

FEATURE REVIEW

The Evidence Supporting a Systematic Approach to the Care of the Injured Patient: From Prevention to Rehabilitation¹

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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 secondarily to injury (8% of all deaths) (5). It is also a major cause of morbidity in both the short and long-term (6). Furthermore, injury is a leading cause of disability, potential years of life lost and a major contributor to overall health care costs (7,8,9). 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 (10). In 1994, 8,687 people died following accidents in Canada (1). Approximately four times as many patients suffer severe disability related to accidents each year.

The cost of acute medical care for injured patients is in excess of \$16 billion per annum (11). 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, and lost wages and taxes (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 (12). If productivity costs due to premature death are taken into account, the total savings could total \$10.3 billion.

TRAUMA SYSTEMS

Trauma care throughout Canada and the rest of North America has seen tremendous changes over the last 30 years. The regionalisation 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 regionalised 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 (13,14). 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 is to get the injured patient to definitive care as soon as possible (15,16).

Trauma systems have been designed to render "optimal care" to injured patients. Eggold defines optimal care as being based on two implied premises (17): One premise is that suboptimal trauma care 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 is assured (18).

The care of injured patients is a continuum from the moment of injury, until the return to daily life (19,20). Regionalised trauma care incorporates several different elements, which together make up the trauma "system".

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These systems have been repeatedly shown to decrease mortality and improve the outcome of injured patients in multiple different regions throughout the Western world.

EPIDEMIOLOGY OF TRAUMA DEATHS

Trauma is a devastating disease. It contributes to approximately 140,000 deaths per year in the United States (21). 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. (22) Injuries 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 (19,23,24,25,26). These peaks were first alluded to in reports by Beebe and DeBakey in 1952 (27) and by Zollinger in 1955 (28) and later expanded on by Trunkey in 1983 (19). 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 (29). 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 (30). Injury prevention and control has been shown to have more immediate health and economic benefits than the prevention and control of chronic diseases (31).

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 (19). Deaths in this period are secondary to injuries that require urgent and emergent care. These injuries are time-critical and the sooner the patient receives definitive care for these injuries, the better the outcome. 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 and stop the hemorrhage or to evacuate a compressive hematoma (cerebral hemorrhage), or an interventional procedure (tube thoracostomy, pericardiocentesis, angio-embolisation...). If these procedures are not provided

promptly and properly by the appropriate personnel in the appropriate setting, mortality occurs.

It is for the patients in the second period of trauma deaths that systematic trauma care attempts to make an impact. These are the time-critical patients, desperately 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 regionalised 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 is that which occurs in the first year following injury (32). 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.

PROCESS OF REGIONALISATION, BUILDING A "TRAUMA SYSTEM"

The basis for the regionalisation of trauma care or the development of a "trauma system" is the need to link all aspects of 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 centres), as well as health care and public safety agencies (33). Ideal trauma systems include prevention, access, acute hospital care, rehabilitation, and research activities (34). 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 goals of regionalised trauma care are to improve the quality of care and to decrease its cost (35).

The American College of Surgeons Committee on Trauma clearly outlines the importance of emphasising the trauma system, rather than the trauma centre as being integral in improving trauma patient outcome

(34).

"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 centre 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 regionalised 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.

Trauma centres serve as the hubs of these systems. Trauma centres also exist in areas without formal trauma systems in place. In these areas they are usually not designated as trauma centres, but act as "de facto" or "functional" centres (36). Tertiary trauma centres (level I centres) 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 centres. 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.

West identified eight essential elements that were integral to an inclusive trauma system based on criteria from the American College of Surgeons (37). These criteria were: (a) the presence of a lead agency with legal authority to designate trauma centres; (b) the use of a formal process for trauma centre designation; (c) the use of American College of Surgeons standards for trauma centres; (d) the use of an out-of-area survey team for trauma centre designation; (e) limiting the number of designated trauma centres in a community based on assessment of population need; (f) the application of written triage criteria that form the basis for bypassing non-trauma centre hospitals; (g) the presence of ongoing monitoring systems for trauma centres; and (h) the state-wide availability of trauma centres.

The integral steps in developing a regional trauma system are (37):

1. Basic Data

The first step is defining the magnitude of the problem in the area to be regionalised. This can be carried out using autopsy studies (38,39), preventable death studies (40), and/or regional trauma reviews (41). Out-of region experts should be recruited in order to provide objective assessments of the system in place.

