Original Article

Essential processes of successful trauma systems: template for analysis of trauma systems

James S. Gregory[1], Charles Walker[2], Katelyn Young[3], Anna Ralchenko[4]

[1]Surgical Institute, Department of Trauma Surgery Geisinger Medical Center, Geisinger Commonwealth School of Medicine, Danville, PA, USA; [2]Department of General Surgery, Residency Geisinger Medical Center, Danville PA, USA; [3]Department of General Surgery Trauma & Emergency General Surgery Research, Geisinger Medical Center, Danville, Pennsylvania, USA; [4]Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA

Contributions: (I) Conception and design: JS Gregory; (II) Administrative support: None; (III) Provision of study material: K Young; (IV) Collection and assembly of data: K Young; (V) Data analysis and interpretation: C Walker, A Ralchenko; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: James S. Gregory, MD, FACS. ACS/Trauma Surgeon, Associate Professor of Surgery, Geisinger Medical Center, Trauma/Acute Care Surgery MC 21-68, 100 North Academy Rd Danville, PA, USA. Email: jgregory1@geisinger.edu.

Background: Several papers have attempted to define one unified best trauma system. Our working hypothesis was that analysis of large systems many of which have similar elements was likely to produce inconclusive results, if the goal was to identify an ideal or model trauma system. Our premise was that any system with the similar processes would likely yield similar outcomes. We reviewed the literature with an eye towards identifying the common processes present within successful trauma systems.

Methods: A systematic literature search was performed using the United States National Library of Medicine's PubMed database in October 2017. 8,459 articles were screened and full-text original research studies were included if they reported trauma patient outcomes in association with the implementation of trauma training or trauma system infrastructure. Articles meeting these criteria included case-control and cohort studies, which incorporated prospective and retrospective study designs. There were 51 articles that met our criterion for inclusion.

Results: Twenty-seven focused on different elements of trauma systems and 24 concentrated on training both individual and team. Nine processes were identified with significant interrelatedness between them.

Conclusions: Previous papers were seen to confuse outcomes of these processes with the effect of the trauma system. We suggest that further research be careful to not mix system analysis with process analysis and be cognizant that components of processes. We suggest that trauma systems be analyzed based on the effect of "Right Care to the Right Place at the Right time".

Keywords: Trauma; systems; processes; components

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Introduction

Organized care of patients with traumatic injuries has advanced dramatically since the inception of the first trauma programs in Illinois, United States of America and Japan in the mid-1960s (1,2). This organized care has largely focused on establishing trauma centers that are now recognized worldwide to produce superior outcomes in patient care (3). Trauma centers now exist in all 50 of the United States and in many other countries throughout the world, each with regional adaptations and variations to suit particular socio-geographic needs. Trauma centers have been the core of trauma systems however defining the ideal or model trauma system has been difficult. There have been numerous papers published on various components of trauma systems

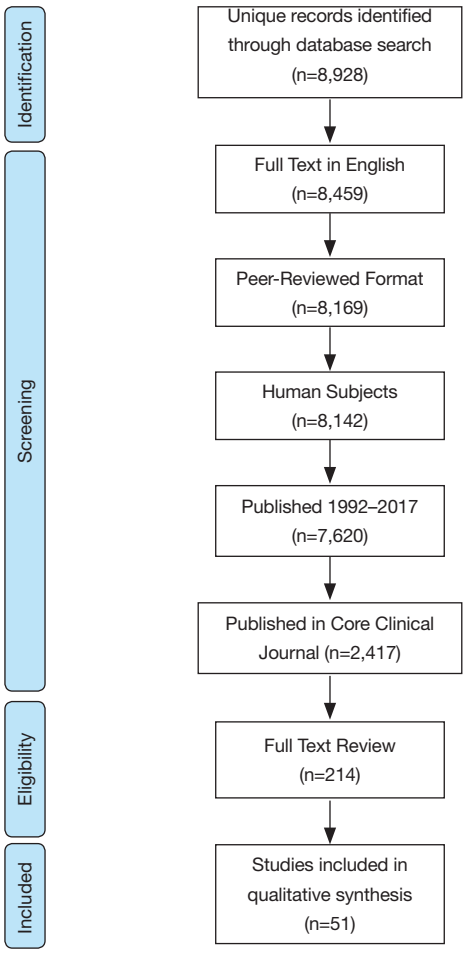

Figure 1 Flow chart of study selection.

