Trauma Systems and Trauma Care

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3.1 Introduction

Trauma systems are designed to care optimally for a population and its injured members. These systems extend far beyond in-hospital care of the injured patient. They must also include injury prevention, prehospital care, hospital care, education, and research, as well as long-term rehabilitation and recovery. Trauma systems require coordination between hospitals, physicians, nurses, allied health professionals, policy makers, governing bodies, community leaders, and many others to be successful. This review will describe the history and development of trauma systems, the key components of such systems, and the impact that trauma systems have on a population.

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A. Gullo and G. Ristagno (eds.), *Resuscitation*,
DOI: 10.1007/978-88-470-5507-0_3,

3.2 History of Trauma Systems and the Development of the American Trauma System

Although the foundations arose from military conflicts, the American College of Surgeons Committee on Trauma was instrumental in the creation of the modern day trauma system in America. In 1966, the Committee on Shock and the Committee on Trauma of the Division of Medical Sciences of the National Academy of Science/National Research Council published the landmark "Accidental Death and Disability: The Neglected Disease of Modern Society" [1]. In this report, injury was identified as the "neglected epidemic," and leadership to overcome this epidemic was encouraged. The focus of this document was on research, education, and training for those involved in the care of the injured patient from the prehospital phase to the acute care institution. As such, the initial trauma systems in this country were focused primarily on the prevention of unnecessary death in the severely injured patient [2]. The "Accidental Death and Disability" report laid the groundwork for what would eventually become trauma center designations, as well as the emergence of the specialty of Emergency Medicine [1]. The concept of trauma registries and quality improvement can also be traced back to this report, with a brief mention also made on the need for research, education, and regulations aimed at injury prevention.

After the publication of "Accidental Death and Disability," regionalized trauma systems began to emerge throughout the US, starting in Maryland, Illinois, and Virginia [3]. These efforts were furthered in the late 1970s by the American College of Surgeons Committee on Trauma publication "Optimal Hospital Resources for the Care of the Seriously Injured" [4]. This document provided a framework not only for care, but also for evaluation of care, and for the first time, suggested criteria for the categorization of hospitals based on the ability to provide varying degrees of trauma care. There have been multiple revisions of this document since its initial publication, and references can be found in the operating procedures of many American trauma centers.

In the early 1980s, in response to the personal tragedy of an orthopedic surgeon, the American College of Surgeons Committee on Trauma initiated the Advanced Trauma Life Support (ATLS) Course [5]. The ATLS course is designed to train all providers in the initial stabilization and life-saving techniques vital in the early management of the critically injured patient. Training in the standardized initial assessment and management of the injured patient has been shown to improve knowledge of what to do in an emergency situation [6], as well as outcomes [7], and has become an important part of many trauma systems.

Finally, as trauma systems have evolved, so has the understanding that the focus must expand from the immediate care of the injured patient to include prevention, education, and long-term recovery [2]. The National Research Council published a document entitled "Injury in America: A Continuing Health Care Problem" in 1985 [8]. This report outlined the progress to date on the development of trauma systems, and, while recognizing the importance of the trauma systems

present at the time, the overall progress toward organization was felt to be limited. Further, the importance of research on epidemiology and injury prevention was again stressed in this document, coinciding with a decision to identify the Centers for Disease Control as the coordinating body for American injury research.

Today, both the American College of Surgeons Committee on Trauma and the American College of Emergency Physicians work with a goal of improving the care of the injured patient [9]. The foundations laid have contributed to the ongoing development of trauma systems and, though the process continues to be in evolution, have educated the involved parties on the importance of such systems.

3.3 Components of a Trauma System

3.3.1 Prehospital Care

Efficient and effective identification, management, and transportation of patients from the scene of injury to specialized trauma centers are essential components of any trauma system. For those sustaining injury, prehospital personnel will be the first point of contact with the trauma system, and these personnel, along with the system in which they work, can have a direct impact on the patient's outcome. A comprehensive trauma system requires easy access to the system in the prehospital setting. Further, both the training of the prehospital personnel and the mechanisms in place to safely and expeditiously transport patients are vital.

