Analysis of Life-Saving Interventions Performed by Out-of-Hospital Combat Medical Personnel

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Background: To analyze casualties from the Camp Eagle Study, focusing on life-saving interventions (LSI) and potentially survivable deaths.

Methods: Retrospective cohort of battle casualties from a forward base engaged in urban combat in Central Iraq. Medical support included emergency medicine practitioners and combat medics with advanced training and protocols. LSI were defined as advanced airway, needle or tube thoracostomy, tourniquet, and hypotensive resuscitation with Hetastarch. Cases were assessed retrospectively for notional application of a Remote Damage Control Resuscitation protocol using blood products.

Results: Three hundred eighteen subjects were included. The case fatality rate was 7%. "Urgent" (55) or "priority" (88) medical evacuation was required for 45% of casualties. Sixty-one LSI were performed, in most cases by the physician or PA, with 80% on "urgent" and 9% on "priority" casualties, respectively. Among survivors requiring LSI, the percentage actually performed were airway 100%; thoracostomy 100%; tourniquet 100%; hetastarch 100%. Among nonsurvivors, these percentages were 78%, 50%, 100%, and 56%, respectively. Proximate causes of potentially survivable death were delays in airway placement and ventilation (40%), no thoracostomy (20%), and delayed evacuation resulting in hemorrhagic shock (60%). The notional Remote Damage Control Resuscitation protocol would have been appropriate in 15% of "urgent" survivors and in 26% of nonsurvivors.

Conclusion: LSI were required by most urgent casualties, and a lack or delay in their performance was associated with increased mortality. Forward deployment of blood components may represent the next addition to LSI if logistical and scope-of-practice issues can be overcome.

Key Words: Military medicine, War, Emergency medical services, Remote damage control resuscitation, trauma resuscitation.

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Severely injured individuals with continuing hemorrhage and delayed evacuation are more likely to die from hemorrhage and the "lethal triad" of hypothermia, acidosis, and coagulopathy.[1–3] Damage Control Resuscitation (DCR) is an emerging approach to the polytrauma patient which uses life-saving interventions (LSI) and selected use of blood products early in the course of trauma resuscitation, in anticipation of continued resuscitation in the intensive care unit and staged restorative surgical procedures under the Damage Control Surgery paradigm.[4]

The concept of DCR is emerging as state-of-the-art in civil sector trauma care.[4] In addition to the timely performance of the aforementioned LSI, DCR uses lower volume intravenous fluid infusion (thus, the associated term "hypotensive resuscitation"), and the early administration of nearly equivalent ratios of packed red blood cells, platelets, and plasma, or if available, fresh whole blood.[5,6] It is believed that employment of DCR may improve survival from 16% to 40% over standard trauma care.[5] Translation of DCR principles into the combat surgical setting has likewise yielded encouraging preliminary results.[4]

Remote Damage Control Resuscitation (RDCR) is a concept envisioned for use in the out-of-hospital combat casualty care setting, in cases where severely wounded casualties with continuing noncompressible torso hemorrhage (NCTH) face delays in evacuation to resuscitative surgical intervention.[7] RDCR is envisioned as being anchored in the principles of Tactical Combat Casualty Care (TCCC), beginning with the identification of life-threatening conditions followed by the appropriate and timely performance of LSI before tactical evacuation, with care continuing en route to resuscitative surgery and theater hospitalization.[8] In cases of NCTH when standard prehospital interventions have been exhausted, the RDCR algorithm would seek to further mitigate end-organ hypoxia and the "lethal triad" through the judicious employment of blood products, pro-coagulants, and anti-fibrinolytic agents by far-forward combat medical personnel, leveraging remote decision support technology and emergency telemedical reach-back to a specialist capable of providing informed medical direction. In such cases, RDCR may provide a coherent diagnostic and therapeutic algorithm for early intervention in the out-of-hospital phase, with the objective of delivering optimized preoperative patients to the trauma surgeon.

It is commonly acknowledged by the military combat casualty care community that the next "great leap forward" in casualty survival will likely arise from the out-of-hospital and presurgical combat casualty care setting.[9] If logistical and scope-of-practice issues can be overcome, the projection of RDCR principles into the setting of far-forward care may become a reality. Thus, RDCR may provide a mechanism for

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mitigating the deleterious effects of protracted time intervals between wounding and resuscitative surgery.

The objectives of this study were to examine an existing database of combat casualties to determine the frequency of requirement and performance of LSI, to determine whether Prehospital performance of LSI improved the likelihood of survival, and to gain insight into the potential proportion of casualties who might benefit from the notional application of an RDCR protocol.

