Death on the battlefield (2001–2011): Implications for the future of combat casualty care

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BACKGROUND: Critical evaluation of all aspects of combat casualty care, including mortality, with a special focus on the incidence and causes of potentially preventable deaths among US combat fatalities, is central to identifying gaps in knowledge, training, equipment, and execution of battlefield trauma care. The impetus to produce this analysis was to develop a comprehensive perspective of battlefield death, concentrating on deaths that occurred in the pre–medical treatment facility (pre-MTF) environment.

METHODS: The Armed Forces Medical Examiner Service Mortality Surveillance Division was used to identify Operation Iraqi Freedom and Operation Enduring Freedom combat casualties from October 2001 to June 2011 who died from injury in the deployed environment. The autopsy records, perimortem records, photographs on file, and Mortality Trauma Registry of the Armed Forces Medical Examiner Service were used to compile mechanism of injury, cause of injury, medical intervention performed, Abbreviated Injury Scale (AIS) score, and Injury Severity Score (ISS) on all lethal injuries. All data were used by the expert panel for the conduct of the potential for injury survivability assessment of this study.

RESULTS: For the study interval between October 2001 and June 2011, 4,596 battlefield fatalities were reviewed and analyzed. The stratification of mortality demonstrated that 87.3% of all injury mortality occurred in the pre-MTF environment. Of the pre-MTF deaths, 75.7% (n = 3,040) were classified as nonsurvivable, and 24.3% (n = 976) were deemed potentially survivable (PS). The injury/physiologic focus of PS acute mortality was largely associated with hemorrhage (90.9%). The site of lethal hemorrhage was truncal (67.3%), followed by junctional (19.2%) and peripheral-extremity (13.5%) hemorrhage.

CONCLUSION: Most battlefield casualties died of their injuries before ever reaching a surgeon. As most pre-MTF deaths are nonsurvivable, mitigation strategies to impact outcomes in this population need to be directed toward injury prevention. To significantly impact the outcome of combat casualties with PS injury, strategies must be developed to mitigate hemorrhage and optimize airway management or reduce the time interval between the battlefield point of injury and surgical intervention.

Understanding battlefield mortality is a vital component of the military trauma system. Emphasis on this analysis should be placed on trauma system optimization, evidence-based improvements in Tactical Combat Casualty Care guidelines, data-driven research, and development to remediate gaps in care and relevant training and equipment enhancements that will increase the survivability of the fighting force. (*J Trauma Acute Care Surg*. 2012;73: S431–S437. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Military; mortality; hemorrhage; prehospital; outcomes.

The vision of the Joint Trauma System is that every soldier, marine, sailor, or airman injured in the battlefield or in the theater of operations has the optimal chance for survival and maximal potential for functional recovery. Implicit within this vision is the mission to improve trauma care delivery and patient outcomes across the entire continuum from point of injury through rehabilitation using techniques for continuous performance improvement driven by evidence-based medicine across the entire continuum. A preliminary study evaluated these issues in Special Operations forces early in the war.[1] Within the past decade, a tremendous amount of evidence has been amassed validating improvements in combat casualty care once a casualty has reached a military medical treatment facility (MTF). However, no studies have comprehensively evaluated the outcomes of wounded warriors who died of their injuries before reaching an MTF. This relative blind spot is exacerbated by several factors, including lack of prehospital data,[2] the incomplete understanding of the tactical circumstances during which the injuries were sustained, and the integration of existing data sources into the Joint Theater Trauma Registry.

For the last decade of continuous war, the dominant mechanism of injury on the battlefield has been overwhelmingly penetrating in nature occurring in nearly 75% of casualties associated with explosive fragmentation and gunshot wounds. The survivability of those injured on the battlefield is an unprecedented historical level of 90%, compared with

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84% in Vietnam and 80% in World War II.[3] Some of the likely factors influencing this improved survivability include advances in personal protective equipment, a deployed trauma system, and improved training of medics and corpsman based on the concepts of Tactical Combat Casualty Care (TCCC).[4] In addition, within the historical context, the nature of the current war is different in that enemy tactics using small explosive devices are intrinsically different compared with small unit fire and maneuver prominent in Vietnam or large set piece battle with artillery, aerial bombs, armor, and littoral and sea-based engagements seen in World War II.