Trained Emergency Medical personnel deliver the majority of prehospital care. Providers are typically Emergency Medical Technicians (EMTs), trained and certified for varying degrees including basic and advanced life support [9]. The job of these EMTs extends beyond the clinical patient care provided to include important roles in triage and prioritization, as well as education and safety. Triage in the prehospital setting can be a complex process, and includes adequately determining the appropriate facility to which to transport a given patient to, as well as determining which patients to prioritize when faced with a multiple casualty situation. EMTs work within a system that requires coordinated transportation systems, as well as access to remote backup from experienced EMTs and physician medical directors [9]. In extreme circumstances, it may even be necessary for trained medical personnel, including physicians, to travel to the prehospital setting to assist with triage or medical care of patients who cannot be evacuated, and an effective prehospital system will have a mode to facilitate this process.

In the presence of highly trained EMTs, the question arises as to whether or not time should be spent stabilizing the patient in the field, or if it is better to "scoop and run" to the nearest hospital or trauma center. Despite the clinical skills of many EMTs, procedures and interventions beyond the level of basic life support in urban centers have not been shown to improve outcomes, and in fact may worsen outcomes compared to patients who are simply removed from the scene and rapidly transported to more definitive care [10, 11]. A similar strategy of minimal

intervention applies to prehospital fluid resuscitation, with evidence supporting restriction of fluid administration prior to hospital arrival [12]. Delays in transport to a trauma center, even when patients are transported quickly to hospital, appear to be associated with an increased mortality [13].

Much has been written on the most efficient way to transport the injured patient. The most common modes discussed include ground transportation, helicopter, and fixed wing aircraft. Though helicopter transport was considered by many to be ideal, the importance of location is paramount in the discussion of the ideal mode of transportation, as are local factors including weather and traffic. Further, identification of the severely injured patient most likely to benefit from helicopter transport is essential [14, 15]. Heterogeneity in the literature surrounding the impact of helicopter transport on the outcomes for trauma patients makes definitive conclusions difficult. A recent Cochrane review of this topic concluded that an accurate composite estimate of the benefits of helicopter emergency medical services could not be made based on the available evidence, and that further research is required in this area [16]. What appears clear from the literature is that the most rapid form of transport is likely the best [9]. Therefore, for patients in urban areas at the time of injury, there may be little benefit to air transportation over traditional ground transportation [15]. Additionally, in this setting, there may be an increased risk associated with the risk of crash during air transportation. For patients in rural settings at the time of trauma, this risk is outweighed by the benefit of expedited transport to specialized care that is typically some distance away.

3.3.2 Hospital Care

Of all the components of a trauma system, the hospital care of the injured patient is the most discussed, and therefore the most established. As previously mentioned, the initial foundations of trauma systems focused on the in-hospital care of the injured patient, from the initial resuscitation to the operative management to the post-injury convalescence and prevention of secondary insult. The importance of a coordinated effort in response to the arrival of a trauma patient cannot be understated, and will be discussed further below.

To better delineate a given hospital's capabilities to manage the acute trauma patient, the concept of trauma center verification was introduced. This process involves evaluating a given center in five key areas: institution commitment to trauma care; injury volume and acuity; facility layout, dedicated material, and human resources; operation of the clinical trauma team; and the trauma performance improvement program [17]. Verification of these components and designation of a trauma center level are performed in many places by the American College of Surgeons, though it is important to recognize that this task may fall to other bodies as well. Trauma centers are designated from level I to level IV based on available resources and involvement in trauma systems. Level I trauma centers

are leaders in the trauma field, and are the specialists in trauma care. Level IV trauma centers are typically found in small rural areas, and focus only on initial stabilization of the patient prior to transfer to a larger facility for definitive management. The American College of Surgeons recently recommended that all level I trauma centers admit at least 1,200 patients per year, with at least 240 of these being severely injured, while others suggest a threshold of 915 patients, irrespective of injury severity [18]. Though the exact number of patients required appears to remain unknown, it is clear that level I trauma centers should be high-volume centers to maximize patient outcomes.

Triage, though traditionally thought of in the prehospital setting, also has an important role to play in in-hospital care. Some patients will be initially triaged to a hospital without the expertise or resources required for their care, while others will develop complications requiring more specialized care. In such circumstances, a rapid method for identification and transfer of such patients to an appropriate center must exist. The risks of patient transport should be balanced against the need for more specialized care [19, 20]. Further, even within a specialized trauma center, multiple patients may require care with limited resources. In such circumstances, physicians must decide how best to share these limited resources for the best possible care of all patients.

3.3.3 Rehabilitation

In recent years, more recognition is being given to the importance of post-injury rehabilitation. The majority of trauma patients are young, previously healthy, productive members of society. As such, the importance of rehabilitation to the previous level of functioning is paramount.

