avant son arrivée?
OUI □ NON □

Y a t-il un hôpital qui assume le leadership dans votre région? OUI □ NON □

Si oui, centre tertiaire □ centre secondaire □ centre primaire □

Services de trauma dédiés dans votre hôpital? OUI □ NON □

Participation au registre de trauma? OUI □ NON □

Existe-t-il un programme obligatoire de désignation des centres de traumatologie dans votre région? OUI □ NON □

Présence du programme d'amélioration continue de la qualité des soins dans votre hôpital? OUI □
NON □

Coopération avec d'autres centres de votre région? OUI □ NON □

Si oui, pour: Transfert □ éducation médicale continue □
Programme d'amélioration continue de la qualité □

Y a t-il des services de réhabilitation disponibles dans votre hôpital? OUI □ NON □

Y a t-il, avec les services de réhabilitation, des ententes en place pour les transferts?
OUI □ NON □

Type de clientèle? Principalement Rurale □ Principalement Urbaine □

Lieu de l'hôpital? Rural □ Urbain □

Y a t-il un système héliporté pour les traumatisés en fonction dans votre région?
OUI □ NON □

Quel est le temps de transport approximatif par ambulance terrestre vers le centre tertiaire en traumatologie (minutes)? <10 □ 11-20 □ 21-30 □
31-40 □ 41-50 □ 51-60 □ 61-120 □ 121-180 □ >180 □

Le nombre de centres tertiaires dans votre région ________

Le nombre de centres secondaires dans votre région ________

Le nombre de centres primaires dans votre région ________

Le nombre de centres de stabilisation dans votre région ________

Territoire de desserte <50,000 people □ 50-100,000 □ 100-500,000 □
500,000-1 million □ 1-5 millions □ >5 millions □

Désignation selon les critères de "l'ACS" I (tertiare) □ II (secondaire) □ III (primares) □ IV (stabilization) □

N/A □

Nombre de lits 0-50 □ 51-100 □ 101-200 □
201-400 □ 401-600 □ >600 □

Nombre de traumatisés admis/ année <100 □ 101-1000 □ 1001-3000 □ 3001-6000 □ >6000 □

Le nombre de lits aux soins intensifs 0 □ 1-5 □ 6-10 □ 11-20 □ 21-40 □ 41-60 □ >60 □

Nombre de médecins traitant principalement les traumatisés_________

Affiliation universitaire OUI □ NON □

Programme de résidence Chirurgie □ Médecine d'urgence □ Aucun □

Directeur de la traumatologie Médecin d'urgence □ Chirurgien Général □
Chirurgien de trauma □ Médecin Généraliste □
Autre □________________________

Médecins traitant les traumatisés Chirurgien de trauma □ Chirurgien Général □
Chirurgien Général et de Trauma □
Médecin d'Urgence □
Médecin Généraliste □

"Trauma team leader" Chirurgien Général et de Trauma (résident et fellow inclus) □
Médecin d'urgence (résident et fellow inclus) □

Présence d'un chirurgien 24 heures par jours? OUI □ NON □

Présence d'un résident en chirurgie senior/fellow 24 heures par jours?
OUI □ NON □

Présence d'un anesthésiste 24 heures par jours? OUI □ NON □

Présence d'un radiologiste 24 heures par jours? OUI □ NON □

Présence d'un résident en radiologie 24 heures par jours? OUI □ NON □

Disponibilité d'un chirurgien orthopédiste 24 heures par jours? OUI □ NON □

Disponibilité d'un neurochirurgien 24 heures par jours? OUI □ NON □

Activités de recherche (entreprises dans l'institution)? OUI □ NON □
Si oui: Cliniques □ Sciences de base □ Les deux □

Figure 6 – Survey Cover Letter - English

Dear Trauma Coordinator,

We are circulating a survey to all hospitals that receive and treat trauma patients and contribute data to either the National Trauma Database (United States) or the National Trauma Registry (Canada). The goal is to try and understand the variability in trauma systems and trauma care throughout North America. We would greatly appreciate if you could fill in this quick survey and return it in the stamped envelope provided.

If you are not the trauma coordinator or physician in charge of trauma care in your hospital, could you please give this survey to the appropriate person, or let us know and we will assure that the proper person receives a survey.

Thank you very much for your time and cooperation,

Moishe Liberman, MD	John Sampalis, PhD	David Mulder, MD

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Department of Surgery
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Figure 7 – Survey Cover Letter – French

Cher coordinateur de trauma,

Nous distribuons présentement un questionnaire pour tous les hôpitaux qui reçoivent et traitent des patients qui ont subi un traumatisme et qui contribuent au “National Trauma Database” des États-Unis ou au Registre National de Traumatismes du Canada. Le but de cette étude est d’essayer de comprendre les variations dans les systèmes de trauma, ainsi que dans les soins de trauma, à travers l’Amérique du Nord. Nous apprécierions énormément si vous pouviez répondre à ce court questionnaire et nous le retourner dans l’enveloppe affranchie qui vous est fournie.