Historically, the epidemiology of combat injury has been documented by individual observers, by compilations of medical administrative data or by post hoc evaluations of data sources such as the Wound Data and Munitions Effectiveness Team from Vietnam.[5] Data derived from these sources from the wars of the last century note that 90% of battlefield casualties died in the battlefield before ever reaching medical care.[6–9] The technological advances of the 21st century have improved battlefield communications and data capture, thereby improving the quality and quantity of combat casualty care data available for review and analysis. Most of the previous writing on this topic has focused on casualties who reached the hospital, leading to significant selection bias because we did not have visibility on those casualties who died before reaching medical care. As a result, the past decade of combat has produced, for the first time in history, near-census data on serious combat injuries and deaths contained in a number of trauma registries. This has enabled us to identify the most significant causes of lethal pathophysiology in the pre-MTF subset of fatalities and determine which lethal injuries may be potentially survivable, thus facilitating development of a blueprint to guide future mitigation strategies.

MATERIALS AND METHODS

Institutional review board approval and oversight for this study was provided by the US Army Medical Research and Materiel Command and the former Armed Forces Institute of Pathology.

All US combat casualty deaths from theater are recovered and transported to Dover Air Force Base, Delaware, where complete identification and forensic examination are performed by the Armed Forces Medical Examiner System (AFMES). The AFMES Mortality Surveillance Division maintains the Department of Defense Medical Mortality Registry, which has the broader mission of analyzing all active-duty deaths for trends and preventable or modifiable risk factors. For this analysis, the AFMES Mortality Surveillance Division was used to identify US military casualties who died from an injury that occurred while they were deployed to Afghanistan or Iraq from October 2001 to June 2011. The primary focus of this analysis was to specifically evaluate casualties who died of injury in the battlefield with particular emphasis on those who died before reaching a military MTF. The autopsy records and Mortality Trauma Registry (MTR) of the AFMES was used to compile mechanism of injury, cause of injury, medical intervention performed, Abbreviated Injury Scale (AIS) score, and Injury Severity Score (ISS) on all lethal injuries. The autopsy reports and other perimortem records, the MTR, and photographs on file with the AFMES were used by the expert panel to conduct the study.

The expert review panel for this study consisted of military trauma surgeons, forensic pathologists, preventive medicine physicians, an emergency medicine physician with expertise in prehospital care, an expert injury coder with MTR expertise, and a trauma epidemiologist. As in the earlier mortality review, the panel used a consensus rule paradigm.[10,11] To maintain consistency and potential comparison value with past combat mortality analyses, the panel classified the fatalities as "nonsurvivable" (NS) or "potentially survivable" (PS) after evaluation of the individual perimortem records mentioned previously.[10,11] Similar analyses in the civilian trauma literature denote these as "preventable" deaths. For this analysis, we chose not to use this language because it invokes the perception of wrongdoing or blame. Instead, language monikers were specifically used to denote opportunities for performance improvement. As in previous analyses, when multiple wounds were identified, each injury focus was evaluated independently with respect to the potential for survivability. The consensus was to err toward the maximal inclusion of these casualties as "PS" to be introspective and critical to further develop the paradigm of combat casualty care performance improvement and identify potential gaps requiring further research and development. Specific wounds deemed to be NS were physical dismemberment, catastrophic brain injury (brain evisceration, transcranial penetrating brain injury involving deep nuclei or critical vasculature, and brain stem injury), cervical cord transection (above cervical level 3), airway transection within thorax, cardiac injury (>1/2 inch), thoracic aorta injury, pulmonary artery, hepatic avulsion, and catastrophic abdominopelvic injury characterized by lower-extremity amputations with open pelvis and large soft tissue loss/traumatic hemipelvectomy. All other injuries were deemed to be medically PS with the caveat that this analysis did not take into account the context of the mission and combat scenario, the nature of the enemy force, equipment and supply constraints, limitations in evacuation time and platforms, as well as the impact of weather, terrain, and other environmental factors. In addition, care was idealized with the assumption of immediate access to a US military MTF with advanced surgical capabilities and robust clinical resources.