METHODS

This was a retrospective cohort subanalysis of prehospital and definitive care combat casualty data from the Camp Eagle Study, which has been published previously.[10] It represents a unique sample in that the role-I medical care rendered to the subjects involved combat medics operating with advanced training, established Emergency Medical Services style treatment protocols, and active medical direction or direct care by a board-certified emergency physician or emergency medicine specialty-trained physician assistants.[11]

This study used a retrospective cohort design. Data were abstracted from computerized, daily-collated aid station records generated prospectively at the study facility, a consolidated battalion aid station located on a Forward Operating Base which housed two separate combat maneuver battalions and their constituent medical platoons. The supported units were engaged in full-spectrum operations in the urbanized terrain of the Sadr City subdivision of Baghdad, Iraq during the period from March 31, 2004, to February 15, 2005. The medical unit under study differed from standard medical platoons solely by the circumstantial presence of emergency medicine specialists (one board-certified emergency physician, and two emergency medicine physician assistants who completed a formal 1-year fellowship in emergency medicine). Combat medics certified as National Registry of Emergency Medical Technicians—Basic (NREMT-B) were trained and credentialed to perform selected advanced interventions, and had concurrent medical direction available via radio or often in-person (Table 1).

TABLE 1. Predeployment Advanced Training Conducted for Combat Medics Participating in This Study

- Didactics
  - Current combat wound demographics and ballistic patterns
  - TCCC review
  - Excerpts from the International Trauma Life Support (ITLS) curriculum (patient assessment, triage, and patient transport)
  - Operational "lessons learned" by recently-returned combat medic veterans
- Laboratory/practical exercises
  - Simulator-based task-trainer and combat casualty treatment scenarios:
    - Initial stabilization and patient assessment
    - Application of a tourniquet for uncontrolled extremity hemorrhage
    - Laryngoscopic endotracheal intubation
    - Needle and surgical cricothyroidotomy
    - Peripheral intravenous access
    - Intra-osseous access
    - Needle and tube thoracentesis
    - Needle pericardiocentesis
  - Live-tissue vivarium training
    - Peripheral intravenous access by percutaneous and cut-down approach
    - Intra-osseous access
    - Needle and tube thoracentesis
    - Needle pericardiocentesis
    - Needle and surgical cricothyroidotomy
- Advanced treatment protocols
  - Surgical cricothyroidotomy (airway obstruction or respiratory insufficiency due to shock)
  - Blind-insertion airway device (King-LT) for advanced airway
  - Tourniquet use (initial hasty hemostasis, definitive placement for amputation)
  - Needle thoracostomy for chest decompression
  - Hetastarch for intravascular volume replacement in hemorrhagic shock
  - Morphine intramuscular autoinjector for analgesia after penetrating trauma or fractures
  - Combat Pill Pack (Levofloxacin, Celecoxib, Acetaminophen) administration in remote care

The provider/medic-to-population ratio at the study facility closely approximated the contemporaneous ratio throughout the theater. Medical equipment sets, pharmaceuticals, and evacuation assets were identical to standard U.S. Army issue for units deployed in this setting.

All combat casualties from tenant units undergoing medical treatment at the study facility from March 31, 2004, to February 15, 2005, for whom electronic medical record and outcome data were available were included in the study. Demographic, epidemiologic, and evacuation data were abstracted from the electronic medical situation reports. Specific data points collected for analysis included the following: age, sex, date of wounding, anatomic location and mechanism of wounding, field diagnosis, triage and evacuation category, prehospital procedures performed, evacuation destination, final diagnosis, survival, and clinical outcome. Outcome data were abstracted from daily reports from higher headquarters, medical treatment facilities (MTFs), and from autopsy data obtained from the Armed Forces Institute of Pathology. Data were collected and maintained in accordance with current privacy safeguards.

From the electronic dataset, rates of battle casualties, KIA, died-of-wounds, case fatality rate, and out-of-theater evacuations (OOTE) were calculated.[12] Also, performance of rapid-sequence or pharmacologically-assisted endotracheal intubation, cricothyroidotomy, needle or tube thoracostomy, tourniquet placement, and use of hypotensive resuscitation with Hetastarch (HEXTEND, Hospira, Inc.) were abstracted. The aforementioned interventions constituted this study's definition of LSI.

From the epidemiologic, disposition, and interventional data, the investigators adjudicated whether an LSI was required, whether the required LSI was performed, the proximate cause of death when applicable, and whether the notional employment of an RDCR protocol, including the administration of blood products and pro-coagulant agents alone or in combination, might have been appropriate. The primary criteria for this determination were (1) in the case of

KIA, the cause of death was potentially survivable (absent catastrophic central nervous system, heart or great vessel damage; burns under 90% total body surface area); (2) any subject manifested physical signs or postmortem data consistent with hemorrhagic shock; and (3) if at any point any subject underwent out-of-hospital hypotensive resuscitation with administration of intravenous hetastarch.