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 (42,43,44) and have local surgeons heavily involved in planning and development.

The plan should address the following issues:

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

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.

4. Develop a Management Structure

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

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 (45). 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 (46). It requires intensive study, coordination and financial commitment. In the United States, 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 commitment on the part of systems for the care of these patients are vital to the success of these systems in the future.

THE ELEMENTS OF A TRAUMA 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 regionalised trauma systems are: (1) a lead public agency with legal authority to establish and enforce trauma system policy; (2) facility categorization; (3) trauma centre 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 centre (47,48,49). 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 centre designation (48). Bazzoli et al identify three key elements integral to trauma care regionalisation: pre-hospital care, organization of hospitals and inter-hospital transfer agreements (50). By assuring appropriate and timely inter-hospital transfers, patients can be appropriately treated in a system encompassing remote and rural areas (51).

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 (52):

Fundamental Components

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

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 (53). Systems need to be created with geographic, time-transportation factors and maximum health delivery capabilities of a region in mind (54).

Another crucial element involved in maintaining an effective regionalised 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 (21). 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 centralised 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 that 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 (55,34). Triage schemes have been shown to be effective at decreasing trauma mortality (56,57,58). The algorithms outline strategies for transporting the seriously injured patient to an appropriate centre, bypassing lower level centres, which are often closer to the scene of the accident.

Trauma centres remain a key component in the systems approach to the acute care of the severely injured patient (59,60). Designation of these centres is integral to improving outcomes (36,61). By having designated centres 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 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 centres shifts more severely injured patients to designated hospitals (62), trauma centre 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 (63). Patients directly transported to trauma centres also have less missed injuries than transferred patients (64). However, it has also been demonstrated that hospitals in remote areas that do not possess all elements necessary for the designation of trauma centres, can have similar, if not better, outcomes than those meeting criteria (65).

Surgical leadership is vital to maintaining an effective trauma system (66,67,68). 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 centre (34). The American Association for the Surgery of Trauma (AAST) expands on this and requires that a trauma surgeon be (69):

- 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 prioritise 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 (44). In fact, prevention is probably the single most effective way to decrease mortality and morbidity associated with injury.

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 (53).

IN-HOSPITAL CARE - CHARACTERISTICS OF TRAUMA TREATMENT CENTRES

The categorisation of hospitals based on their ability to care for injured patients was first suggested by Youmans and Brose in 1970 (70). They conceptualised 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 centres.

Designated trauma centres have been shown to decrease mortality, complication rates, and length of hospital stay compared to non-trauma centres (71,72,73,74,75). Verification has also been shown to improve the process of care within trauma centres

(76,77,78). An overview of a centre's role and requirements as part of a system of trauma care based on the ACS criteria for trauma centre designation is as follows:

Level I

Level I trauma centres are tertiary care facilities that are the focal point of a regionalised trauma system. These centres 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 (59).

Level II

Level II trauma centres function in a similar capacity to level I centres, however, they do not have the extensive resources and facilities as level I centres. They are required to provide initial definitive trauma care to injured patients regardless of injury severity.

Level III

Level III centres usually occur in communities that do not have access to level I or II centres. These centres 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.

Level IV

Level IV centres are those centres treating and stabilizing injured patients in rural areas without other hospitals. They are the "de facto trauma centres" in these regions due to geographical location (59). They are responsible for providing Advanced Trauma Life Support care (55) in remote areas where no higher level of care is available prior to transfer to an advanced level centre.

The evaluation and management of severely injured patients requires significant institutional commitment and the commitment of skilled personnel (13). Recently, there has been much debate over the American College of Surgeons' requirements for minimal trauma centre volume in order for a centre to receive a designation (34). 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 (79,80,81,79,82,83,81), however others have demonstrated a lack of association (84,85,65,86,87). Guidelines for level I trauma centre verification require 1,200 admissions per year. Many centres in the US and Canada that cannot meet these requirements do, however, meet all other requirements for level I status.