Si vous n’êtes pas le coordinateur de trauma ou le médecin en charge des soins de trauma dans votre hôpital, pourriez-vous donner ce questionnaire à la personne appropriée ou, nous informer des coordonnées ainsi que du nom de la personne en charge afin que nous puissions lui remettre le questionnaire.

Merci pour votre temps et votre coopération,

Moishe Liberman, MD   John Sampalis, PhD   David Mulder, MD

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Figure 8 – Evolution of Trauma Care Regionalization – Evidence Based Changes in an Evolving System

	1987-88	1993	1993-95	1995	1998
Observation / Evaluation	Increased mortality for major trauma in Montréal compared to MTOS [20].	Study comparing mortality of patients pre- and post-trauma center designation shows a >2 fold increase in mortality prior to designation [21].	All patients transported to nearest ED for stabilization.	Study comparing trauma patients stabilized at nearest ED and then transferred to trauma center with patients transported directly to Level I trauma center shows an increased odds of mortality of almost 3X [22].	Study comparing the trauma system before and after initiation of triage system shows a decrease in mortality from 52% to 18% [23].

	1990	1993		1995-96
Response	*Government of Québec defines* trauma care as a priority.	*Four Québec hospitals* designated as Level I trauma centers.	*Governmental external review* board for trauma center accreditation maintenance put in place.	• *Implementation of triage and* transfer protocols. • Designation of Level II and III centers.

Figure 9 – Evolution of Pre-Hospital Trauma Care – Evidence Based Changes in an Evolving System

	1987-88		1997		1998	
Observation / Evaluation	Study shows that on-scene ALS and pre-hospital time >60 mins. increases mortality [19,24].	Study shows that ALS in Montréal increases scene time by 6.5 mins. This translates into a 2.5 X increase risk of death [26].	On-scene intravenous therapy increases mortality [27].	Pre-hospital ALS by MDs increases mortality by 17% [28].	Study shows a decrease in pre-hospital time of 18 mins. after implementation of time reducing guidelines [23].	Reduction in mortality by 34% following implementation of guidelines [23].

	1993	1995	2000	2002
Response	Introduction of guidelines aimed at reducing pre-hospital times.	Introduction of official pre-hospital criteria for direct transfer to level I trauma centers.	Unofficial guidelines to decrease MD dispatch to trauma cases.	Official withdrawal of MDs from pre-hospital trauma patient care.