In addition to the aforementioned analyses, the Injury Severity Scores (ISS) for casualties who were treated at the study facility and who underwent OOTE, along with the corresponding ISS for all OIF-II casualties who underwent OOTE during the same time frame, were obtained from the Joint Theater Trauma Registry for comparative analysis.[10]

Statistical Analysis

Standard descriptive statistics were used to interpret the study set. LSI performance rates were compared using Fisher's exact test. This study was reviewed and approved by the Institutional Human Subjects Committee of Brooke Army Medical Center, and by the US Army Clinical Investigation Regulatory Office.

RESULTS

Data were available for 318 subjects. The case fatality rate was 7%. NCTH was identified in 8% of all casualties (27% of urgent, 0% priority, and 26% of deaths). Of all casualties, 55 (17%) required urgent and 88 (28%) required priority medical evacuation (MEDEVAC) to a surgical facility, respectively. The average ISS for survivors who underwent OOTE due to the requirement for additional surgery or recuperation beyond the scope of theater hospitalization was 10 (95% CI, 8–12). Wounding patterns and mechanisms, while not reportable in this setting due to operational security requirements, generally reflected the aggregate theater casualty population. Proximate causes of potentially survivable death were delays in airway placement and ventilation (40%), thoracostomy (20%), and delayed evacuation resulting in hemorrhagic shock (60%).

A total of 61 LSI were performed, with 80% of urgent and 9% of priority casualties receiving them, respectively. The results of LSI analysis, survival outcome, and relative impact of LSI performance on the entire study population are depicted in Table 2. In all subjects who required LSI, a significantly higher rate of LSI performance was identified among survivors for chest decompression and for hypotensive resuscitation with hetastarch. The preponderance of LSI was performed by the emergency medicine physician or emergency medicine PAs after arrival at the battalion aid station or forward aid station element during offensive operations (Table 3).

A total of 24 casualties (8%) were identified with NCTH, of which nine (38%) were nonsurvivors and 15 (62%) survived. LSI rates and comparisons within this subset are depicted in Table 4. Hypotensive resuscitation with Hetastarch was administered to 5 (56%) of nonsurvivors versus 15 (100%) of survivors ($p < 0.02$). By our definition, the notional RDCR protocol would have been appropriate in 15% of survivors requiring urgent MEDEVAC, and may have been appropriate in 26% of nonsurvivors.

TABLE 2. LSI in All Casualties

	Nonsurvivors	Survivors	Fisher's Exact Test; *p*
Airway required	9	7	NS
Airway done	7	7	
Chest decomp required	4	17	<0.01
Chest decomp done	2	17	
Tourniquet required	2	7	NS
Tourniquet done	2	6	
Hypotens resusc needed	9	15	<0.01
Hypotens resusc done	5	15	
Total LSI required	24	46	<0.01
Total LSI done	16	45	
LSIs performed per casualty	0.7	0.2	

TABLE 3. Prehospital Interventions Performed by Type and Provider

		Performed by		
Intervention	N	MEDIC-NPOI	MEDIC-BAS*	MD/PA
Surgical Cric	4	0	1	3
ET-intubation	10	0	0	10
Tube or needle thoracostomy	19	0	2	17
Tourniquet	8	3	1	4
Hypotensive resus/hetastarch	20	2	18	0

* Denotes procedure performed under supervision of licensed practitioner.
NPOI, near point-of-injury; BAS, Battalion Aid Station or Forward Aid Station.

TABLE 4. LSI in Casualties With NCTH

	Nonsurvivors	Survivors	Fisher's Exact Test; *p*
Airway required	7	3	NS
Airway done	6	3	
Chest decomp required	4	8	NS
Chest decomp done	2	8	
Tourniquet required	2	3	NS
Tourniquet done	2	3	
Hypotens resusc needed	9	15	<0.02
Hypotens resusc done	5	15	
Total LSI required	22	29	<0.01
Total LSI done	15	29	
LSIs performed per casualty	1.67	1.93	

Limitations

Inherent in all retrospective study designs is the limitation that while associations might be identified among variables, cause-and-effect cannot be established. Thus, while we detected an association between improved survival and increased rate of performance of LSI, we are unable to directly attribute a survival benefit to their performance.

The differential impact of transport time from point-of-injury to surgical facility arrival is worth considering as well. In this study, virtually all casualties were transported from point-of-injury to the study facility, which was co-located with the only available helicopter landing zone in the local area of operations, which resulted from its dense, nonpermissive urban terrain. The average transport time from the study facility to the nearest combat support hospital by air was under 25 minutes. Belying this fact was the average air ambulance request-to-arrival time interval, which was widely variable, ranging in practice from as little as 20 minutes to greater than 2 hours during major combat operations. In addition, the field transport time from point-of-wounding to arrival at the aid station could vary considerably due to tactical constraints, such as incoming hostile fire, patient transport logistical issues, and surface road navigability.

