Analysis of remote trauma transfers in South Central Texas with comparison with current US combat operations: Results of the RemTORN-I study

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BACKGROUND:	This study aimed to analyze demographic, epidemiologic, temporal, and outcome data from an integrated trauma registry of patients undergoing initial stabilization and transfer within a mature domestic trauma network; compare data with a companion subset from the Department of Defense Trauma Registry. Texas Trauma Service Area-P is composed of 25 counties, 15 rural Level IV trauma centers (no acute care surgery), and two Level I trauma centers.
METHODS:	This study has a retrospective cohort design. We hypothesize that Injury Severity Scores (ISSs), time intervals, and other clinical indicators would be complimentary to contemporary combat casualties. Inclusion criteria include age 18 years to 80 years, transferred from Level IV to Level I trauma center, or expired en route.
RESULTS:	A total of 543 subjects (84%) met the criteria and were analyzed. Averages and confidence intervals were as follows: age of 40 years (38–41 years), males at 81%, ISS of 10 (10–11), intensive care unit stay of 2 days (1–3 days), and hospital stay of 5 days (4–6 days). Mechanisms of injury were as follows: penetrating (15%), blunt weapon (19%), stabs (9%), burns (5%), and gunshots (5%). Eight percent received blood within the first 24 hours. Survival was at 98%. Time intervals (95% confidence interval) were as follows: prehospital at 1:43 (1:29–1:58), Level IV dwell time at 3:17 (3:06–3:28), interfacility transfer at 1:43 (1:36–1:49), and total at 6:39 (6:20–6:58). RemTORN cases were older, spent longer time en route to Level I, and had ISS similar to combat casualties. Rates of blood transfusion in the first 24 hours and survival were similar in order of magnitude.
CONCLUSION:	The RemTORN platform is operational. Demographic, epidemiologic, and temporal characteristics as observed will support clinical investigations of traumatic coagulopathy, shock, and potential interventions before Level I arrival. Results of such investigations will likely be applicable to the contemporary and future battlefield. (*J Trauma Acute Care Surg*. 2013;75: S164–S168. Copyright © 2013 by Lippincott Williams & Wilkins)
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KEY WORDS:	Wounds and injuries; prehospital care; coagulopathy of trauma; resuscitation; military medicine.

While the past decades have witnessed the establishment of regionalized systems of care, emergency medical services systems, and national standards, trauma remains a primary cause of death and disability.[1,2] While factors such as injury severity, time elapsed before definitive care, and mechanism of injury have been identified as contributing both individually and collectively with poorer clinical outcomes, what remains largely undefined are the specific details of the pathologic sequence that unfolds during the initial out-of-hospital time frame.[3,4]

The phenomenon of prolonged evacuation and its consequences are also familiar in the setting of armed conflict. The contemporary operational environment encountered by US and Coalition forces remains highly lethal, often remote and geospatially dispersed.[5,6] Advances in personal protective equipment, rudimentary first-responder care, forward resuscitative surgery, and intertheater evacuation have contributed substantially to improvements in both survival and functional recovery, but for these trends to continue, resources will require refocus toward the out-of-hospital, preoperative care environment (referred to in military circles as NATO Role I health support).[7]

Today, there remain two broad categories contributing to potentially survivable combat death: (1) underperformance of lifesaving interventions when required and (2) uncontrolled

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The conclusions as reported herein are those of the authors, and do not necessarily represent the Department of Defense or the US Army.
This study was conducted under a protocol reviewed and approved by the US Army Medical Research and Materiel Command Institutional Review Board and in accordance with the approved protocol.
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major hemorrhage coupled with delays in evacuation.[8–10] The former cause will require innovations in scope of practice, improved clinical competence, and appropriate medical direction mechanisms for tactical medical personnel. The latter will require a workable strategy for better preoperative hemorrhage control and a better intravascular fluid replacement compared with current crystalloids and colloids, neither of which are capable of mitigating acidosis, coagulopathy, or tissue oxygen debt.