To demonstrate the effectiveness of instituting interventions in the pre-MTF environment on mortality, we evaluated the fielding of tourniquets for the control of extremity bleeding.

RESULTS

For the study interval between October 2001 and June 2011, 4,596 battlefield fatalities were reviewed and analyzed. The causes for the lethal injuries were 73.7% explosive, 22.1% gunshot wounds, and 4.2% other (vehicle crash, industrial, crush, etc.). The stratification of mortality was notable that 87.3% of all injury mortality occurred in the pre-MTF environment (Fig. 1). Of the composite of all battlefield deaths, 35.2% (n = 1,619) were instantaneous, 52.1% (n = 2,397) were acute (minutes to hours) pre-MTF, and 12.7% (n = 580) of casualties died of wounds after reaching an MTF.

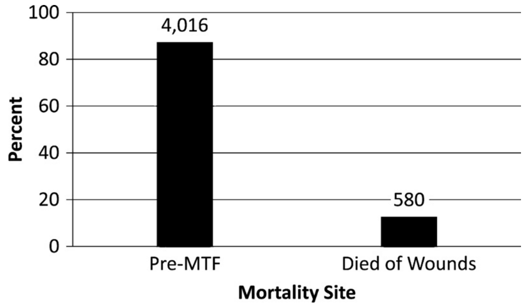

Figure 1. Battlefield mortality location.

Of the pre-MTF deaths, 75.7% (n = 3,040) were classified as NS, and 24.3% (n = 976) were deemed PS (Fig. 2). The ISSs of the PS mortality casualties are shown in Figure 3.

The injury focus of casualties who died instantaneously was substantively related to physical dismemberment, catastrophic brain injury, and destructive cardiac and thoracic great vessel injury (Table 1). The most prominent injury focus of NS casualties who died acutely before admission at an MTF was traumatic brain injury, heart and thoracic vessel, high spinal cord injury (above C3), and destructive abdominopelvic injury (Table 1). In contrast, the primary injury/physiologic focus of PS acute mortality was associated with hemorrhage (90.9%) and airway compromise (8.0%) (Fig. 4). Further stratifying the site of lethal hemorrhage, the most substantial anatomic region of hemorrhage was truncal (67.3%), followed by junctional (19.2%) and peripheral-extremity (13.5%) hemorrhage (Fig. 5). Truncal injury was characterized as 36% thoracic (maximum AIS score, 3) and 64% abdominopelvic (maximum AIS score, 4 and 5). PS junctional injury was noted to be cervical in 63 (39.2%) and axillary and groin in 104 (60.8%) of these casualties.

To assess the effectiveness of fielding pre-MTF medical interventions, we evaluated the system-wide introduction of tourniquets. Modern tourniquets were initially fielded to conventional US forces in late 2005. Implementation was ubiquitous after 2007. Before the introduction of tourniquets, the death rate from peripheral-extremity hemorrhage was 23.3 deaths per year, which was reduced to 17.5 deaths per year during the training and dissemination period from 2006 to 2007. After full implementation, this number was reduced to 3.5 deaths per year, an 85% decrease in mortality. If not for the innovative and improvised tourniquets used by Special Operations forces and unit-based initiatives of some conventional forces before modern tourniquet fielding, this reduction in mortality would have probably been even greater.

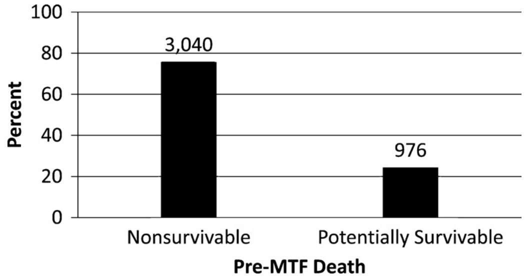

Figure 2. Survivability pre-MTF casualties.

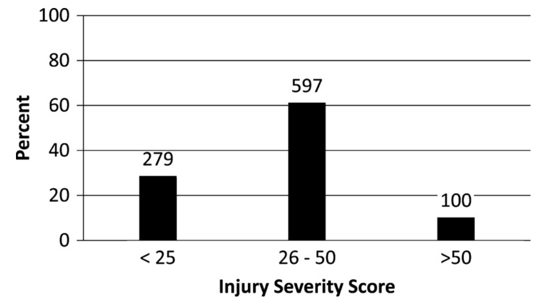

Figure 3. ISS PS pre-MTF deaths.