such as prehospital care, hospital care transport types and Trauma center designation. Several papers have been published analyzing the systems themselves. Each looking for the "ideal" trauma system which hopefully would then lead to one unified best trauma system. Unfortunately, none of these publications has been able to achieve this goal, often leading to conflicting conclusions on the value of various trauma system elements. The reader is referred to the wildly divergent opinions on helicopter transport as an example (4,5). The recent meta-analysis of trauma systems worldwide by Moore, which was published while we were actively pursuing research on our paper, also failed to identify the ideal system (6). Our working hypothesis was that analysis of large systems many of which have similar elements was likely to produce inconclusive results, if the goal was to identify an ideal or model trauma system. Our premise was that any system with the proper elements or processes would likely yield similar outcomes. We reviewed the literature with an eye towards identifying the common elements or processes present within successful trauma systems. The design of our review was not to establish primacy but rather to define the relative frequency of processes in the trauma literature as a template for a Trauma System. The literature to date has never considered this as a unifying foundation for research into systems design. As such each article tried to imply it was talking about a System or assumed a system when really, they were discussing processes.

Methods

Literature search

A systematic literature search was performed using the United States National Library of Medicine's PubMed database in October 2017. Works containing at least one of the following terms in their title or abstract were identified: trauma care, trauma system, trauma team, trauma training, trauma team training, Advanced Trauma Life Support (or ATLS®), International Trauma Life Support (or ITLS®), Prehospital Trauma Life Support (or PHTLS®), Advanced Trauma Care for Nurses (or ATCN®), trauma registry, trauma database, injury registry (Supplementary).

Study selection

Details regarding study selection are reported in *Figure 1*. Exclusion criteria were (I) publications not available in English; (II) non-peer-reviewed work; (III) non-human experimental subjects; (IV) studies published prior to January 1, 1992; and (V) non-clinical research. The exclusion criterion regarding publication year was selected to focus this investigation on the modern era of trauma care.

Ultimately, full-text original research studies were included if they reported trauma patient outcomes in association with the implementation of trauma training or trauma system infrastructure. Articles meeting these criteria included case-control and cohort studies, which incorporated prospective and retrospective study designs.

Data collection and quality assessment

Data on the following aspects were extracted from included studies: year of publication, study design (randomized

control trial, prospective observational, retrospective), study population (single center or multi-center), sample size, statistical significance of reported outcomes, and subjective assessment of potential bias or confounds.

More specifically, studies assessing the impact of trauma system infrastructure were reviewed for the type of system (pre-hospital, hospital-based or combination), the extent of the system (institutional, state/regional or national), the rationale of the system (mandated or voluntary), the state- or American College of Surgeons-designated level of the system (if applicable), and the reported elements composing the system. Studies investigating the effect of trauma training were similarly reviewed for the training program, the focus of training (pre-hospital or hospital-based), the type of training (individual/skills-based or team), the rationale of the training (mandated or voluntary) and the format of the training.

Results

There were 51 articles that met our initial criterion for inclusion, however the article by Nirula only looked at trauma centers and assumed they represented a trauma system so was excluded on detailed review (7). This left 27 focused on different elements of trauma systems and 25 concentrated on training both individual and team.

Review of 27 domestic and international research articles on the impact of trauma systems on survival and functional status post injury uncovered several processes common to these systems (*Table 1*). The most cited reason for a favorable outcome related to timely transport and transfer of critically ill patients to trauma centers, was mentioned in 11 papers (8-18). Timely transport was highly important and included the availability of EMS services by ground or air. System inclusiveness and regionalization was felt to be an important process in nine papers (10,12,13,19-24). Pre-Hospital care was mentioned six times (8,14,21,25-27), and Education that included ATLS® and ongoing refresher courses five times (8,23,28-30). Noted four times were system maturity, (14,19,25,31), and TEAM/CRM training (8,19,29,32). Mentioned 3 times each were: Communication either within the hospital, between EMS and hospital personnel, or between hospital, but largely prehospital (8,15,21), Hospital care (15,26,28), and Formal verification (8,22,32). Interestingly, one of the authors found that even voluntary designation of a trauma center improved patient outcomes (32) (*Table 1*).