In response to this emerging requirement, remote damage-control resuscitation was conceptualized as a strategy to delay or prevent the onset of tissue hypoxia and coagulopathy while undergoing prolonged tactical evacuation to surgical intervention.[4,11] It is unknown whether first responders and primary care practitioners, who compose the bulk of rural and otherwise remote emergency care workforce in both domestic and combat settings, can successfully perform remote damage-control resuscitation interventions traditionally performed by emergency physicians, trauma surgeons, and critical care nurses in trauma centers. In addition, the potential use of blood products or procoagulants by paramedical personnel in the out-of-hospital setting will likely face significant regulatory and operational challenges.[9]

In response to this formidable clinical challenge and with the recognition of the unique characteristics of the regional trauma system surrounding the San Antonio metropolitan area, the Remote Trauma Outcomes Research Network (RemTORN) project was initiated as a civil-military partnership by the US Army Medical Research and Materiel Command's Institute of Surgical Research and the Southwest Texas Regional Advisory Committee for Trauma (STRAC).[12] Currently, RemTORN partners include two American College of Surgeons/Texas Department of State Health Services–verified Level I trauma centers (San Antonio Military Medical Center and University Hospital System—San Antonio); four Texas Department of State Health Serviced–verified Level IV trauma centers, offering 24-hour daily emergency care but lacking in the consistent availability of emergent resuscitative surgical services and located within a radius extending 75 nautical miles to 150 nautical miles from San Antonio (Fort Duncan Regional Medical Center, Eagle Pass, Texas; Val Verde Regional Medical Center, Del Rio, Texas; Uvalde Memorial Hospital, Uvalde, Texas; and Dimmit County Medical Center, Carrizo Springs, Texas); more than 20 local emergency medical service agencies habitually providing initial scene response and transport to the these Level IV centers; and the predominant air medical transport provider for this region (San Antonio AirLIFE, Inc.). In addition to these clinical entities, STRAC was selected to provide community liaison, regional project management, and data management site services.

The objective of this study was to characterize injury patterns and severity and medical evacuation times in a large civilian trauma system interfacing with the Department of Defense's only Level I trauma center. An additional objective was to compare and contrast findings in this civilian trauma system with those encountered in combat to establish a model for military research related to prehospital data collection, monitoring, and resuscitation outside of the combat environment.

PATIENTS AND METHODS

Both the RemTORN I and the Tactical Study of Care Originating in the Prehospital Environment (TACSCOPE) studies were reviewed and approved by the Human Subjects Institutional Review Board of the US Army Medical Research and Materiel Command.

To initially validate the model, we used a retrospective cohort design. Demographic, epidemiologic, and time interval data were extracted from a comprehensive subset of the regional clinical registry integrating first-responders, intermediate resuscitation facilities, interfacility transport, and definitive treatment and outcome (Tables 1 and 2). Clinical record data from each respective phase of care were identified, integrated, and extracted using the Collector registry program (Digital Innovations, 2011). The final data set was deidentified before this analysis.

Inclusion criteria were (1) age of 18 years to 80 years; (2) accepted for trauma transfer by receiving trauma surgeon; (3) underwent interfacility transfer (ground or air); and (4) was admitted by the receiving trauma service or died en route. Exclusion criteria were (1) age more than 60 years with "fall from under 1 m" mechanism; (2) elapsed time of more than

TABLE 1. RemTORN I Clinical Data Points

Data	Initial Emergency Medical Services	RemTORN Network Facility	Interfacility Transfer	Trauma Center
Demographics	X	X	X	X
Treatment facility/unit identifier	X	X	X	X
Injury mechanism	X			
Elapsed time intervals	X	X	X	X
Revised Trauma Score (RTS)	X	X	X	X
Glasgow Coma Scale (GCS) score	X	X	X	X
Blood product transfusion (24 h/total)		X	X	X
Final diagnosis				X
Hospital/intensive care unit (ICU) length of stay				X
Final disposition				X
Abbreviated Injury Scale (AIS) scores				X
ISS				X

TABLE 2. RemTORN Time Intervals

Total prehospital interval
Intermediate stabilization facility (level IV) dwell time
Interfacility transport interval
Total time interval before Level I trauma center arrival

24 hours from injury to arrival at definitive care; or (3) incomplete data set.