DISCUSSION

In-depth analysis of injury death is vital to improving trauma systems and injury outcomes.[12] Previous studies of wars of the last century have demonstrated substantial casualty loss on the battlefield before the wounded could reach surgical care. These studies were developed from convenience samples and administrative manpower data and weapons effectiveness analyses.[7,13–15] Before the current study, the most contemporary analysis of casualty deaths before admission at an MTF was a convenience sample during the early phases of current military operations, which demonstrated that 75% to 85% of deaths occur on the battlefield.[1,11] The importance of the current study is that it is comprehensive and is built on the evidence of previous analyses and includes all battlefield deaths from the current military operations to portray a composite overview of mortality on the battlefield. Despite the limitations of civilian injury taxonomies and multiple injury modeling for combat injured, the casualty databases and injury descriptions used here provide a standardized and reasonable approach to addressing some of the challenges in categorizing the macroanatomic and early pathologic consequences of injuries that occur in the battlefield.

Of the 4,596 casualties in our analysis, 87% died before reaching surgical care. This is in contrast to lower number presented in earlier reports.[11] This difference could be caused by a reduction in the died-of-wounds rate, an increase in immediate deaths, which were not previously reported, or the conduct of operations in more extreme environments dissociated

TABLE 1. Injury Focus of Patient With NS Injuries Who Died Instantaneously or Acutely Before Admission at a MTF (pre-MTF)

Cause of Death	Instantaneous (n = 1,619)	Acute (n = 1,624)
Brain injury	38.3% (620)	53.0% (753)
High spinal cord injury	—	9.2% (131)
Dismemberment	31.6% (512)	—
Heart/thoracic injury	23.6% (383)	21.8% (310)
Open pelvic injury	—	6.5% (93)
Other	6.5% (104)	9.5% (134)

Values are percentages of the total deaths and the number of deaths.

from definitive treatment facilities. The present analysis is hampered by the lack of correlation with the confounding variables of operational and evacuation scenarios necessary to address these differences.

The cause of injury in these casualties was predominantly explosions. The causality of explosions (primary through quaternary effects) was not specifically determined in this analysis.[16] Casualty deaths on the battlefield occurred in two discrete time phases: 35% of combat casualty deaths occurred instantaneously and 52% acutely in the minutes to hours after injury. Further stratification of pre-MTF deaths indicated that 3,040 (75.7%) of the prehospital deaths were NS, whereas 976 (24.3%) of deaths were PS from a strictly medical perspective. These results are similar to analyses conducted earlier in the war and validate the experimental design, reiterating the opportunity for effective interventions.[1,11]

The injury focus of the instantaneous NS mortalities included physical dismemberment, catastrophic brain injury, and destructive cardiovascular injury. From the perspective of acute, but not instantaneous NS pathology, most casualties died of severe traumatic brain injury, thoracic vascular injury, high spinal cord injury, and destructive abdominal pelvic injury. This latter category became a more prominent injury pattern during the counterinsurgency phase of military operations in Afghanistan from 2010 until the present, when service members were injured by explosive devices while conducting dismounted (foot) patrols. This injury pattern was coined *dismounted complex blast injury* (DCBI) and was the focus of a task force convened by the US Army Surgeon General. DCBI was characterized by multiple amputations, especially of the lower extremities; massive abdominal, pelvic, and urogenital injury; and often, exsanguination from truncal or junctional hemorrhage. These casualties are especially challenging to care for since they may involve concurrent extremity, junctional, and truncal hemorrhage, all in the same individual.[17] From the qualified perspective of the review panel, since these NS injuries would not have been survivable with currently fielded medical therapies, the only way to impact this mortality cohort would be through injury prevention. During analyses of these multimechanistic, multisystem injuries, it was further emphasized that the current civilian injury taxonomies have limitations in characterizing complex combat injury. To that end, since 2008, a triservice, multidiscipline team has been developing a combat-specific injury