Figure 10 – ISS versus Percent Mortality

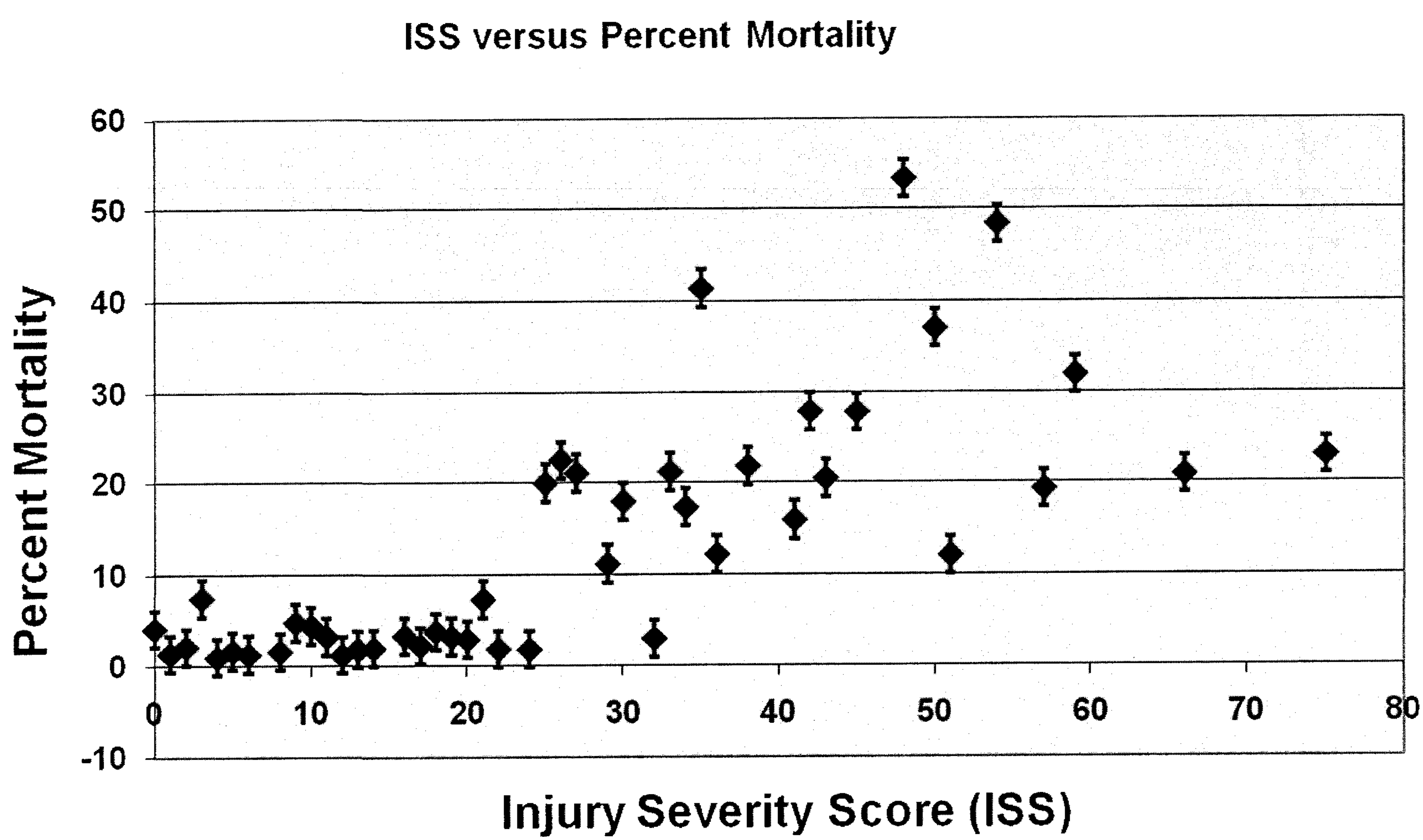


Figure 11 – Quebec Trauma Centers by Region

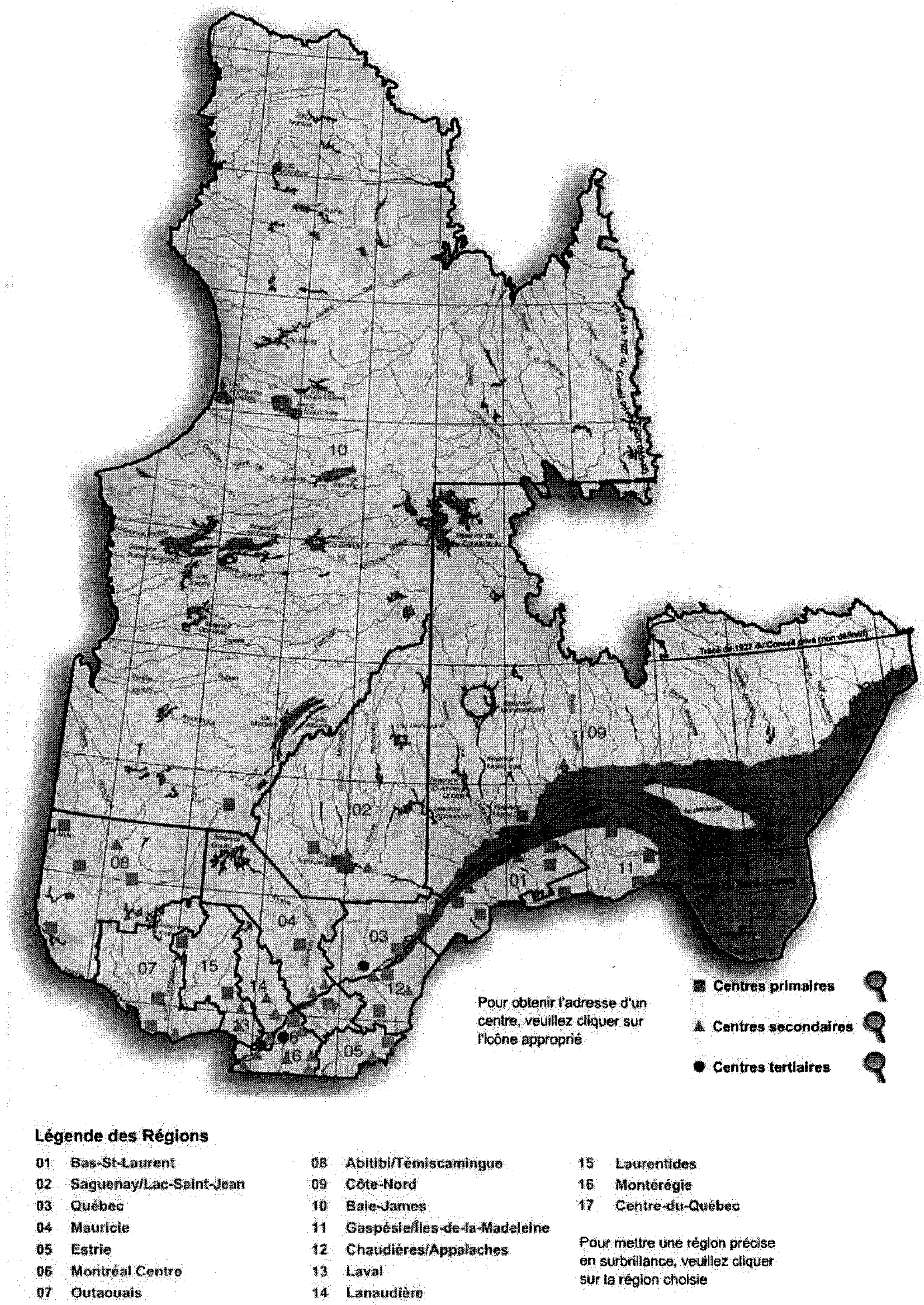


Figure 12 – Quebec Trauma Centers by Level of In-Hospital Care

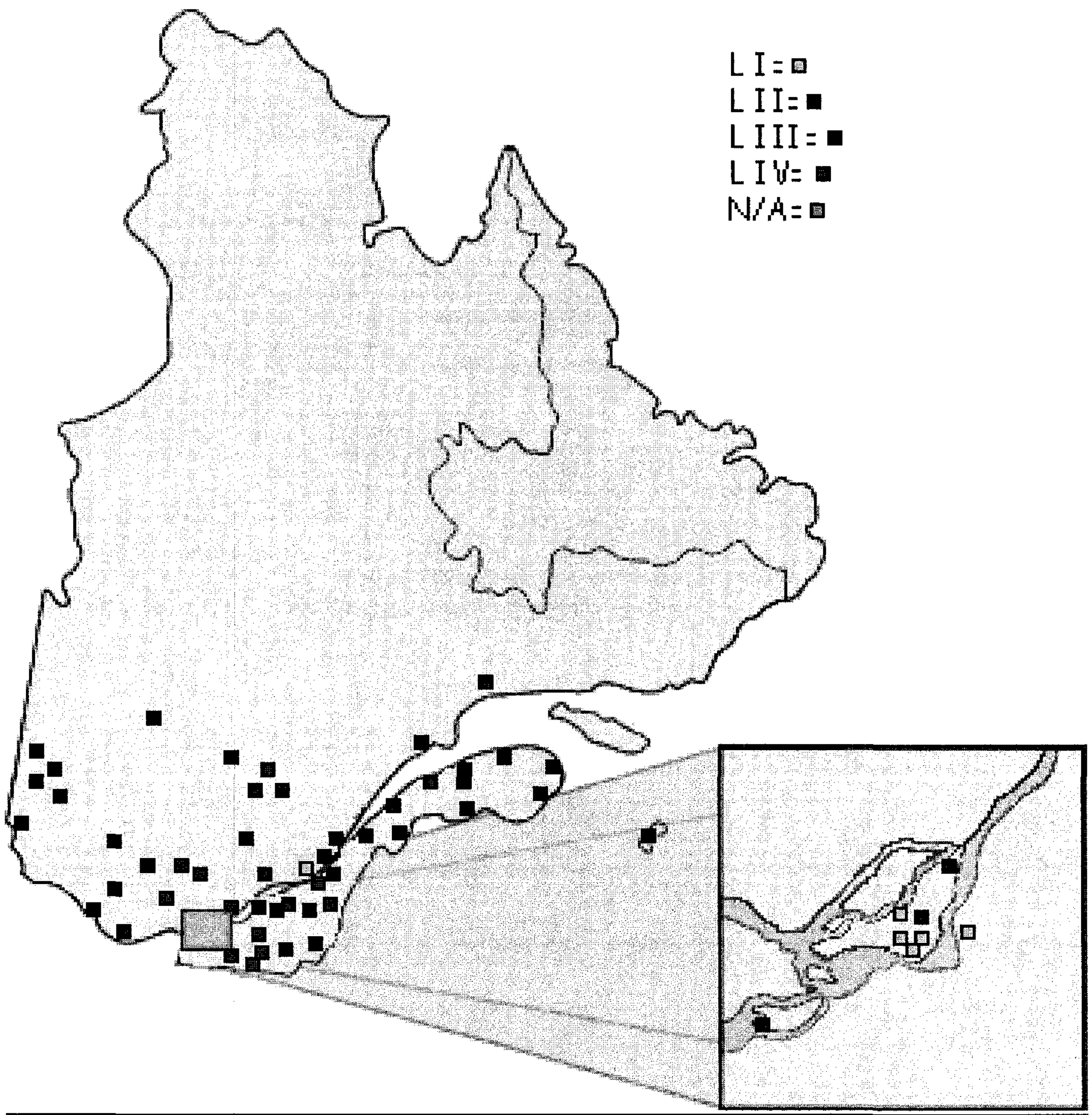


Figure 13 – Quebec Trauma Centers by Demographic Location

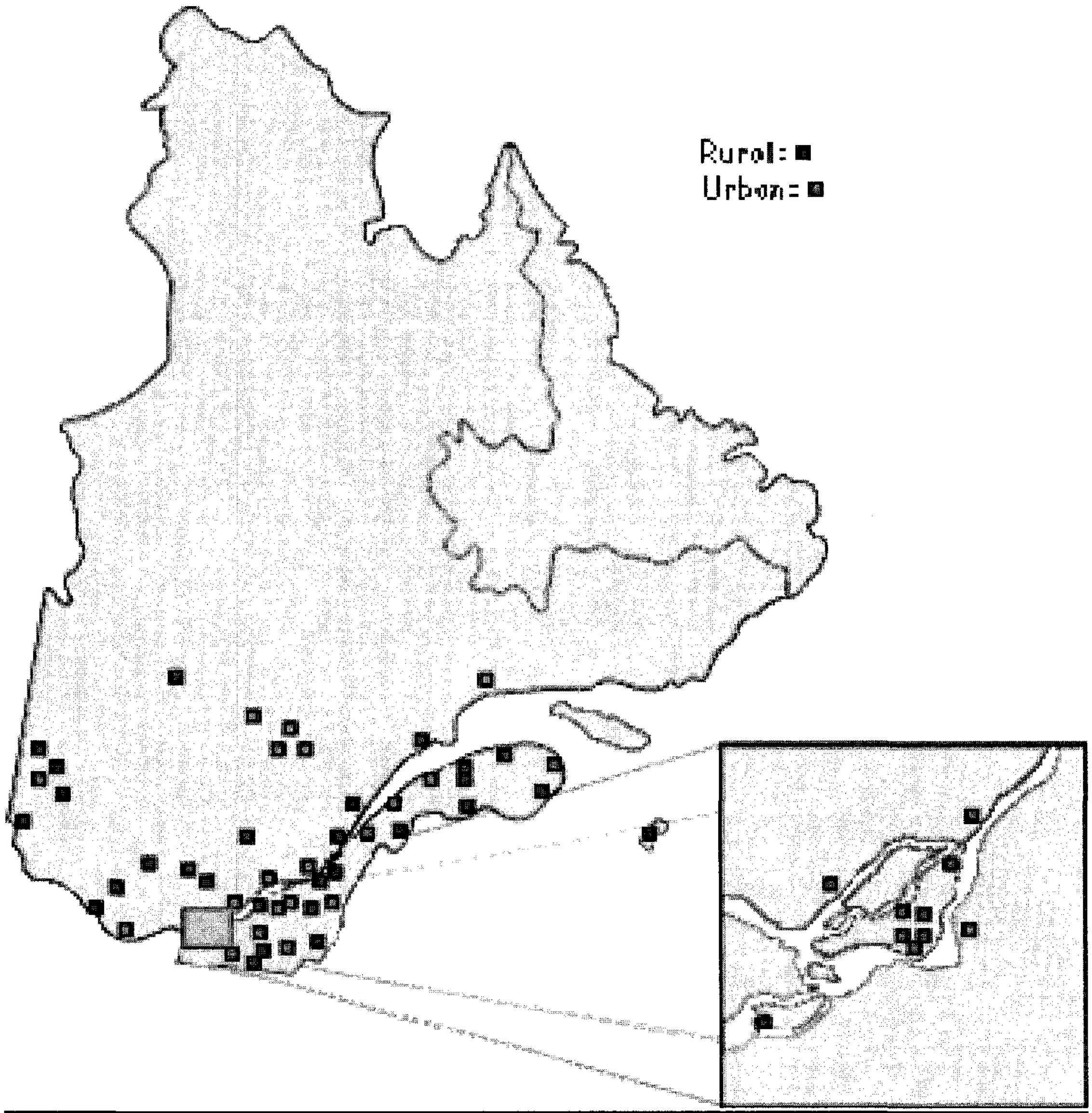


Figure 14 – North American Trauma Centers by Level of In-Hospital Care

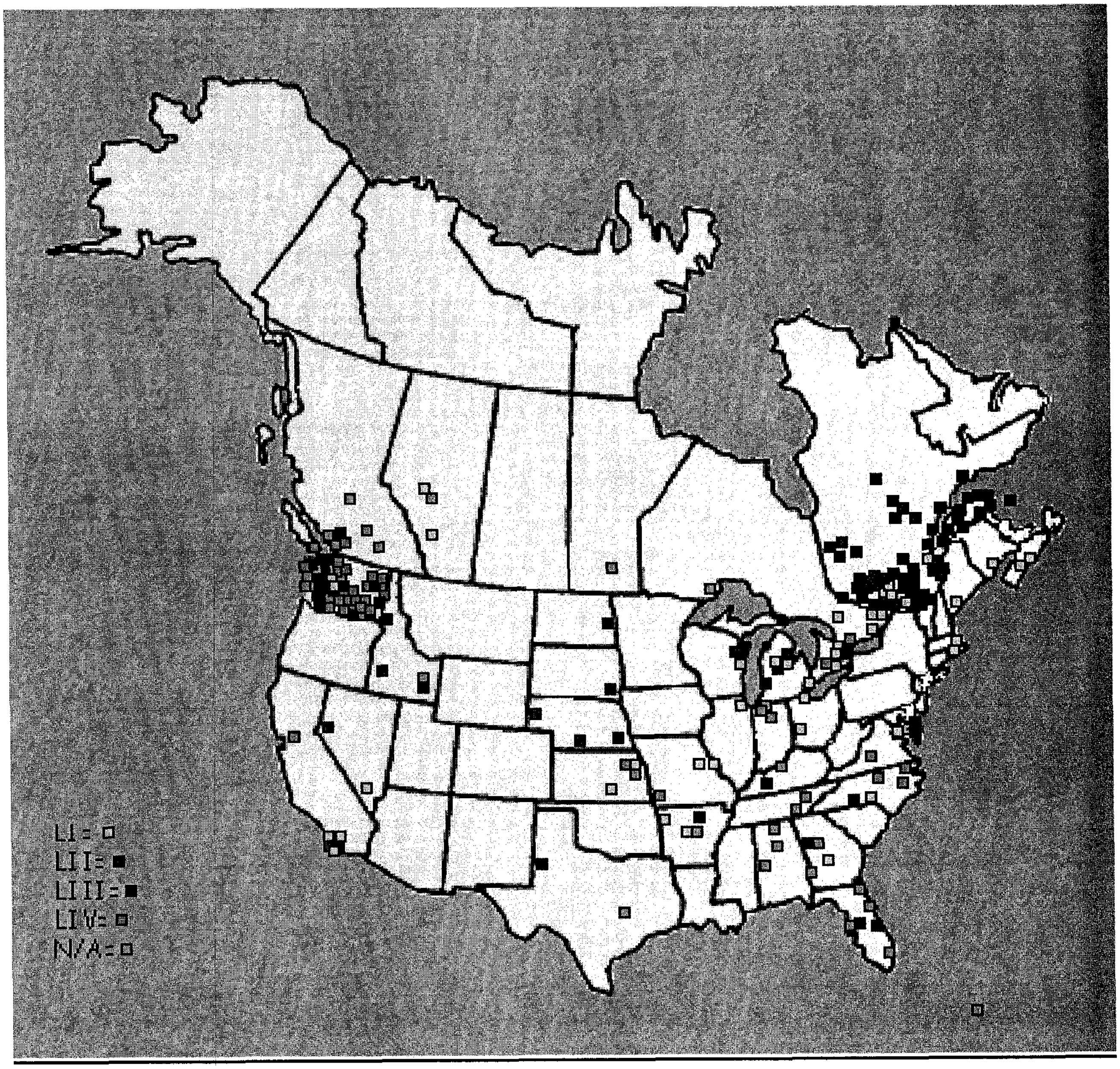


Figure 15 – North American Trauma Centers by Demographic Location

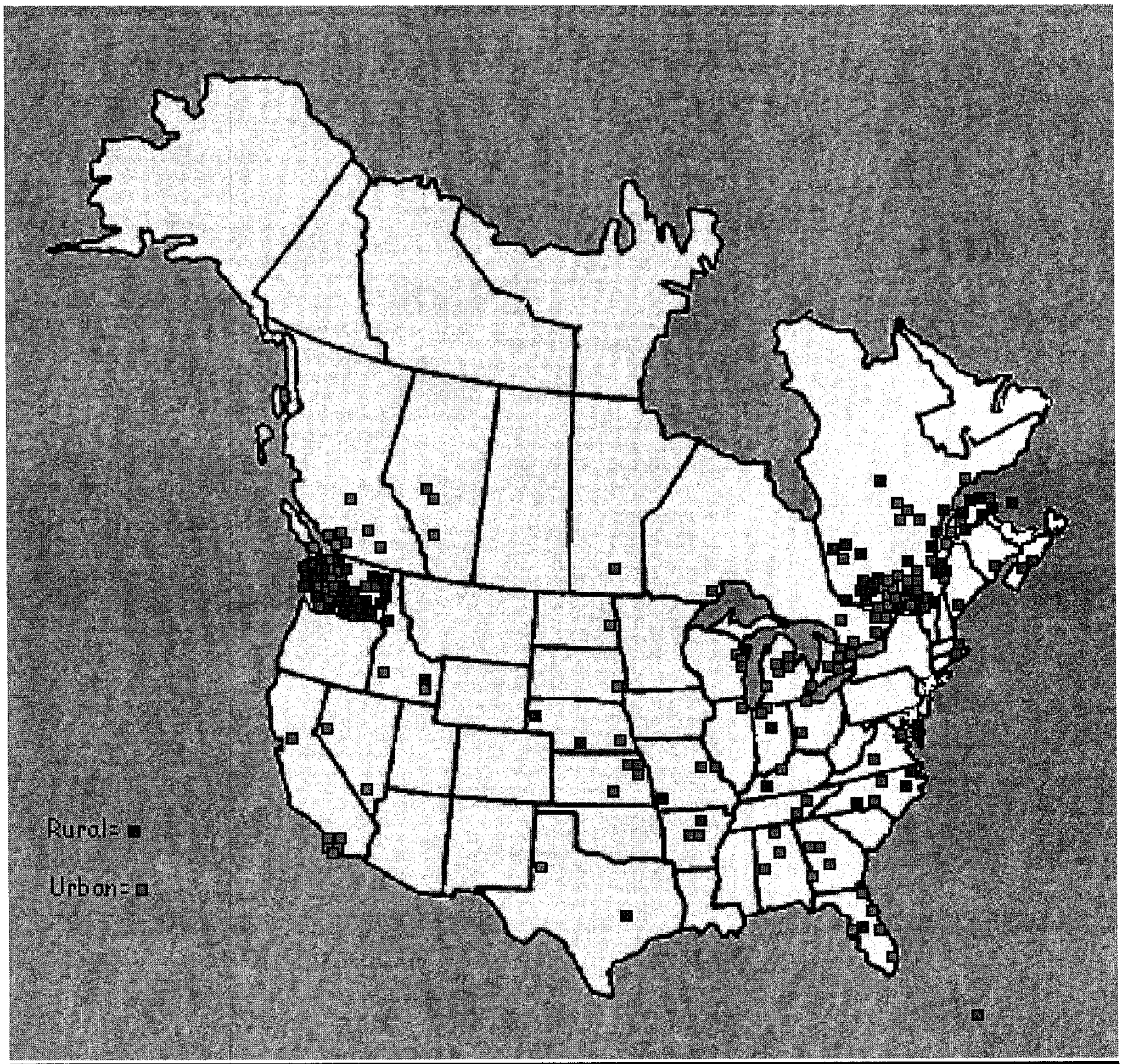


Figure 16 – Expert Survey