In addition to the potential effect of these prehospital time intervals, it is also noteworthy that roughly 25% of casualties were sustained as the result of hostile weapon detonations occurring directly within our forward operating base. Because the average time interval between wounding and access to the battalion aid station for these subjects was often shorter than that for soldiers wounded outside the base, it is possible that this phenomenon may have injected bias. Mitigating this finding is the observation that similar indirect fire attacks on Coalition operating bases remains common throughout the theater. It is also possible that our findings may in themselves demonstrate the survival benefit conferred by access to skilled advanced life support providers and their interventions near-point-of-wounding.

This dataset is nonrepresentative of current theater out-of-hospital medical care in the sense that the study's combat medics had higher levels of training, were operating under established EMS-style treatment protocols, and had active expert emergency medical direction, to include on-scene emergency practitioners in many instances. This observation likely injects an unquantifiable level of survival bias, but simultaneously underscores the importance of clinical competence in order for the TCCC paradigm to be used effectively, and to enable the future application of an RDCR protocol including out-of-hospital blood product administration by conventional forces combat medics or corpsmen under emergency telemedical direction.

DISCUSSION

In this sample of combat casualties sustained in the contemporary operational environment, both a significant requirement for the performance of LSI in the Prehospital setting and an association between the rate of their performance and survival have been demonstrated. In addition, some insight has been gained with regard to the proportion of casualties that might be expected to sustain NCTH in similar settings.

In addition to this study's epidemiologic contributions, it has also demonstrated our capacity for decreasing combat mortality not only by the addition of technologies, but by simply assuring the clinical competence of forward-deployed combat resuscitators. While the study associated with this manuscript focused on a combination of forward-deployed emergency medicine practitioners and an EMS-style medical direction model for conventional combat medics which resulted in a 35% decrease in the odds ratio for case fatality, similar results were obtained by medical elements of the U.S. Army 75th Ranger Regiment employing advanced tactical practitioners approximating the scope-of-practice and clinical competence of EMT-paramedics.[10,12,13] Thus, while further technological innovations involving new devices and pharmaceuticals will be required to overcome mortality associated with NCTH, traumatic brain injury, and the "lethal triad", we must not lose sight of the importance of seeking solutions that assure our forward-deployed combat medical force is clinically and tactically competent to perform the fundamentals of combat casualty care.

To minimize potentially survivable combat deaths arising from NCTH in the prehospital and presurgical component of the modern battlefield (NATO Role-I), it will first be necessary to assure that the TCCC paradigm be executed efficiently and flawlessly, as demonstrated in the aforementioned studies. Once LSI have been performed and initial intravascular hetastarch aliquots are administered, however, the TCCC paradigm has essentially been exhausted and if delays in tactical evacuation to a resuscitative surgical facility are anticipated, there is currently little more that can be offered. It is precisely at this point in a casualty's prehospital care that the concept of RDCR might be used.

The out-of-hospital use of blood products for the severely wounded has been accomplished successfully both by Israeli and British conventional military medical elements, although administration was done exclusively by credentialed practitioners.[14,15] Numerous logistical, human systems and regulatory constraints will likely complicate the development of an out-of-hospital blood product capability for employment by conventional U.S. Forces forward of a MTF. At the current juncture, however, such a capability appears to offer the most promise for saving the lives of casualties sustaining NCTH and who face significant delays in access to resuscitative surgery. We base this hypothesis on the premise that if the employment of hospital-based DCR may improve survival from 15% to 35% over standard trauma care, then translation of RDCR into the Role-I setting may yield likewise encouraging results, particularly in the setting of delayed evacuation due to weather, terrain, logistical constraints, or hostile action.[5,16]

CONCLUSION

LSI were required in most casualties requiring evacuation. The scope-of-practice required for performing these LSI before MTF arrival were beyond that of the current civil-sector equivalent of conventional forces combat medics, and few LSI were performed by them near point of injury despite protocols and training. To improve survival, training to increase scope-of-practice, the inclusion of meaningful and proctored clinical patient contact both in- and out-of-hospital as part of the training regimen, and clinical validation of combat medics must be expanded. Real-time emergency medical direction, whether in-person or via telemedical links,

may ameliorate this situation. Establishment of an advanced practice combat medic approximating NREMT-Paramedic coupled with the aforementioned emergency telemedical direction would likely enable the deployment of a viable RDCR solution. Forward deployment of blood components out-of-hospital may represent the next addition to LSI if logistical and scope-of-practice issues can be overcome.

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