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Maximizing Military Emergency Medicine

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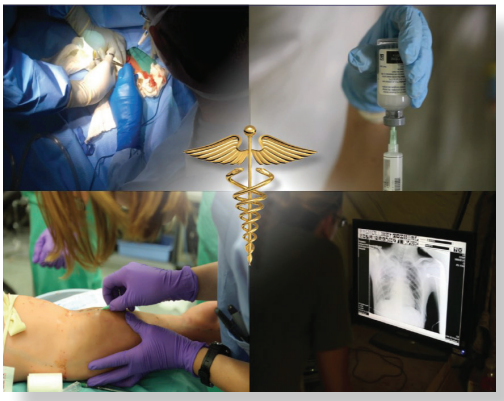

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Note from the Editor...

The Medical Journal continues its coverage of military emergency medicine in this issue. This is the second quarterly issue dedicated to the special focus topic, encompassing a wide swath of military emergency medicine issues, all of which seek to enhance and advance the field. From leadership to resuscitation, intubation to scholarly activity this issue offers a wide spectrum of research, lessons learned, as well as analyses.

Once again, *The Medical Journal* received an overwhelming number of submissions for this area of specialty, and we want to ensure it is shared with as many as possible in the field.

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Defining Combat-Relevant Endpoints for Early Trauma Resuscitation Research in a Resource-Constrained Civilian Setting

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Abstract

Introduction: Studies assessing early trauma resuscitation have used long-term endpoints, such as 28- or 30-day mortality or Glasgow Outcomes Scores at 6-months. These endpoints are convenient but may not accurately reflect the effect of early resuscitation. We sought expert opinion and consensus on endpoints and definitions of variables needed to conduct a Department of Defense- (DoD) funded study to epidemiologically assess combat-relevant mortality and morbidity due to timeliness of resuscitation among critically injured civilians internationally.

Methods: We conducted an online modified Delphi process with an international panel of civilian and US military experts. In several iterative rounds, experts reviewed background information, appraised relevant scientific evidence, provided comments, and rendered a vote on each variable. *A-priori*, we set consensus at ≥80% concordant votes.

Results: Twenty panelists participated with a 100% response rate. Eight items were presented, with the following outputs for the epidemiologic study: Assess mortality within 7-days of injury; assess multi-organ failure using SOFA scores measured early (at day 3) and late (at day 7); assess traumatic brain injury mortality early (≤7-days) and late (28-days); hybrid (anatomic and physiologic) injury severity scoring is optimal; capture comorbidities per the US National Trauma Data Standard list with specific additions; assign resuscitative interventions to one of five standardized phases of trauma care; and, use a novel trauma death categorization system.

Conclusions: A modified Delphi process yielded expert-ratified definitions and endpoints of variables necessary to conduct a combat-relevant epidemiologic study assessing outcomes due to early trauma resuscitation. Outputs may also benefit other groups conducting trauma resuscitation research.

Background

Trauma continues to be a leading cause of global morbidity and mortality in military and civilian populations alike.[1,2] Among US combat-wounded personnel, hemorrhage causes the overwhelming majority of early and preventable battlefield deaths, with about 90% of these battlefield casualties dying before ever reaching a military medical treatment facility.[1,3] In civilian populations, hemorrhage, traumatic brain injury, and multiple organ failure are leading causes of death and disability, with populations in lower income countries facing disproportionately worse outcomes compared to those in high income countries.[4-9] More effective and evidence-based interventions are needed to help reduce post-injury morbidity and mortality in military and civilian populations worldwide.

In critically injured persons, timely quality care can improve outcomes. The prehospital setting is the earliest opportunity to recognize life-threatening injuries and initiate life-saving interventions.[10-12] Life-saving interventions (as stipulated by Tactical Casualty Combat Care (TCCC) and Prehospital Trauma Life Support (PHTLS)) often need to be delivered within the first few critical minutes to hours post injury to avert death and minimize morbidity.[13-16] Prior studies have demonstrated that an early mortality peak exists within the first

24-hours, thereby challenging older tenets regarding bimodal or trimodal distributions of death.[15,17] Additionally, it has been demonstrated that early resuscitative interventions reduce instances of short-term morbidity, such as multiple organ failure, which in turn positively influences disability and survival.[18] Yet, the majority of prior studies assessing early trauma resuscitation have used long-term endpoints, such as 28- or 30-day mortality or Glasgow Outcomes Scores at 6-months, which are convenient but may not accurately reflect the effect of early resuscitation.[19]

In a recent commentary, a team of trauma investigators noted that only five prospective trials have been conducted since 2008, which have enabled a data-driven and physiologically-based discussion of endpoints.[19] In 2019 and 2020, the US Department of Defense funded a pair of research studies titled, "The Epidemiology and Outcomes of Prolonged Trauma Care (EpiC): a Multicenter Prehospital Observational Study in the Western Cape of South Africa."[20,21] The goal of EpiC is to epidemiologically assess combat-relevant mortality and morbidity outcomes due to timeliness of pre- and in-hospital resuscitation of critically injured civilians. EpiC will be conducted in a high-volume trauma, but resource-constrained, setting located in the Western Cape province of South Africa. Since no widely accepted standardized definitions or endpoints exist for studies on early trauma resuscitation, the EpiC study investigators sought expert opinion and consensus.