Level of Trauma Care Regionalization	Responses	Your Score
Trauma system operating in region	YES, NO	
Trauma care regionalization in your area	YES, NO	
Years of regionalization	Please Indicate number of points / year	
Are there prehospital triage guidelines in region	YES, NO	
Does pre-hospital system notify hospital regarding patient status	YES, NO	
Is there a lead hospital in region	YES, NO	
Level of lead hospital	LI, LII, LIII, LIV (points per level)	
Dedicated trauma service in hospital	YES, NO	
Participation in trauma registry	YES, NO	
Trauma center accreditation/audit program mandatory in region	YES, NO	
Performance improvement program used in hospital	YES, NO	
Cooperation with other centers in region	YES, NO	
Cooperation with other centers in region (type of cooperation)	TRANSFER	
Cooperation with other centers in region (type of cooperation)	TEACHING	
Cooperation with other centers in region (type of cooperation)	PERFORMANCE IMPROVEMENT	
Are there rehabilitation facilities available in center	YES, NO	
Are transfer agreements in place with a rehab facility	YES, NO	

Level of Trauma Care in Hospital	Responses	Your Score
Helicopter pre-hospital system in use	YES, NO	
Catchment area	<50000, 50-100000, 100-500000, 500000-1M, 1-5M, >5M (points per category)	