The process of rehabilitation includes both physical and psychological components, and should begin as early as possible in the patient's injury course [21]. A recent retrospective review by Clark and colleagues compared trauma and burn intensive care unit patients before and after implementation of an early mobility program [22]. Early mobilization was associated with a decrease in pulmonary and vascular complications without an increase in adverse events. In recovery from brain injury, active high-intensity rehabilitation programs have been shown to lead to improved functional outcomes particularly in those with injury due to trauma [23]. With admission to acute inpatient rehabilitation, the majority of patients with even severe traumatic brain injury will be able to achieve independent ambulation [24], an outcome of significant importance post-injury. The importance of psychosocial support must also be recognized post-injury. Strategies shown to be effective to assist in psychosocial rehabilitation and coping with post-injury include inpatient counseling, acute rehabilitation, and telephone-based community counseling [25–27]. Such strategies should be in place for a successful trauma system. Further, up to 32 % of patients may develop posttraumatic stress disorder after trauma, and early identification and psychological intervention should be considered for successful prevention and recovery [28, 29].

3.3.4 Injury Prevention, Education, and Research

It is estimated that over 50 % of deaths due to trauma are preventable in the preinjury phase [30], and as such, the importance of strategies to prevent injury in the first place cannot be overestimated. In fact, prevention may be considered the most important part of any trauma system, though it is often overlooked in favor of the management of the injured patient. A recent policy review published by Kone and colleagues highlighted some of the Centers for Disease Control and Prevention's injury prevention success stories from the last decade [31]. These include the impact of laws for maximum blood alcohol concentration while operating a motorized vehicle, the use of child restraints, and programs aimed at the prevention of shaken baby syndrome. This review also highlighted the ongoing need for not only research, but also for outcome evaluation and knowledge translation. On the twentieth anniversary of the establishment of the National Center for Injury Prevention and Control of the Centers for Disease Control and Prevention, Greenspan and colleagues published an additional review of the Center's injury prevention work [32]. The Injury Center focus lies in four areas: Motor vehicle-related injury, traumatic brain injury, violence against children and youth, and prescription drug overdose. Despite these identified foci, however, the Injury Center attempts to apply the public health model to any injury pattern to identify prevention strategies and assist in the implementation of such strategies [32].

One important component of both research and quality improvement is the trauma database or registry. Many individual institutions maintain databases of prospectively collected demographic, injury, management, and outcome data on all admitted patients during the acute phase after injury [33, 34]. State-wide registries, with both mandatory and voluntary reporting, also exist [33]. The National Trauma Databank is maintained by the American College of Surgeons, and contains data voluntarily contributed by level I and II trauma centers throughout the country [35]. Trauma registries can be linked to population-level administrative databases to further improve their inclusiveness [36]. Trauma registries have numerous applications, including quality improvement, evaluation of clinical interventions, identifying areas for prevention, and assessment of both pre and posthospital care [33]. Further, despite the limitations of database-driven research, these registries provide a rich dataset for conducting retrospective research, and for identifying areas for prospective research.

3.3.5 Quality Improvement

The ongoing assessment of the structure and function of a trauma system is imperative to its success. Although quality improvement initiatives should exist at all levels of a trauma system, perhaps the most recognized is at the level of the trauma center itself. Quality improvement initiated at the trauma center can reach to all levels of the system and intervene when required. Bailey and colleagues

outline the quality indicators for trauma center performance in their 2012 review [17]. The first is phases of care, including the prehospital, hospital, posthospital, and secondary prevention phases. Second is the structure, including triage, information sharing, rehabilitation referral, and prevention such as alcohol screening. Third is the process, including response times of EMS, wait times in the ED and hospital, and alcohol recidivism. Fourth, and finally, is outcome, including not only mortality, but also admission to long-term care and the incidence of recurrent injury. It is important to recognize that this is just one scheme through which to approach quality improvement, as there is a paucity of evidence to support any particular scheme as it relates to outcomes. Nonetheless, a scheme should remain in place to allow ongoing improvement in any trauma system.