There were 24 articles reviewed regarding trauma training and care for the trauma patient as a team, these all broadly would fit into education (33-56). Sub-analysis revealed general physician education using ATLS® or ATLS® like courses was noted in seven articles (33,34,47,48,50,52-56), Results as measured by mortality were not consistent with the one Cochrane analysis showing no difference in mortality with ATLS® training (50). Six team training: two RTTDC® (35,36), four other facility based individualized team training including simulation (37-39,56). Sixteen specifically noted System Inclusiveness (34,40-46,48-55), 13 regionalization (33-36,48-56), 7 pre-hospital care (40-46). Transport and communications are part of ATLS®, PTHLS®, ALS®,BLS® and RTTDC® so they also fit these categories 21 times. ATLS® and RTTDC® both allude to some sort of verification but the articles did not stress that point (*Table 2*).

There were eleven articles which dealt exclusively with the Advance Trauma Life Support (ATLS®) program and its impact on patient care (33,34,48-56). These articles dealt primarily with care of the trauma patients once they arrived at the hospital, particularly the initial assessment. Two articles reported a decrease in mortality and improved patient outcomes (53,55), while two other articles reported improved outcomes in the first 24 hours, but no improvement in overall mortality (48,49). One article reported an improvement in cognitive performance and a positive impact within the trauma team (54). Three articles referred to alternative standardized training programs for the care of trauma patients, and these articles showed improved patient outcomes, including improved mortality (39,44,47). Three of the eleven articles were systemic reviews and they showed no improvement in mortality, but one of them did comment on improved knowledge, clinical skills, and decision making with ATLS® (34,50,51). One article compared physicians with varying levels of ATLS® training which showed improved patient assessment by physicians with ATLS® exposure (56). This was contradicted by the article from Drimousis, which showed worse outcomes in trauma patients treated by ATLS® certified physicians, but this was done in non-trauma hospitals which lacked some resources typically seen in trauma centers (i.e., CT scanners) and the providing physician was not always a surgeon (52). The article by Vestrup showed no improvements in patient outcomes and had more missed injuries post ATLS® (33).

There were 7 articles that were reviewed that involved prehospital trauma life support (PHTLS) and other pre-hospital support programs (40-46). The outcomes

Table 1 Analysis of trauma systems papers

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
McDermott 2007	(I) Noted greater use of helicopter crews at rural crash scenes with direct admission to MTS, and the frequent bypassing by ambulances of rural and metropolitan hospitals post trauma system utilization. (II) Triage criteria: major trauma patients must be taken to trauma center (MTS) IF transport time <30 minutes; otherwise patient is triaged to nearest hospital and transferred after stabilization. (III) Rotary and wing fleets have been upgraded. State trauma registry has been established to monitor, evaluate, and report on progress	ATLS trained paramedics	Increased number of intubations post ATLS-trained paramedic implementation	–	Trauma team: ED consultant, surgical registrar, anesthetic registrar; consultant general surgeon must be available within 15 minutes	Directors of trauma services at MTS are responsible for improvement of management through coordination, audit, and feedback	–	Early communication between crash scene and receiving facility	–
Hartl 2005	Direct transport to level I or II trauma center resulted in decreased mortality as compared to indirect transport. Ground transport (i.e., ambulance or private vehicle) had shorter transport time than air transport (i.e., helicopter/ emergency airlift)	–	–	–	–	–	–	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
McKee 2015	Noted that once an all-inclusive trauma system was implemented, patients were sent to the most appropriate (as opposed to the closest) hospitals for treatment in the shortest amount of time	–	–	–	–	–	–	–	Noted that once an all-inclusive trauma system was implemented, patients were sent to the most appropriate (as opposed to the closest) hospitals for treatment in the shortest amount of time
Mullins 1994	Emphasized timely transfer of patients to trauma center	–	–	–	–	–	–	–	–
Hulka 1997	Emphasized timely transfer of patients to trauma center	–	–	–	–	–	–	–	–
Twijnstra 2010	Noted a nationwide helicopter program	–	–	–	–	–	–	–	Stressed impact of inclusive trauma system on patient survival
He 2016	–	–	–	–	–	–	Creation of a dedicated TICU, staffed by surgical critical care faculties at NOTS L1TC, allowed the most complex patients to be cared for by a dedicated trauma critical care team	–	Emphasized importance of inclusive, regionalized trauma system