Methods

We used a modified Delphi process, a widely used methodology to determine expert group consensus where there is little or no definitive evidence and where opinion is important. The modified Delphi process includes iterative cycles of discussion and voting to facilitate arrival at an expert consensus.[22]

Ethical Approval: The Colorado Multiple Institutional Review Board (COMIRB) determined protocol application 19-1872 as exempt from IRB oversight, and the US Army Medical Research and Development Command Human Research Protections Office (HRPO) reviewed submission E01142.1a and concurred with COMIRB exemption.

Panel Selection: To satisfy multiple contextual aspects of our study, we invited a multi-disciplinary panel of experts and thought leaders representing military and civilian clinicians and researchers from the US and South Africa with expertise in military operational medicine, emergency medicine, prehospital care, trauma, and surgical critical care. We selected the expert panel members via a discussion among the study's investigator team. *A-priori*, we set a goal of 18-22 panelists, which allowed a balance of logistic feasibility with panel diversity.

Literature Review & Synthesis of Evidence: We started by reviewing the list of variables relevant to answer the EpiC research questions of morbidity and mortality outcomes due to early resuscitation in trauma patients. Via discussion, we created a shortlist of ambiguous variables. We performed a literature review in PubMed to understand how prior relevant trauma studies had defined these ambiguous variables. We collated and prepared relevant findings for presentation to the expert panel as the evidence-basis for the modified Delphi process.

Delphi Format: We chose an online survey platform as the optimal format for consensus-building, considering the wide geographic distribution of panel members and the challenges with trying to convene them in person. We selected a secure electronic data capture tool hosted at University of Colorado, called Research Electronic Data Capture (REDCap), as the electronic survey platform.[23] First, we created and pilot tested all REDCap surveys prior to distributing to panelists. We sent individual panelists a link to the electronic survey via e-mail during each survey round. In each round of the REDCap survey, we presented panelists with background information, relevant data from prior studies, and asked specific questions, organized by topic areas. Panelists completed the surveys independently and entered their own data directly into REDCap (i.e., electronically). We anticipated and planned to conduct several rounds of consensus-building, each round providing ample opportunity for comments and opinions, consistent with the modified Delphi methodology.[24]

We commenced the panel process on June 16, 2020 and ended on August 24, 2020. In the first consensus round, we introduced the variables as "items" to the panel by explaining the relevance and challenges associated with the variable for the EpiC study. For each item, we took the following approach: (i) Explained the evidence-base regarding that variable; (ii) provided relevant data and references; (iii) proposed a solution for using the variable in the EpiC study; (iv) posed a series of questions to the expert panel; (v) collected their opinions and comments; and (vi) asked for their vote on each item. We conducted item voting using a three-point scale (e.g., agree, agree with a caveat, or disagree).

Panelists were anonymous to each other but identifiable by the investigators. In subsequent rounds, we provided panelists with a blinded summary of comments and opinions from the prior round, to allow panelists to consider divergent opinions and approaches. Items

approaching consensus were reintroduced in subsequent rounds with relevant opinions and comments from the expert panel. Items with extreme divergence in opinion, and for which consensus would be highly unlikely, did not advance to subsequent rounds. Similarly, items that reached consensus in a particular round did not advance to the next round.

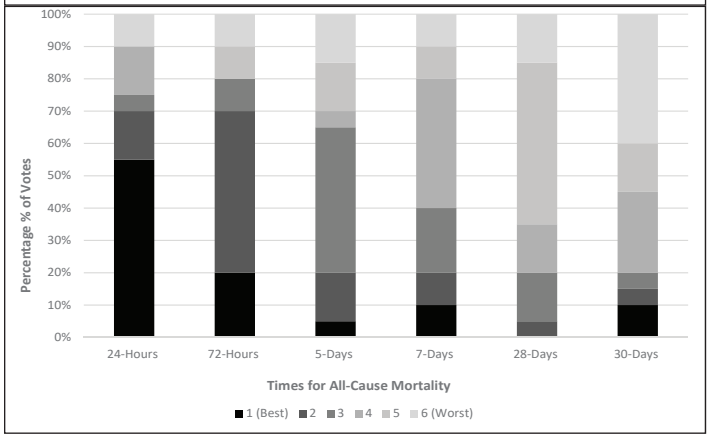
Data Collection & Analysis: We collected and stored data (i.e., comments and votes) in REDCap.[23] After each round, we downloaded data from REDCap, collated and reviewed the feedback and totaled the votes. We descriptively analyzed quantitative results with proportions and percentages. We analyzed feedback and comments qualitatively by grouping similar comments that were for or against each item. *A-priori*, we defined consensus as greater than or equal to 80% of similar votes on one item. After the final results were analyzed, we presented a draft report to the large panel for final comments and ratification.