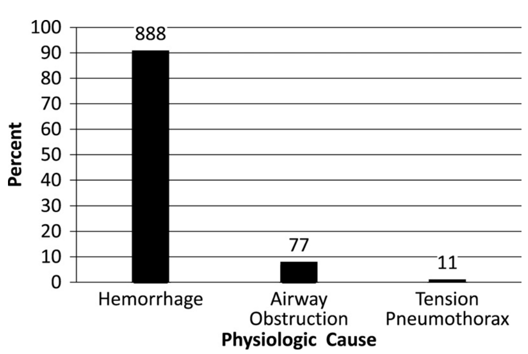

Figure 4. Injury/physiologic focus PS acute mortality (n = 976).

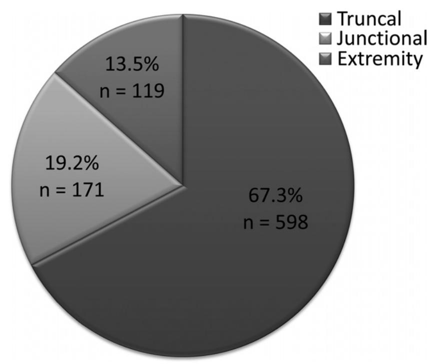

Figure 5. Anatomic focus of lethal PS hemorrhage.

taxonomy and appropriate multimechanistic modeling scheme to be published shortly.

In the cohort of casualties with PS wounds, the majority of mortality was associated with hemorrhage (90.9%). This hemorrhage was further stratified by anatomic focus with 67.3% of the hemorrhage being truncal, 19.2% junctional, and 13.5% extremity. These data are a slight divergence from previous recent reports of combat deaths[1,11] and may represent the impact of the dissemination of the prehospital battlefield treatment algorithms of TCCC[4] during the course of the current wars. More specifically, the difference in hemorrhage outcome data should be considered in light of the following two factors: TCCC was being used by only a few select units in the US military at the start of the wars in Afghanistan but is now used throughout the US military and by most coalition partner nations[4,18] and the DCBI injury pattern has been more commonly encountered since 2010 in Afghanistan and accounts for a very severely wounded cohort of casualties. From previous studies of casualties who died of wounds, the focus of PS hemorrhage was 48% truncal, 31% extremity, and 21% junctional.[19] The disparity in these two data sets may be a representation of survival bias in that some casualties with extremity and junctional hemorrhage may have been more likely to have survived long enough to reach MTF secondary to TCCC hemorrhage control modalities such as tourniquets, pressure dressings, and hemostatic dressings that have slowly but continuously increased in quantity, quality, and use during the past decade.

In contrast, during this study period, there was no effective means to control or temporize junctional or truncal sources of hemorrhage in the battlefield. This signifies a clear and persistent gap in medical treatment capability that has been present for the entire history of warfare and well documented for nearly a century.[1,5,6,11,20–23] This scenario concomitantly represents a potential high impact opportunity for research and development to improve combat casualty outcomes.[7,24] Recent emphasis in battlefield trauma care has focused on reducing death from noncompressible hemorrhage through the use of tranexamic acid,[25,26] controlling junctional hemorrhage with the Combat Ready Clamp, providing fluid resuscitation that minimizes dilutional coagulopathy and providing a battlefield analgesia option that does not cause respiratory depression or exacerbate hemorrhagic shock. Research resources should be heavily focused on both local hemostatic capabilities for field care and systemic, procoagulant therapies that might help mitigate the exsanguination process.

The second most common cause of the PS physiologic cause of mortality was upper-airway obstruction caused most prominently by direct injury to the airway structures of the face and neck. Our data corroborates the analysis of previous studies, which demonstrated the 1% to 2% incidence of fatal airway obstruction in the battlefield.[6,11,27] Although our data demonstrated that airway obstruction represented 8.0% of the PS fatal pathology, it likewise represented 1.6% of the total lethal pathology overall. Many of the casualties with physiologic airway compromise had concomitant cervical vascular injury, which compounded the deleterious effect of the injury. The ability to manage the airway in the austere tactical situation is a challenge that must be met with improved airway devices as well as training the medics and corpsmen on the battlefield and maintaining their skills.