Standard descriptive statistics were used to define the data set to internally validate the model and set baseline metrics. Relevant time intervals were modified from previous definitions established by Spaite et al.[13] (Table 2). In addition, multivariate linear regression was used to explore associations among individual Injury Severity Scores (ISSs) and total elapsed time before Level I trauma center arrival.

For contextual reference, we compared data from a deidentified subset of combat casualties obtained from the Department of Defense Trauma Registry (formerly Joint Theater Trauma Registry), which were contemporary to the RemTORN sample set. These data consisted of 8,913 cases included in the TACSCOPE (R.T. Gerhardt, unpublished data, 2012). Analyses were performed using the two-tailed unmatched *t* test for comparison of age, time intervals, and ISS. Moreover, interquartile ranges (IQRs) were calculated for ISS comparison. Mantel-Haenszel χ^2 technique was used for comparison of survival rates.

RESULTS

A total of 646 subjects were eligible for evaluation. Exclusions were as follows: 8 lacked ISSs; 44 were elderly falls of less than 1 m; 28 had total out-of-trauma center intervals in excess of 24 hours; and 31 lacked other critical data, including final outcome, destination, and time intervals. A total of 543 subjects were included in the analysis (84%).

Demographic and selected epidemiologic characteristics for the RemTORN cohort are depicted in Table 3. Of note is the finding that burns accounted for the highest percentage of all deaths (29%).

TACSCOPE data set depicts the interrelation of ISS and total time elapsed between injury and Level I trauma center arrival, stratified by sending Level IV facility. Multivariate linear regression with ISS serving as Y intercept and comparing total time before Level I arrival and sending Level IV facility code revealed a correlation coefficient r^2 of 0.04. While constrained by protocol from specifically identifying specific facilities in this article, we interpret these observations as combined effects of initial scene response, intermediate resuscitation, trauma surgical consultation, and interfacility transport upon patient movement. While many of these characteristics are unalterable, there are systems-based issues that uniformly show potential for improvement throughout the entire regional trauma system.

The results of the comparison of selected clinical data points between the RemTORN sample and the TACSCOPE prehospital study set are depicted in Table 4. In general, they may be summarized as follows: RemTORN patients were generally older, spent longer time intervals en route to Level I trauma centers, and had higher ISS compared with contemporaneous combat casualties. The latter observation likely reflects an observed limitation of ISS in cases involving polytrauma and blast mechanisms, previously elucidated.[14] Rates of blood product transfusion in the first 24 hours and survival to hospital discharge were on similar orders of magnitude between the respective data sets.

DISCUSSION

When one considers the storied and still evolving relationship between the military medical and civilian trauma care communities in south Texas, RemTORN represents a life cycle on both a philosophical and practical level. Historically, State Trauma Service Area-P and the STRAC consortium served as an early and critical model for military trauma system development prior and up to 2003. Specifically, the "Del Rio Model" was frequently cited as an inspiration by Jenkins, Dorlac, Eastridge, Holcomb and others for the development of the first, coordinated trauma system in Afghanistan and Iraq (i.e., the Joint Theater Trauma System).[15,16] A decade later with the anticipated conclusion of combat operations in Afghanistan, there is the recognition that this same model has sustained through the years an out-of-hospital care platform that is comparable with the military's current and projected