THE IMPACT OF TRAUMA CARE REGIONALISATION

The initial fervour for trauma system implementation was backed by very few studies and lacked the large amounts of evidence that were to come over the years (88,89). However, since the late 1960s

there have been over thirty studies demonstrating a positive impact on survival in regionalised compared to non-regionalised trauma systems (Table 1). Furthermore, the lack of a trauma care system has also been repetitively shown to contribute to substandard care and outcomes (90,91,92,93,94). By centralising the care of severely injured patients in to a few highly specialized centres, as well as creating corridors for direct entry and easy exit from acute care, trauma systems significantly improve the outcome for injured patients (46,95,96,97,98,99,100,101,102,103) and change the pattern of preventable mortality from delays or inadequate interventions to postoperative care errors (104). Aggregated population-based evidence (61,71,72,73,105,106,107,108,109,110,111,112,113,114) has demonstrated a 15 to 20% improved survival rate for seriously injured patients following trauma system implementation (115).

Shackford (116) found that in the first year following establishment of a regionalised trauma system in San Diego County, severely injured patients (TS = 8) had a probability of survival (Ps) of 18% compared to injured patients treated at numerous centres throughout the US and Canada (117), and an actual survival of 29%. Many subsequently used this evidence in order to push healthcare systems and governments to establish organised systems of trauma care. San Diego County instituted a regionalised trauma system in 1984. Guss subsequently performed a before and after preventable death evaluation in the County (118,119) using the validated autopsy review methodology proposed by West (120). 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 (40). Guss found that by expert panel evaluation, 2 out of 211 deaths (1%) were preventable post regionalisation compared to 20 out of 177 (11.4%) pre-regionalisation ($p < 0.001$). Similar to the Orange County and San Francisco County patients, the decline in mortality post regionalisation was mostly attributed to a decline in mortality from non-central nervous system deaths.

Shackford studied the effect of regionalised trauma care on outcomes of "major trauma victims" in the first 5 months post-regionalisation 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 (121). He found suboptimal care was rendered in 32% of cases prior to regionalisation, and that the implementation of a trauma system decreased the proportion to 4.2% (122). 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 regionalisation in San Diego County (121). He compared actual survival to predicted survival based on the Major Trauma Outcome Study (MTOS) (117). Following regionalisation, 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 regionalised trauma system. The risk of death in level I trauma centres improved following implementation of a regionalised system in the North Willamette region of Oregon between 1984 and 1991 (odds ratio = 0.65 post regionalisation) (109). The establishment of a regionalised trauma system also shifted the more seriously injured patients to the level I centres (123). Mullins then evaluated the influence of the implementation of a state-wide trauma system in Oregon on the location of hospitalisation and outcome of injured patients before and after regionalisation (110). In Oregon, following state-wide regionalisation, chances for an injured patient being admitted to a level I or II trauma centre 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 (111). In this study injured patients in Oregon and Washington were compared before either state had a regionalised 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 (107). Secular trends in trauma mortality are best adjusted by the types of studies that compare two systems over the same time period (124).

Kane evaluated the survival of seriously injured patients in Los Angeles County prior to (1982) and following (1984) implementation of a regionalised system of trauma care (108). There was an observed significant improvement in the adjusted odds of survival following regionalisation (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

(125). There was also a significant decrease in motor vehicle collision mortality that was related and attributed to the establishment of a regionalised 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 regionalised trauma care (126). States that contained regionalised trauma systems (n=22) had a 9% lower crude mortality rate compared to those without regionalised 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 regionalised trauma care on motor vehicle crash mortality throughout the United States between 1979 and 1995 (127). He found that it took approximately 10 years following regionalisation 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 centre 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 (109), Cayten (125) and Nathens (127), 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 (128). He found that the positive impact of trauma system regionalisation 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 (129). 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) (130,131,132). 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 (133). 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 (134,135). 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 (136). 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 (10). 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 (137,138,139). 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 = 16 over 10 years at a single level I trauma centre between 1986 and 1995 (140).

The effects of regionalisation in Canada have not been as extensively studied as the systems of trauma care in the United States. However, the impact of regionalisation on the outcome of trauma patients in the province of Quebec has been studied in depth over the last 15 years (58,93,138,141,142). Regionalisation of trauma care has been shown to significantly improve outcome for seriously injured patients in Quebec.