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Barquist 2001	Patient survival improved with appropriate and timely transfer	–	–	–	–	–	–	–	Noted the importance of an inclusive trauma system
Maggio 2009	–	–	–	–	Surgical/ trauma ICU was managed by a team of dedicated surgical intensivists	–	New trauma protocols were developed for severely injured patients in the trauma bay, and a massive transfusion protocol was instituted. In the surgical ICU, ventilator and central-line bundles were initiated	–	Emphasized importance of interfacility transfer to get patient to the right place in the right time: the transfer center maintains 24 hours per day coverage and an on-call attending trauma surgeon handles all trauma-related requests. In consultation with the nursing supervisor, the trauma surgeon makes all decision regarding acceptance of the transfer
Tallon 2005	improved timely delivery of major trauma patients to definitive care	–	Noted EMS component	–	–	–	system maturity must occur over a 10-year period for a significant (8%) decrease in mortality to occur independent of secular trends in other injury prevention initiatives	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Utter 2006	–	–	early care of severely injured patients transferred from referring hospitals is improved in inclusive systems	–	–	–	–	Coordination and cooperation between rural and urban hospitals is a vital aspect of inclusive systems	Coordination and cooperation between rural and urban hospitals is a vital aspect of inclusive systems. Care of severely injured patients transferred from referring hospitals is improved in inclusive systems
Murphy 2015	–	Blunt trauma related splenectomies decreased with inception of pediatric trauma center; credited to non-op management of this injury. Value of education emphasized	–	–	–	–	–	–	–
Liberman 2005	–	–	–	–	Stressed importance of trauma team. Noted that EM residents and attendings produce results similar to their surgery counterparts	–	–	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Gabbe 2012	–	–	–	–	–	Improved outcomes in level I trauma centers hinge on greater collective experience with trauma cases	–	–	Access to rehab
Gerndt 1995	Pre-hospital trauma classification system aids in triaging patients to appropriate level of care	–	–	Presence of board certified attending general surgeon improves patient outcomes	–	–	–	Stressed importance of communication between trauma team members; noted that radio system in particular	–
Simons 2002	–	–	–	–	A trauma team was defined as a surgeon-led team including attending staff, residents, trauma trained nurses, and allied health staff responding to uniformly defined criteria for trauma team activations within a defined period of time. The trauma director may or may not be the trauma team leader	performance gains are realized during preparation for accreditation/ verification of the trauma program	–	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Olson 2001	–	ATLS training endorsed to address that the majority of preventable deaths occurred in the ED phase of care as a result of a failure to recognize and treat problems affecting airway, breathing, and circulation	–	CXR, HCT in ED, lateral cervical spine X-ray, one MD in trauma bay on arrival, intubated in ED before discharge, Initial and final AVPU/GCS in ED, initial and final pupil examination in ED, Arterial blood gas/ O_2 saturation in ED, Initial and final systolic blood pressure in ED, Pelvic X-ray in ED	–	–	–	–	–
Groven 2011	–	Emphasized importance of education: compulsory ATLS, video coaching, and extensive trauma surgical training	–	–	Emphasized importance of team interaction and communication	–	–	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Leung 2010	–	Emphasized importance of education: these included symposiums and seminars on the current management of severe trauma, covering topics such as damage control surgery, transfusion strategies, and intensive care	–	–	–	–	–	–	• Authority to designate, certify, identify, or categorize trauma centers • Existence of a formal process to designate or otherwise identify trauma centers • Use of ACS standards to designate/identify trauma centers • Inclusion of on site verification during the designation/ identification process and use of out of area supervisors • Authority to limit the number of trauma centers based on the need for trauma services • Existence of prehospital triage protocols for trauma patients • Existence of a process for monitoring trauma center performance • Statewide coverage of trauma system