TABLE 3. RemTORN Demographic and Epidemiologic Data

Variable	RemTORN-I
n	543
Age, (95% confidence interval [CI], SD), y	39 (38–41, 16)
Sex	81% male
Time intervals (95% CI, SD), h:min	
Injury to Level IV arrival	1:43 (1:29–1:58, 2:47)
Level IV dwell time	3:17 (3:05–3:28, 2:12)
Interfacility transfer	1:42 (1:36–1:48, 1:13)
Total out-of-trauma center interval:	6:38 (6:19–6:58, 3:43)
Selected mechanisms of injury, n (%)	
Penetrating	88 (15)
Fall > 1 m	103 (20)
Motor vehicle collision	118 (30)
Assault or other blunt mechanism	96 (19)
Motorcycle or recreational vehicle collision	52 (10)
Stab wounds	46 (9)
Gunshot wound	25 (5)
Pedestrian with motor vehicle collision	24 (7)
Burn	27 (5)
Animal/snake bite	35 (7)
Occupational	17 (3)
ISS (IQR)	11 (4–14)
LD50-ISS (IQR)	33 (25–48)
Level I length of stay (95% CI, SD), d	
ICU	2 (1–3, 10)
ICU-free days	3 (3–4, 5)
Total hospital days	5 (4–6, 12)
Required blood in the first 24 h^	20 (8)
Survival to discharge	527 (97)

LD50, lethal dose for 50% of the population.

TABLE 4. Comparison of Key Components Between RemTORN and TACSCOPE Populations

Variable	RemTORN I	TACSCOPE	*p*
n	543	5,528	—
Age (95% CI, SD)	39 (38–41, 16)	26 (26–26, 6)	<0.001
Penetrating mechanism, %	15	47	—
Elapsed time before surgery	6:38 (6:19–6:56)	2:55 (2:21–3:28)	<0.001
ISS (IQR)	11 (4–14)	8 (2–10)	<0.001
LD50-ISS (IQR)	33 (25–48)	25 (9–29)	<0.001
Required blood in the first 24 h†	8%	10%	—
Survival to discharge	97%	98%	<0.04

In TACSCOPE cases reporting elapsed time before Role 3, these data were calculated based on reported times of wounding (estimated) and arrival at Role 3 military treatment facilities (actual) but do not reflect arrival times at Role 2 forward resuscitation facilities (forward surgical teams, surgical shock trauma platoons, etc.). Exact time intervals during tactical phases of out-of-hospital care remain classified for operational security purposes.

†Within the RemTORN I database, fields for packed red blood cell administration in RTC 1 ED and RTC 1 over the first 24 hours contained data in only 43% of all cases; the TACSCOPE database contained Role III transfusion data for all cases.

areas of operations abroad (Fig. 1). RemTORN seeks to build upon this foundation and mature a needed domestic prehospital trauma care laboratory to facilitate future advances for military members and domestic victims of trauma alike.[4,12]

Through this first retrospective exploration of the RemTORN study platform, we have demonstrated the capacity to capture, integrate, and analyze a comprehensive trauma data set, which continues to accumulate in South Texas. With the current exception of engagement by hostile fire, this experimental platform offers a sustainable and relevant model that replicates time-distance intervals, injury severity, pathology, and the progressive levels of care in a manner complementary both to other regional trauma systems and to the contemporary operational environment encountered by our deployed military forces.

Our findings seem generally comparable with those reported by Rogers et al.[17] in a 1999 case-control study comparing epidemiology and outcomes of patients admitted directly at a trauma center versus those undergoing intermediate stabilization then interfacility transfer from rural facilities. Where this study departs from its predecessor is in the ability to obtain and integrate discreet clinical data from the individual phases of care conducted before Level I trauma center arrival. In addition, the potential for superimposing prospective observational studies and clinical trials adds an exciting dimension.