In the early years of trauma care regionalisation, designation of trauma care centres does not lead to increases in patient volume at designated trauma centres. Instead, there is a redistribution of patients, with the more severely injured patients being transported to the higher level centres (29,143). However, once a system becomes established and is running efficiently, outcomes improve (137) and proportions of trauma patients being transported to higher level centres increase (144,145). 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

Table 1 . Studies Demonstrating Survival Benefit Following Trauma System Implementation

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalised Mortality	Regionalised Mortality	Change
Mullins RJ {158}	1994	Four Counties in Portland, Oregon (pre- and post-regionalisation)	Hospital Discharge Data Analysis	Injured patients	25,145 pre 21,806 post	O.R. for death in Level I centres = 1.0		
Karsteadt LL (155)d}	1994	North Coast EMS Region of California (rural trauma system post-regionalisation 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 {61)d}	1993	North Carolina Counties With Trauma Centres versus Counties Without Trauma Centres	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 {159)d}	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 (104)d}	1993	Hillsborough County, Florida (pre- and post-regionalisation)	Medical Audit - PDA	Non-CNS Trauma Deaths	452 pre 504 post	PDR = 2.3%	PDR = 7%	16% improvement in PDR
Kane G (108)d}	1992	Los Angeles County (pre- and post-regionalisation)	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-regionalisation
Rutledge R (72)d}	1992	North Carolina Counties With Trauma Centres versus Counties Without Trauma Centres	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 (160)d}	1992	Washington Hospital Centre (pre- and post-trauma centre 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

Table 1. Studies Demonstrating Survival Benefit Following Trauma System Implementation (continued)

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalised Mortality	Regionalised Mortality	Change
Smith JS ({73}d)	1990	Western Pennsylvania and Maryland (Trauma Centres versus Non-Trauma Centres)	Hospital Discharge Data Analysis	Patients with femoral shaft fracture requiring operation	718 non-trauma centre 614 trauma centre	2.2% crude mortality	1.0% crude mortality	1.2% improvement in crude mortality (Non Significant)
Guss DA ({119}d)	1989	San Diego County, California (pre- and post-regionalisation)	Medical Audit - PDA	All injury deaths	177 pre 211 post	PDR = 11.4%	PDR = 1%	10.4% improvement in PDR
Shackford SR ({161}d)	1987	San Diego County (post-regionalisation 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 ({122}d)	1986	San Diego County (pre- and post-regionalisation)	Medical Audit - PDA	Seriously injured patients	591 pre 1366 post	PDR = 13.6%	PDR = 2.7%	10.9% improvement in PDR
Clemmer TP ({71}d)	1985	Salt Lake County, Utah (level I centres vs. community hospitals)	Hospital Discharge Data Analysis	CRAMS = 6	56 LI 24 community	46% crude mortality	75% crude mortality	29% improvement in crude mortality
Omato JP ({113}d)	1985	Nebraska (pre- and post-regionalisation)	Dept of Health Database	All injury deaths	474 pre 349 post			23.9% improvement in crude mortality
Cales RH ({162}d)	1984	Orange County, California (pre- and post-regionalisation)	Medical Audit - PDA	MVC Deaths	58 pre 60 post	PDR = 34%	PDR = 15%	20% improvement in PDR
Alexander RH ({106}d)	1984	Florida (comparison of counties with level I equivalent hospitals to those without)	Highway Patrol Database	Mileage Population Death Index (MPDI)	467 pre 214 post	MPDI = 24.5	MPDI = 0.82	Reduction in MPDI = 23.7
West JG ({163}d)	1983	Orange County, California (pre- and post-regionalisation)	Medical Audit - PDA	Non-CNS MVC TC Deaths	21 pre 23 post	PDR = 71%	PDR = 9%	62% improvement in PDR
West JG ({164}d)	1979	Orange County, California (non-regionalised) vs. San Francisco County, California (regionalised)	Medical Audit - PDA	Non-CNS MVC related deaths	30 non-regionalised 16 regionalised	PDR = 73%	PDR = 6%	67% improvement in PDR

Table 1. Studies Demonstrating Survival Benefit Following Trauma System Implementation (continued)