ACS Verification Level	I, II, III, IV (points per level)	
Number of hospital beds	0-50, 51-100, 101-200, 201-400, 401-600, >600 (points per category)	
Trauma patient admissions/year	<100, 101-1000, 1001-3000, 3001-6000, >6000 (points per category)	
Number of ICU Beds	0, 1-5, 6-10, 11-20, 21-40, 41-60, >60 (points per category)	
Number of MDs dealing primarily with trauma	## (number of points per MD)	
University affiliated	YES, NO	
Residency training program - Surgery	YES, NO	
Residency training program - Emergency Medicine	YES, NO	
Director of trauma	ED, GS, TS, GP, OTHER (Please indicate points per type of MD)	
Physician treating trauma patietns	TS, GS, TS+GS, ED, GP (Please indicate points per type of MD)	
Trauma team leader	GS, ER (Please indicate points per type of MD)	
24-hour in house trauma/general surgeon	YES, NO	
24-hour in house senior surgery resident/fellow	YES, NO	
24-hour in house anesthesiologist	YES, NO	
24-hour in house radiologist	YES, NO	
24-hour in house radiology resident	YES, NO	
24-hour available orthopedic surgeon	YES, NO	
24-hour available neurosurgeon	YES, NO	
Trauma research at institution	YES, NO	

ED = Emergency Department physician, GS = General Surgeon, TS = Trauma Surgeon, GP = General Practitioner