Casualty loss from extremity hemorrhage is one area of battlefield mortality in which a clear outcome impact has been made through the use of tourniquets. Previous studies during current military operations have demonstrated a consistent and profound survival advantage for casualties in whom tourniquets were applied early and effectively on the battlefield.[11,28–30] Our analysis substantiates this claim in that casualty deaths from extremity hemorrhage occurred at a rate of 23.3 deaths per year in the pretourniquet years of the war but decreased to 3.5 deaths per year after tourniquets were fully fielded.

Understanding the change in the rate of PS injury throughout the course of the wars in Afghanistan and Iraq is complicated by ongoing changes in battlefield trauma care techniques used to treat casualties. There has been a dramatic transition in the concepts and execution of battlefield trauma care during the last decade of war. Beginning with innovations pioneered by the US Special Operations Command and using new combat trauma technologies tested by the US Army Institute of Surgical Research,[31–35] TCCC has revolutionized how combat medicine is practiced in the battlefield. Use of TCCC concepts progressed sporadically throughout the US military, with widespread concept acceptance occurring in the latter part of the war. The value of TCCC implementation and use was highlighted in a recent study of preventable death on the battlefield in the 75th Ranger Regiment. Investigators demonstrated that the use of an aggressive command-directed casualty response system and TCCC-based Ranger First Responder program was able to reduce the incidence of preventable death to the unprecedented low level of 3% of their total fatalities.[22]

From the perspective of injury severity in the PS casualties, 28.6% had an ISS of less than or equal to 25; 61.2% had an ISS between 25 and 50; and 10.2 had an ISS greater than 50. It should be noted that with an ISS of 25, there is a predicted mortality of 20% to 30% with a near linear increase in mortality from an ISS of 25 to 75, which is associated with an approximately 75% mortality. Therefore, even in our idealized construct of immediate access to surgical care, a substantial number of the PS casualties would have ultimately died of their injury or complications of injury.

Frustration with the lack of improvement in the outcomes of casualties who die in the battlefield has been voiced as a primary concern of battlefield surgeons for 50 years. During the Korean war, Bowers and Hughes[36] noted that "little, if any, improvement have been made in the prehospital phase of treatment of combat wounds in the past 100 years, most of the startling developments and improvements having been in the field of definitive care." In Vietnam, Maughon[23] commented, "Have we made no progress in control of initial non-lethal wounds, or has our attention been diverted from such simple matters to the complicated physiology of massive trauma in the Hospital?" During current overseas contingency operations, Blackbourne[37] insightfully noted that "while the technology to locate, track, and destroy our enemies has taken huge strides since 1831, our prehospital technology to help save life and limb has not kept pace."

As with previous studies on the topic, the study has limitations intrinsic to retrospective nature of the analysis and the limitations associated with large data repositories such as the MTR, including misclassification bias, observer bias, and data integrity. The expert review panel and consensus rule paradigm are inherently sources of potential bias. Exacerbating the limitations of investigating this facet of pre-MTF death is that very few clinical data are generated from the prehospital environment on which to make performance improvement evaluations.[2] Since unit-level medical support is not controlled by the military medical community, but rather the line, the onus to ameliorate this issue is education, sustainment, and emphasis by line commanders. Another valid limitation of the outcomes of this analysis is intrinsic in the definition of casualty statistics and assumes capability for casualty salvage at the lowest level of MTF. To more appropriately classify battlefield injury, outcomes would require restructuring of casualty definitions using a level of care at which surgical capability was possible, the lowest current level being forward deployed surgical elements. Another limitation of the study includes the fact that the data are almost entirely drawn from ground combat and thus cannot be extrapolated to littoral/shipboard environments in which drowning, burns, toxic gas, steam, and particulate inhalation add to the complexity of injuries and further emphasize the need to continue to capture combat injury data from all sources and events.