While these initial findings are encouraging, much work remains. Although the architecture is in place, additional resources, protocols, and people remain to be coordinated and placed in preparation for prospective investigations to commence. These may include studies to define the triggers and progression of acute traumatic coagulopathy, the early prediction of hemorrhagic shock, digital and telemedical decision support for out-of-hospital blood product and procoagulant use by paramedical personnel, and clinical trials of freeze-dried plasma, tranexamic acid, and other intravascular hemostatic agents among other concepts yet to be conceived. We would propose that a translational model such as that we described will provide a marked improvement in our ability to develop these next generation interventions that may benefit combatants and domestic patients of trauma alike.

This study is limited by several of the characteristics inherent in retrospective study designs. Readers are cautioned to avoid drawing cause-effect linkages from data that rightfully might serve only to identify associations and generate further hypotheses.

Other tangible risks exist for observer, recall, and compliance bias, each a potential result of multiple layers of retrospective medical record review and clinical registry input. We have sought to mitigate these risks through reinforcement and training of personnel performing trauma registrar functions in our collaborating facilities, by the electronic collection of the preponderance of health record information, and by providing resources to support full-time staff focused on management of the RemTORN component of the regional registry.

In addition to the aforementioned risks, this study is focused by design on patients undergoing interfacility trauma transport. This, coupled with a complex bureaucratic landscape to traverse to obtain postmortem data for nonsurvivors, injects significant risk for survival bias. In preparation for commencing prospective studies, we have initiated a process for acquiring sending Level IV facility and interfacility transport mortality data through existing regional process improvement mechanisms.

Also of note is the question as to whether conclusions drawn from the RemTORN platform will translate to similar regions domestically or to contemporary and future battlefields. While no "test bed" short of actual combat can genuinely replicate that experience, it is equally true that well-designed, methodically rigorous, randomized controlled trials cannot be conducted by US Forces on combatants or civilians on the battlefield, and they should not be, given regulatory and ethical considerations. As a consequence, much of what passes for contemporary casualty care "research" bears a greater resemblance to quality improvement/process improvement projects on a grand scale or, perhaps at best, postmarketing surveillance in a manner similar to Food and Drug Administration Phase IV trial.[18] While this approach has served adequately as a means of facilitating a mechanism for clinical inquiry, it has come at some cost in terms of inefficiency, delay, and error.

Despite these limitations, the RemTORN described in this report represents a currently functioning military-civilian prehospital research model. The RemTORN model has many inherent features, which have the potential to mitigate bias and confounding and support the study of prehospital interventions and processes. Furthermore, the RemTORN model provides a unique and important glimpse into the interplay of prehospital circumstance, substrate, and intervention. If this model is allowed to mature to its potential, it stands to improve the military's ability to develop the next generation of lifesaving interventions for combatants and domestic patients of trauma alike.

In conclusion, this study characterizes injury patterns, severity of injury, and medical evacuation times in a large civilian trauma system interfacing with the US Department of Defense's only Level I trauma center. Although not completely alike, similarities do exist between observations within this civilian prehospital trauma network and casualties cared for by the military in contemporary combat operations. Findings from this study demonstrate the feasibility of a stateside,

civilian-military collaboration in prehospital research. With this model and possibly others like it in the United States, the military possesses a needed capacity to pursue elements of prehospital research pertaining to casualty data collection, casualty monitoring, and casualty resuscitation during interwar periods.

AUTHORSHIP

R.T.G. conceptualized the network, performed the literature search, designed the study, analyzed the data, interpreted the data, and wrote the manuscript. A.R.K. assisted with the literature search, assisted with the data collection, and assisted with the data analysis and manuscript writing. T.E.R. assisted with the critical revisions and final manuscript writing. S.S. assisted with the study design and critical revisions. B.W. assisted with the data collection and analysis. E.L. assisted with the data collection and analysis. P.L. assisted with the registry development, data collection, and analysis. E.E. assisted with the study design and critical revisions. R.S. assisted with the study design and critical revisions. B.E. assisted with the critical revisions. L.B. assisted with the design and critical revisions.

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DISCLOSURE

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