Figure 17 – Expert Survey Responses – Level of Trauma Care Regionalization

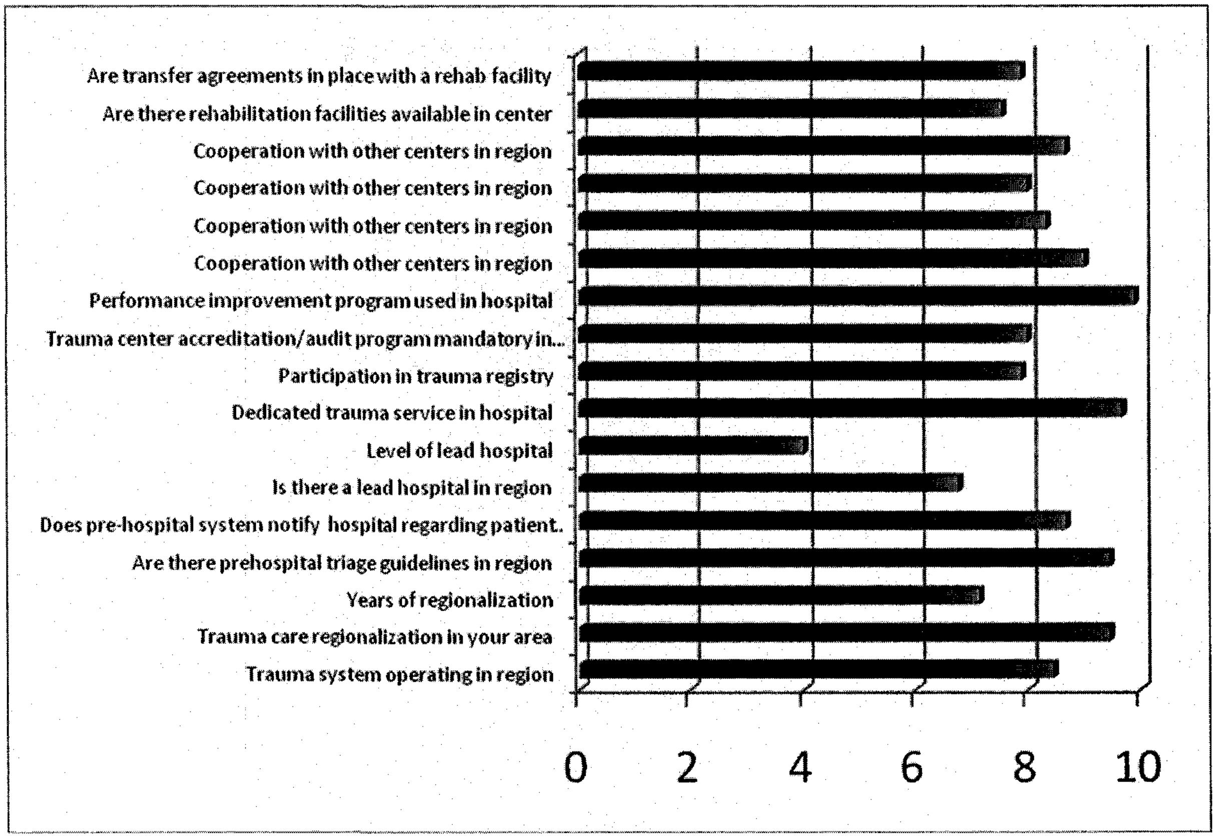
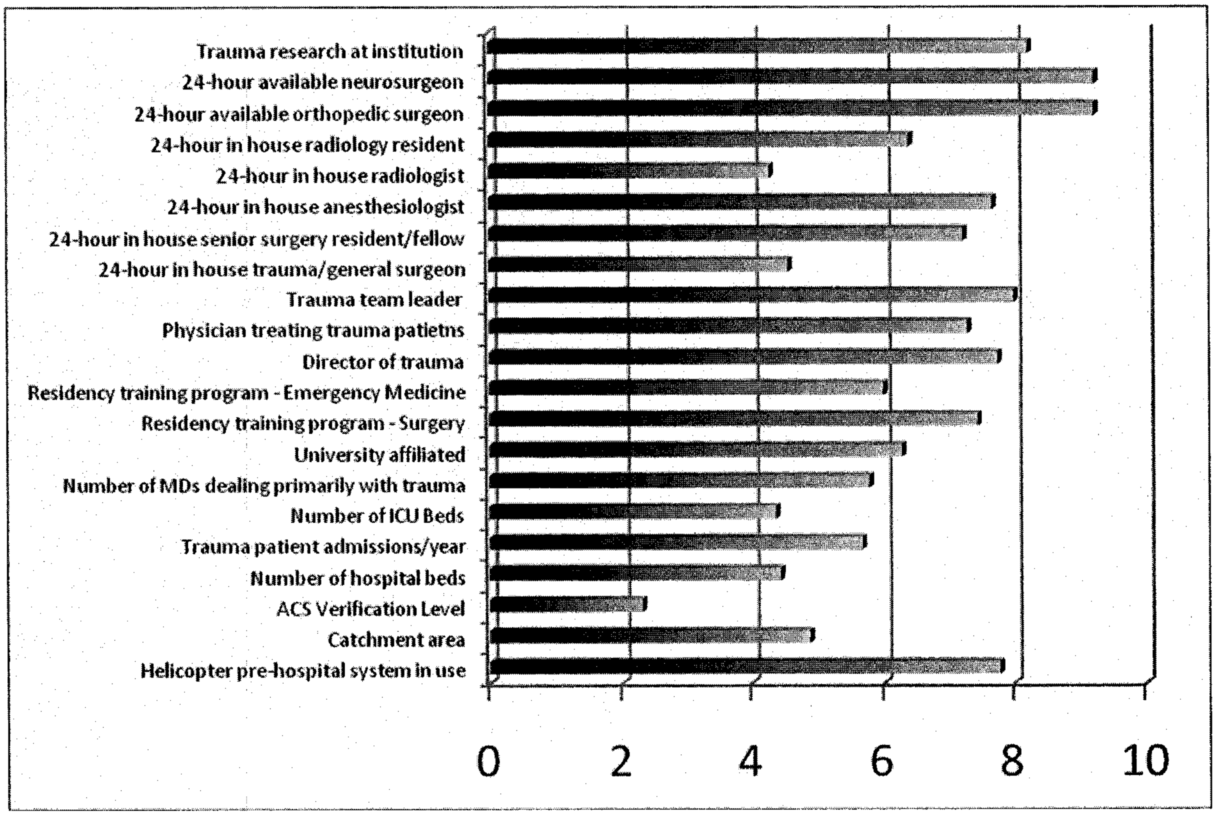


Figure 18 – Expert Survey Responses – In-Hospital Components



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