Among the limitations of this study was that the determination of casualty survivability was based purely on clinical metrics. It is extremely important to caveat this analysis with the fact that the concept of potentially preventable death in this study was conceptualized based on an idealized medical scenario excluding the influence of the confounding variables of operational and evacuation scenarios, mission requirements, enemy forces, logistic constraints, evacuation limitations, and environmental factors. In reality, these confounding variables impact greatly on the outcome of casualties. To minimize the impact of these factors, line commanders should have casualty response training provided as part of their initial and refresher training in combat leadership.[22,38] In addition, focused improvements in the provision of care during tactical evacuation[39,40] have the potential to mitigate tactical and evacuation factors in contributing to preventable death.

We are duly sensitive to the potential for misperception of the data and in no way intend to undermine public confidence or the confidence of the war fighter or their families relative to medical care rendered on the battlefield. It is important to note that this analysis is not an impeachment of any aspect of the trauma system but rather an attempt to identify knowledge gaps to apply resources to substantively improve combat casualty care across the battlefield in the future.

CONCLUSION

Most battlefield casualties die of their injuries before ever reaching a surgeon. As most deaths are NS, mitigation strategies to impact outcomes in this population need to be directed toward injury prevention. To impact the outcome of combat casualties with PS injury, strategies must be developed to mitigate hemorrhage on the battlefield, optimize airway management, and decrease the time from point of injury to surgical intervention. The most substantial, although not exclusive, opportunity to improve these casualty outcomes seems to be in the pre-MTF setting.

Understanding battlefield mortality is a vital component of the military trauma system. Future studies should focus on casualty deaths both before and after reaching the MTF, exploring strategies to impact and improve outcomes. Our analysis suggests that a continuous real-time review of combat fatalities should be a component of the trauma system as a means to evaluate and make concurrent improvements in combat casualty care. This analysis demonstrates that emphasis should be placed on trauma system optimization, evidence-based TCCC improvements, and a comprehensive ongoing analysis of all deaths. This approach will result in data-driven research and device and doctrine development to remediate gaps in training and skill sustainment for immediate care of the combat casualty by all of deployed personnel. Approaching battlefield death in this fashion will result in even lower death rates in the next war.

AUTHORSHIP

B.J.E., R.L.M., J.C., L.O.-G., T.E.R., and L.H.B. contributed in the study design; B.J.E., R.L.M., P.S., J.C., T.T., P.U., O.M., T.Z., and L.O.-G. performed the data collection; B.J.E., R.L.M., and L.H.B. performed the data analysis; all authors participated in the preparation of the article.