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Brink 2002	Stressed importance of transferring patients to the right location	–	–	–	–	–	–	–	–
Porter 2014	Emphasized importance of a mandatory centralized (statewide) call center to transferring patients to the appropriate destination in a timely manner	–	–	–	–	–	–	–	–
Dutton 2009	–	–	–	–	–	–	System maturity leads to increased survival	–	–
Marson 2000	–	–	Stress importance of EMS and pre-hospital care on improvement in survival	–	–	–	–	–	–
Gabbe 2011	–	–	Noted that survival likely to be influenced by advanced prehospital care, early resuscitation, expert supportive care in ICU, and early operation	Noted that survival likely to be influenced by advanced prehospital care, early resuscitation, expert supportive care in ICU, and early operation	–	–	–	–	–

Table 1 (*continued*)

Table 1 (*continued*)

System component	Transport/right place	Education fundamentals	Pre-hospital care	Hospital care	Team CRM	Formal verification	System maturity	Communication	Inclusive regionalized system
Esposito 2003	–	–	Emphasized appreciable reductions in inappropriate care in all phases of care, particularly the ED and prehospital phases post trauma system implementation	–	–	–	–	–	–
Kelly 2014	–	–	–	–	–	–	–	–	Regionalization of trauma center resulted in improved TBI patient outcomes; regionalization is based on effective triage and transfer of patients to appropriate level of care

Gives an analysis of each of the Trauma Systems papers and shows how each of the identified processes is delineated.

of these articles again showed mixed results regarding patient outcomes, with five of these articles reporting improvements in mortality (40-42). No improvement in mortality was seen in the article by Stiell, but this involved BLS and ALS and not specific trauma training (43). The remaining article by Bowman involved pre-hospital training for the military, specifically for pre-hospital pain medication administration, which there was increased compliance after the training (44). These articles not only highlight the importance of pre-hospital care but also the importance of the pre-hospital staff as an integral part of the trauma team and the need for standardized training for these providers.

The composition of the trauma team varied not only from hospital to hospital, but also from state to state and country to country (38). This fact helps reinforce the need for standardized training for the various types of providers. It also highlights the need for these trauma teams to be comfortable and confident when working with each other. Of the articles reviewed two of them involved training for rural trauma teams and in both instances, there was a decrease in transfer time to a trauma center (35,36). Three articles dealt exclusively with training teams and working together in simulated scenarios and in both articles better communication and improved patient care was reported (37,38,56).

The Frequency a at which the different systems component processes were cited in the literature both for trauma systems papers and trauma training papers is summarized in *Table 3*. Meta-analysis could not be performed on the individual processes because the definitions varied form paper to paper and the data was poorly reported.

Discussion

We reasoned that identifying the common Trauma System/Care processes could help developed a template for trauma system design. It was our contention that discrepancies found within the literature may be related to regional modifications of these common elements as well as the erroneous usage of Process outcomes to assess System effectiveness. Moore's paper listed all the processes found in our analysis but did not reach their research goal of describing the "ideal" trauma system (57). Ironically their data did support, that well-developed systems with common elements or better termed processes all had similar effects. This is to be expected, and as we believe resulted from a misrepresentation of what a system is. Processes have outcomes while Systems are composed of processes that result in an effect (58,59). Therefore if we compare "outcomes" of similar processes in various Systems it should not be surprising to find no difference or diametrically opposed results. This can be illustrated by the helicopter transport debate: Efficiently transporting a patient to a receiving hospital is dependent on time versus severity of the injury. When evaluating types of patient transport, one must consider the environment (rural/mountainous/urban/weather), distance and travel times, and severity of injury. Often the question asked is: "Is helicopter transport important in a trauma system;" trauma center mortality by transport mode is then used a surrogate measurement for transport outcome. It is not surprising that the results show urban systems with an increase in mortality and rural mountainous regions may show an improvement (4,5). The question asked tried to use a System effect (mortality) to measure a process outcome. A better system question would be: Is Helicopter transport necessary for a particular system based on types of expected injuries and ability of ground transport to deliver these patients to the hospital in an acceptable time frame for the best outcome? In our opinion, the use of process outcomes to measure System effectiveness is at the crux of the confusion in the literature. The overarching questions facing Trauma System analysis are: What is an Ideal or Model Trauma System and What should be its effect? The components (processes) of the "Ideal" System would each improve the effectiveness.