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalised Mortality	Regionalised Mortality	Change
Abernathy JH (151)d}	2002	Level I TC, University of Alabama at Birmingham (pre- Injured patients 1718 post and post- regionalisation)	Injured Patients Trauma Registry	Hospital-based	1306 pre 1718 post	5.9% crude mortality	3.8% crude mortality	Adjusted Odds of death post regionalisation = 0.48
Nathens AB (152)d}	2000	United States (22 regionalised states versus non- regionalised 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 state
Nathens AB (127)d}	2000	United States (comparison between pre- regionalisation and post- regionalisation 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- regionalisation)
Özgül H (153)d}	2000	Ulđag 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 (154)d}	1999	United States (comparison between pre-regionalisation and post-regionalisation 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-regionalisation)
Sampalis JS (138)d}	1999	Montreal and Quebec City, Quebec (pre- and post- regionalisation)	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 regionalisation)
Mullins RJ (111)d}	1998	Oregon (pre- and post- regionalisation) and Washington State (non-regionalised)	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 regionalisation
Hulka F (107)d}	1997	Oregon (regionalisation) and Washington State (non-regionalised)	Hospital Discharge Data Analysis	Seriously injured children (<19 years)	12,991 non-regionalised 8,981 regionalised	O.R. for death = 1.0	O.R. for death = 0.68	32% adjusted risk-reduction for death in regionalised area
Mullins RJ (155)d}	1997	Oregon (pre- and post- regionalisation) and Washington State (non-regionalize state)	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 regionalisation

Table 1. Studies Demonstrating Survival Benefit Following Trauma System Implementation (continued)

Study Author	Year	Region(s)	Data Source	Type of Patients	Number of Patients	Non-Regionalised Mortality	Regionalised Mortality	Change
Rogers FB (114)d}	1997	San Diego County (urban regionalised trauma system) compared to Vermont (rural non-regionalised system)	State Medical Examiner's Database and Autopsy Database	On-scene deaths	103 non-regionalised 248 regionalised	72% crude mortality	40.5% crude mortality	Rural/non-regionalised have significantly higher proportion of on-scene deaths
Nichol J (156)d}	1997	North Staffordshire Royal Infirmary and 5 district general hospitals in North West Midlands (regionalised) vs. Lancashire and Humberside, England (non-regionalised)	Medical Records Review	Seriously injured patients	1503 non-regionalised 1143 regionalised	45% crude mortality	43% crude mortality	No difference in either crude or adjusted mortality
Mullins RJ (110)d}	1996	State of Oregon (pre- and post-regionalisation)	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 regionalisation
Sampalis JS (142)d}	1995	Montreal, Quebec (pre- and post-trauma centre designation)	Regional Trauma Database Analysis	Seriously injured patients	158 pre 288 post	20% crude mortality	10% crude mortality	Mortality pre-regionalisation significantly greater than MTOS, post-regionalisation no change
Stewart TC (157)d}	1995	Victoria Hospital, London, Ontario (pre- and post-regionalisation)	Hospital-based Trauma Registry (TRISS)	MVC patients, ISS>12	156 pre 189 post	Z = -0.40	Z = +0.72	6 more survivors per 100 death post regionalisation patients post regionalisation
Waters JM (165)d}	1973	Jacksonville, Florida (pre- and post-regionalisation)	Highway Death Rate Analysis	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 (105)d}	1973	State of Illinois (pre- and post-regionalisation)	Highway Death Rate Analysis	All highway injuries		2.8% mortality rate	2.1% mortality rate	Decline in highway fatalities of 8%

*Based on the % reference according to each individual patient's age, sex, and height. +This parameter is not a score but the actual dose converted into beclomethasone units (mcg) d Statistically significant p-values accounting for non-independence PDA = Preventable Death Analysis; PDR = Preventable Death Rate; MVC = Motor Vehicle Collision; TC = Trauma Centre; O.R. = Odds Ratio; R.R. = Relative Risk; MRR = Mortality Rate Ratio; Mileage Population Death Index (MPDI) = average death rate per one hundred million miles driven divided by the population at risk x 105; MTOS = Major Trauma Outcome Study (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); Ps = Probability of Survival (based on MTOS data)

to err on the side of over-triage in order not to miss significant occult injuries (146,147). Furthermore, triage algorithms are designed to over-triage less severely injured patients (43,148,149,150). These factors contribute significantly to the high costs of running a level I trauma centre (48).

CONCLUSION

Regionalisation of trauma care improves outcome for injured patients by utilizing a systematic approach to the care of the injured patient. This approach encompasses all phases of injury from prevention to rehabilitation. A systematic approach to the care of the trauma patient is based on cooperation between pre-hospital emergency medical services, hospitals of all levels, rehabilitation facilities and local, regional, state-wide/provincial and national organizations. By pooling resources and emphasizing teamwork and cooperation, trauma systems have changed the face of trauma patient care, significantly decreased morbidity and mortality secondary to injury and set a benchmark for the regionalised approach to patient management for other areas of healthcare.

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