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DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Holcomb JB, et al. Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. *Ann Surg*. 2007;245:986–991.
2. Eastridge BJ, et al. We don't know what we don't know: prehospital data in combat casualty care. *US Army Med Dep J*. 2011:11–14.
3. Holcomb JB, et al. Understanding combat casualty care statistics. *J Trauma*. 2006;60:397–401.
4. Butler FK. Tactical combat casualty care: update 2009. *J Trauma*. 2010; 69(Suppl 1):S10–S13.
5. Carey ME. Learning from traditional combat mortality and morbidity data used in the evaluation of combat medical care. *Mil Med*. 1987;152: 6–13.
6. Bellamy RF, Maningas PA, Vayer JS. Epidemiology of trauma: military experience. *Ann Emerg Med*. 1986;15:1384–1388.
7. Bellamy RF. The causes of death in conventional land warfare: implications for combat casualty care research. *Mil Med*. 1984;149:55–62.
8. Champion HR, et al. Improved characterization of combat injury. *J Trauma*. 2010;68:1139–1150.
9. Mabry RL, et al. United States Army Rangers in Somalia: an analysis of combat casualties on an urban battlefield. *J Trauma*. 2000;49:515–528; discussion 528–529.
10. Esposito TJ, et al. Analysis of preventable trauma deaths and inappropriate trauma care in a rural state. *J Trauma*. 1995;39:955–962.
11. Kelly J.F, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. *J Trauma*. 2008;64(suppl 2):S21–S26; discussion S26–S27.
12. Medicine IO. *Reducing the Burden of Injury: Advancing Prevention and Treatment*. Washington, DC: National Academy Press; 2003.
13. Champion HR, et al. A profile of combat injury. *J Trauma*. 2003; 54(suppl 5):S13–S19.
14. Hardaway RM 3rd. Viet Nam wound analysis. *J Trauma*. 1978;18: 635–643.
15. Hardaway RM 3rd. Care of the wounded of the United States Army from 1775 to 1991. *Surg Gynecol Obstet*. 1992;175:74–88.
16. Champion HR, Holcomb JB, Young LA. Injuries from explosions: physics, biophysics, pathology, and required research focus. *J Trauma*. 2009;66:1468–1477; discussion 1477.
17. Dismounted Complex Battle Injury, Report of the Army Dismounted Complex Blast Injury Task Force for the Surgeon General. Fort Sam Houston, Texas, June 18, 2011. Available at: http://www.armymedicine.army.mil/reports/DCBI%20Task%20Force%20Report%20(Redacted%20Final).pdf. Accessed July 2, 2012.
18. Savage E, et al. Tactical combat casualty care in the Canadian Forces: lessons learned from the Afghan war. *Can J Surg*. 2011;54: S118–S123.
19. Eastridge BJ, et al. Died of wounds on the battlefield: causation and implications for improving combat casualty care. *J Trauma*. 2011; 71(Suppl 1):S4–S8.
20. Bellamy RF. The medical effects of conventional weapons. *World J Surg*. 1992;16:888–992.
21. Blackbourne LH, et al. Decreasing killed in action and died of wounds rates in combat wounded. *J Trauma*. 2010;69(Suppl 1):S1–S4.
22. Kotwal RS, et al. Eliminating preventable death on the battlefield. *Arch Surg*. 2011;146:1350–1358.
23. Maughon JS. An inquiry into the nature of wounds resulting in killed in action in Vietnam. *Mil Med*. 1970;135:8–13.
24. Alam HB, Koustova E, Rhee P. Combat casualty care research: from bench to the battlefield. *World J Surg*. 2005;29(Suppl 1):S7–S11.
25. Morrison JJ, et al. Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) Study. *Arch Surg*. 2012;147: 113–119.
26. Roberts I, et al. The importance of early treatment with tranexamic acid in bleeding trauma patients: an exploratory analysis of the CRASH-2 randomised controlled trial. *Lancet*. 2011;377:1096–1101, 1101.e1–1101.e2.
27. Mabry RL, et al. Fatal airway injuries during Operation Enduring Freedom and Operation Iraqi Freedom. *Prehosp Emerg Care*. 2010;14:272–277.
28. Kragh JF Jr, et al. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma*. 2008;64(suppl 2):S38–S49; discussion S49–S50.
29. Kragh JF Jr, et al. Battle casualty survival with emergency tourniquet use to stop limb bleeding. *J Emerg Med*. 2011;41:590–597.
30. Kragh JF Jr, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg*. 2009;249:1–7.
31. Butler FK Jr, et al. Tactical combat casualty care 2007: evolving concepts and battlefield experience. *Mil Med*. 2007;172(Suppl 11):1–19.

32. Kheirabadi B. Evaluation of topical hemostatic agents for combat wound treatment. *US Army Med Dep J*. 2011:25–37.
33. Walters TJ, et al. Effectiveness of self-applied tourniquets in human volunteers. *Prehosp Emerg Care*. 2005;9:416–422.
34. Kheirabadi BS, et al. Comparison of new hemostatic granules/powders with currently deployed hemostatic products in a lethal model of extremity arterial hemorrhage in swine. *J Trauma*. 2009;66:316–326; discussion 327–328.
35. Butler FK Jr, Hagmann J, Butler EG. Tactical combat casualty care in special operations. *Mil Med*. 1996;161(Suppl):3–16.
36. Bowers W, Hughes CW. *Self-Help, First-Aid and Rescue. Surgical Philosophy in Mass Casualty Management*. Springfield, MA: Charles C. Thomas; 1960.
37. Blackbourne L. 1831. *US Army Med Dept J*. 2011:6–10.
38. Butler FK Jr. Tactical medicine training for SEAL mission commanders. *Mil Med*. 2001;66:625–631.
39. Mabry RL, De Lorenzo RA. Sharpening the edge: paramedic training for flight medics. *US Army Med Dep J*. 2011:92–100.
40. Mabry RL, De Lorenzo RA. Improving role I battlefield casualty care from point of injury to surgery. *US Army Med Dep J*. 2011:87–91.