Our study identified several common processes in trauma care delivery as measured by mortality and morbidity outcomes (*Tables 1* and *2*) Using this observational approach, the more common the process is the more it was deemed core to a trauma system (*Table 3*). There was clear interrelatedness to several of the processes. This may account for some of diametrically opposed statistically significant literature. When analyzing a system thru its individual processes we are dealing with a domino effect. A failure of one process may doom an entire system or an extremely strong process, such as a highly efficient trauma hospital, can overshadow weakness in other areas such as prehospital care. In addition, some components may be inappropriately invalidated by failure to have supporting essential processes. Such as the disparity in the results of ATLS® like courses in outcomes. At least two studies that showed no improvement or worsening in care each study was hampered by no control over EMS or in hospital care (50,52).

System inclusiveness is a somewhat nebulous concept

Table 2 Analysis of trauma training/team papers

Trauma training papers	Education fundamentals	Pre-hospital care	Team/CRM
Adam 1994	Implemented ATLS in Trinidad and Tobago and showed a decrease in mortality after program was initiated. Recommended ensuring necessary equipment for pre- and in-hospital care is present	PHTLS initiated after need for further trauma care in Trinidad and Tobago	–
Ali 1993	Improved patient outcomes post ATLS as well as physical changes in the hospital/ trauma bay	–	–
Ali 1994	ATLS improved cognitive performance, increased frequency of life saving interventions, changed the physical environment of the ED	–	–
Drimousis 2011	Patients with worse outcomes when treated by ATLS certified physicians. Had limitations including being at non-trauma hospitals, had limited resources	–	–
Jayaraman 2014	–	Cochran review for controlled trials, showed no improvement between ALS and BLS	–
Jayaraman 2009	Cochrane review of controlled trials for ATLS training, showed no change in mortality, did show that education improved knowledge, immediate emergency response and treatment	–	–
Magnone 2016	–	–	Implementation of ATLS and the Trauma team showed decrease in 24-hour mortality, teams had at least 50% ATLS trained
VanOlden 2004	Pre and post ATLS training compared at level III hospital, improved outcomes in the first hour, but no improvement in overall mortality	–	–
Williams 1997	Showed that physicians with ATLS training had increased scores on criteria for assessing the patient	–	Use of mock scenarios to compare physicians with differing levels of ATLS training
Vestrrup 1988	Comparison pre and post ATLS showed no change in outcomes or mortality. Did show improvement airway management but more injuries were missed	–	–
Mohammad 2014	Systemic review on education impact of ATLS, showed improved knowledge, clinical skills, and decision making. Recommended ATLS be taught to all doctors involved in management of trauma patients	–	–

Table 2 (*continued*)

Table 2 (*continued*)

Trauma training papers	Education fundamentals	Pre-hospital care	Team/CRM
Dennis 2015	–	–	Use of Rural Trauma Team Development Course (RTTDC). Decreased transfer time with RTTDC training
Malekpour 2017	–	–	RTTDC training showed decrease transfer times and mortality
Capella 2010	–	–	Used TPOT to evaluate trauma teams. Used simulated cases with nurses, residents and attendings. Led to better communication and evaluation of patients
Hong 2017	–	–	Implemented standardized team training program in China. Created an ideal team based on workflow analysis and trained with group simulation
Siriratsivawong 2016	–	–	US Navy team training using didactics and simulation. Decreased resuscitation time, critical errors. Providers felt more confident Teams functioned better due to individuals being better educated and more confident
Arreola-Risa 2004	–	PHTLS showed a decrease in mortality when compared to BLS/ACLS training	–
Blomberg 2013	–	Reduction in prehospital mortality with the implementation of PHTLS	–
Johansson 2012	–	Study from Sweden which showed 30% relative reduction in mortality after PHTLS initiated, absolute risk reduction 0.5 per 100,000	–
Stiell 2008	–	Standardized training, compared BLS to ALS and found no difference in mortality	–
Bowman 2012	–	Standardized trauma training, outcome measurement was pre-hospital pain control which was improved post training	–