At the level of an individual hospital, even a well-established level I trauma center will have preventable or potentially preventable mortalities and morbidities [30, 37]. A system must therefore be in place to identify and learn from these cases to aid in future prevention [37]. This typically occurs in the form of a regularly scheduled morbidity and mortality conference, designed to provide a forum for open discussion and review of complicated patient encounters [38, 39]. Beyond the individual hospital level, an informative analysis highlighting ongoing quality improvement at the system level was published by Cryer and colleagues in 2010 [40]. Their analysis focused on two train mass-casualty incidents in Los Angeles. After the first crash in 2005, a problem with triage to trauma centers was identified. The majority of patients were triaged to community hospitals as opposed to the trauma centers, and this was felt to have been related to suboptimal patient outcomes. As such, a task force was convened to address the system-wide issues, and to develop a new disaster policy in Los Angeles County. With this new policy in place, a second train crash in 2008 was handled with greater ease, and the vast majority of patients were taken directly to a trauma center. On an even bigger scale, the Trauma Quality Improvement Program was recently created by the American College of Surgeons [17, 41]. This program is the first of its kind, designed to provide a risk-adjusted outcome assessment for participating institutions, and a benchmark to compare to other similar institutions [17, 41]. Although in its infancy, programs such as this can be expected to contribute to the ongoing quality improvement of trauma centers and systems.

3.4 The Impact of Trauma Systems

The development of trauma systems has impacted favorably on patient outcomes. Although it is difficult to measure the improvements made in injury prevention, it is somewhat easier to identify the metric associated with system-wide change. For example, it has been shown repeatedly that the American College of Surgeons Committee on Trauma verification process has led to improved outcomes. The reasons for this are certainly multifactorial, but the role that the system plays in

this improvement must be recognized. As suggested by Bailey and colleagues in their review of trauma systems, the commitment of a facility to the resources for trauma care, as well as the synergy spanning from the highest levels of leadership to the staff, play an important role [17].

Shackford and colleagues were among the first to assess the impact of trauma systems on outcome, and found that, compared to an index population, those triaged to trauma centers after both blunt and penetrating trauma had survival rates much higher than predicted [42]. The authors attributed this improved survival to the integration of prehospital and hospital care, and to rapid surgical intervention. In 1995, Demetriades and colleagues reported on the impact of a dedicated trauma program after implementation at the Los Angeles County-University of Southern California Medical Center [43]. This before–after study demonstrated a 43 % reduction in mortality after penetrating trauma, and a 33 % reduction after blunt trauma, supporting continued investment in the development of dedicated trauma programs.

More recently, Durham and colleagues assessed the impact of a mature trauma system in the state of Florida in 2006 [44]. Results from this study demonstrated an 18 % reduction in the risk of death associated with appropriate triage to a trauma center.

Similarly, the National Study on the Cost and outcomes of Trauma demonstrated a 25 % lower risk of death for those cared for in a level I trauma center [45]. Further, data from this same study were used to demonstrate management in a level I trauma center to be cost-effective based on quality adjusted life years gained, particularly for more severely injured and younger patients [46]. In an analysis of the Glue Grant Trauma Database, Nirula and colleagues demonstrated that patients who were initially triaged to a non-trauma hospital had a 3.8 times higher odds of death than those triaged to a trauma center [13]. The impact of trauma center verification has also been shown for centers that have not achieved level I status. Piontek and colleagues published a before–after study looking at the impact of achieving level II status in a community hospital, and demonstrated a reduction in mortality and cost as well as a reduction in length of hospital stay [47]. Beyond verification, trauma system processes also appear to have a beneficial impact. The importance of a dedicated trauma inpatient service to oversee the complexities of multidisciplinary patient care was highlighted by Davis and colleagues [48]. This study demonstrated that, despite an increase in clinical volume, system efficiency increased significantly with the introduction of a dedicated trauma team. Ryb and colleagues recently assessed the impact of a delay in activation of the in-hospital trauma team for patients meeting activation criteria, and found this delay to be associated with increased morbidity, including length of hospital stay and associated need for rehabilitation after discharge [49].

3.5 The Current State of US Trauma Systems

By 2011, 90 % of the states in America had a state-wide trauma system [17]. Although systems vary widely, the adoption of recommendations for creating a framework for the care of the community and of the injured patient is encouraging. Experts in the field value trauma systems, including leadership, evaluation, research, and formalized operations and procedures [50]. Less encouraging is the fact that, of these state trauma systems, only 60 % are funded at present [17]. A lack of funding for a trauma system suggests questionable sustainability, and may lead to a lapse in the quality of care provided within that system. As such, funding needs to be aggressively pursued to maintain quality trauma care.

3.6 Conclusions

Trauma systems have an extremely important role to play in a community, and the development of such systems continues to evolve. A controlled and integrated response to trauma that is subject to critical review and quality improvement initiatives improves outcomes for the community and its victims of trauma. Continued work should focus on the adequate funding of such systems, and ongoing assessment of emerging strategies for prevention, acute management, and rehabilitation of the trauma patient.

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