Table 2 (*continued*)

Table 2 (*continued*)

Trauma training papers	Education fundamentals	Pre-hospital care	Team/CRM
Ali 1997-May	–	Further decrease in mortality after implementation of PHTLS, may be a by-product of ATLS implementation in the hospitals	–
Ali 1997-June	–	Improved patients outcomes post PHTLS training. Better airway control, c-spine stabilization, hemorrhage control	–
Hondo 2013	Implementation of standardized trauma training in Japan (JATEC), showed decrease in mortality late into study. Advocates for continued education, simulation, training should be expanded across the country	–	–

Gives an analysis of each of the trauma training/team papers and shows how each of the identified processes is delineated. Given the nature of this part of the search, many of the processes in the systems papers were not even discussed and are eliminated from the table for ease of reading.

Table 3 Frequency of reported processes

Process	Transport	Education fundamentals	Pre hospital care	Hospital care	TEAM/CRM	Verification	System maturity	Communication	Inclusive/ regionalized
Systems papers	11	5	6	3	4	3	4	3	9
Training papers	0	10	9	0	7	0	0	0	0
Total	11	15	15	3	11	3	4	3	9

Combines the results of sub-analysis of articles on trauma systems and team/individual training. It summarizes the frequency at which each process was found to be discussed in the literature.

made murkier by the lack of a standardized definition. Several articles credited inclusiveness with improved patient outcomes, collectively describing it as the efficient and timely triage of trauma patients to appropriate sites of care. System inclusiveness requires intra and inter-system communication as in between providers, trauma centers of various level designations, non-trauma hospitals, pre-hospital care teams, etc.; education of trauma care providers; and a hierarchical relationship between area hospitals where injured patients are distributed according to their injury severity. Trauma system inclusiveness seems to occur as a system naturally matures. System maturity implies that patient outcomes improve the longer a trauma system exists. Although once again the concept is poorly defined, it suggests that the mere passage of time correlates to better results. Nevertheless, it is crucial to understand that this depends on conscious actions by the members of a system rather than temporality. More often the system was not evaluated but rather the outcomes at the trauma centers. Mature trauma centers recognize the policies, procedures, and resources that decrease mortality and improve patient care, and prune away those that do not.

Inclusiveness and could be facilitated by regionalization (60). Regionalization implies a trauma system set up to meet the needs of socio-geographic regions thru an organized and regulated process. Regionalization is often voluntary and can be affected by political considerations separate from those directed by patient needs. The states of Illinois and Pennsylvania in the United States have state "Trauma Systems", however, in each state the number of

trauma centers is not mandated nor is a region required to use the trauma centers in its geographic area. As noted in the workshop summary of the Institute of Medicine's Regionalizing of Emergency Care, "regionalization is not about centralization and it's not about designating certain facilities as the place to go for anything. It's about how to structure the utilization of resources in any one location, given that one area will be very different from the next. The aim… is to get the right resources to the right patient at the right time, which may not even involve moving the patient. It can also mean moving resources, personnel, or simply knowledge" (61). Prehospital care is any care a patient receives prior to admission to a trauma center. The details of this topic were poorly addressed but involved EMS and transport to trauma centers.

Verification was an interesting process to review. There are NO verification programs for trauma systems only for trauma centers. When discussing verification of trauma centers there is even more variability as no one verification program exists. In the example above of Pennsylvania and Illinois these states have state mandated verification programs that are distinct from the Trauma Verification Program of the American College of Surgeons®, while Australia and Japan have their own process. What can be said about these verification programs is that they try to analyze how trauma care processes interact to effect care. Therefore, a verification process may not be an essential component in and of itself but maybe seen to monitor whether a system has good and effective processes.

We were particularly interested in the impact of training and education either as an individual or team was a common core element. Observationally it seemed obvious that every process must have an educational component and we wondered if that may be one of the confounders in discerning differences in outcome. The articles on training varied on their opinions about whether standardized training provided any benefit to patient care and outcomes. This can potentially be explained by the inability to measure the effect of training when combined with variations in how the training is applied.

A unifying element of all medical systems was team cohesiveness and that may be achieved best by educational programs. Therefore, solid educational programs that support interdependence and communication within a system may be the single most important factor in developing a trauma system.

The laudable goal of the Meta- analysis performed by the international group headed by Lynne Moore was to help health care planners in allocating resources to Trauma Systems (6). We agree whole heartedly with their conclusion that: "Future research should …aim to… understand (the) interplay between the components of trauma systems" We propose that a Trauma System should be one that contains the common processes identified by the literature. The Effect of a Trauma System is to identify and treat injured patients in the most efficient way to obtain a favorable outcome for each patient. One may argue that this is an Objective and therefore not testable. That is correct. However, one can define individual processes that impact the effect and these can be measured. The sum of these processes results in the effect. The National Conference of State Legislators in the USA stated the "Effect" of Trauma systems this way: "The Right Patient, The Right Place, The Right Time." (62). Nowak in his article on Patient flow within a medical center also echoed this: "right care, right time, right place" (63). The paper by Brink drew conclusions that echo our findings and presents another summary of an "Ideal" Trauma system (see *Table 1*) (28). We hope that our paper will serve as a template for analyzing the effect of the group of processes interacting in a trauma system. We believe that trauma systems should all contain the same common processes but be tailored to the individual needs of the region served (55,64). A good example of this approach can be seen in the adaptation of ATLS® by TEAM Broken Earth® and the novel team training done in Hangzhou, China (38,65). A Google search using the phrase "trauma systems in the United States" only yields articles relating to trauma centers which are one of the processes of a system. Even in the United States of America, arguably the birth place of modern trauma care, there is no one trauma center verification program (66).

Weaknesses

Our study has several weaknesses. As with any descriptive study, there is always a potential for selection bias that can be introduced. This is compounded by selecting only papers written in English. Given the premise of our paper that the current literature had erroneously confused process outcomes with system effectiveness, there was often shared bias between articles reviewed especially when the same author had written several papers on different aspects of the trauma care delivery. We believe our paper does help shed light one of the difficulties of trauma system analysis; that being not confusing process outcome with effect.

Conclusions

The results of our study show that defining an ideal system should not be confused with analyzing the processed within a care delivery system. Individual processes should be analyzed with a view towards how they contribute to the effect of the system they support. A system's effect must be clearly defined. We suggest Nowak's definition of "Right Care to the Right Place at the Right time" as care of the injured patient starts once he/she is identified (63). Outcomes of each the processes that support a System would be judged based on how they supported this effect. This would mean for planners that they should concentrate on building systems with the core processes mentioned above. Resources could be allocated as needed in a step-wise fashion depending on where the needs of the current care delivery system were most acute. An underdeveloped country may wish to start with education while a more developed one may wish to tackle the political hurdle of mandated regionalization. We suggest that further research be careful to not mix system analysis with process analysis and be cognizant that components of processes (transport vehicles/care). Trauma systems and the processes that support them cannot be separated from the socio-geographic-culture in which they function.

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Footnote

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Supplementary

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(((((Trauma System[Title/Abstract]) OR Trauma Care[Title/Abstract])) OR (((Trauma Training[Title/Abstract]) OR Trauma Team[Title/Abstract]) OR Trauma Team Training[Title/Abstract])) OR (((((((ATLS®[Title/Abstract]) OR Advanced Trauma Life Support[Title/Abstract]) OR ITLS[Title/Abstract]) OR International Trauma Life Support[Title/Abstract]) OR PHTLS[Title/Abstract]) OR Prehospital Trauma Life Support[Title/Abstract]) OR ATCN[Title/Abstract]) OR Advanced Trauma Care for Nurses[Title/Abstract])) OR ((((Trauma Registry[Title/Abstract]) OR Trauma Database[Title/Abstract]) OR Injury Registry[Title/Abstract]) OR Injury Database[Title/Abstract])