Results

We selected 20 panelists, 17 (85%) from the US and 3 (15%) from South Africa, with 12 (60%) military and 8 (40%) civilian. Expertise represented in the panel included prehospital care (7, 35%), emergency medicine (7, 35%), trauma surgery (8, 40%), and critical care (6, 30%)—multiple experts had more than one core area of expertise. We presented a total of 8 items to the expert panel, which required three modified Delphi rounds. We had a response rate of 100% for each round. The findings are as follows:

Item 1) All-Cause Mortality Endpoint: Panelists did not reach consensus on a specific time-point at which all-cause mortality should be measured as the primary outcome of the study (i.e., 24-hrs, 72-hrs, 5-days, 7-days, 28-days, or 30-days). However, most panelists strongly preferred earlier time-points as opposed to later time-points (65% versus 20% voted an early versus a late time, respectively, as one of their top 3 preferences) (Figure 1). One panelist stated, "If our intention is to study the mortality associated with the trauma itself (and the effects of co-morbidities), the earliest endpoint is most accurate [...]." Panelists' comments support that they were most in favor of 24-hr, 72-hr, and 7-day mortality for EpiC (Table 1), with few supporting a 5-day mortality time-point. Overall, panelists explained that 24-hour mortality is the best period to reflect prehospital and early hospital interventions, including life-saving interventions e.g., airway management and catastrophic bleeding control. Panelists in favor of 72-hour mortality explained that 24-hours could be too early and 24-hours mostly reflects outcomes among the non-survivable group, whereas 72-hours would reflect outcomes of both very early and on-going resuscitation e.g., on-scene hemorrhage control plus on-going hemodynamic support in the first 48-hours. Those in favor of 7-days explained that measuring mortality at 7-days reflects a combination of the non-survivable group plus those with early deaths, plus patients with significant morbidity (e.g., multi-organ failure) due to early resuscitative interventions.

Figure 1. Panel ranking of all-cause mortality time points (N=20). Bars show the proportions of votes for each item (N=20), ranging from the top choice (i.e., "1-best", darkest shade) to the bottom choice (i.e., "6–worst", lightest shade).



Item 2) Organ Failure Outcome: The panel reached consensus that the Sequential Organ Failure Assessment (SOFA) score (80%) should be used to assess multi-organ failure, in lieu of the Marshall or Denver organ failure scoring systems.[25-27] Panelists commented that since the three organ failure scoring systems had similar input variables and comparable test performance characteristics (e.g., sensitivity, positive predictive value, area under the receiver operated curve), SOFA should be selected for practicality, because SOFA is most widely used internationally and in South Africa—hence, this would promote completeness of data and comparability of organ failure with other international trauma studies. Regarding time-points to measure SOFA scores, panelists unanimously agreed with assessing both an early SOFA score (defined as within 72-hours post-admission) and a late SOFA score (defined as between 4- to 7-days post-admission). In support, panelists explained that measuring early and late SOFA scores "best captures hemorrhage and perfusion," and "best captures neurologic injury and pulmonary injury (likely driven by pro inflammatory states and acute respiratory distress syndrome

(ARDS)." Several panelists commented that to improve standardization of data collection, the early and late SOFA scores should be calculated at (or as close to, as possible) 72-hours and 7-days, post-admission.

Item 3) Traumatic Brain Injury Morbidity Outcomes: The panel reached consensus that discharge destination (95%) and Glasgow Coma Scale (GCS) score at discharge (85%) should be used as outcome measures for TBI patients. The panel acknowledged that although both measures had limitations, resource and practical limitations would limit the study personnel's ability to reliably collect traditional 'gold-standard' TBI outcome measures, such as Extended Glasgow Outcomes Score (GOS-E).[28] Many panelists explained that using discharge destination would pose limitations in comparing study outcomes with non-South Africa (civilian and military) health systems. Panelists also noted that GCS is a poor neurologic functional measure and that using GCS at discharge is an "off-label" use of the score, both factors resulting in poor sensitivity for patients with milder neurologic or functional impairment.

Item 4) Traumatic Brain Injury Mortality Endpoint: Regarding the ideal time-point at which to assess for mortality among TBI patients, the panel voted in favor of both an earlier endpoint, at 7-days, and a later endpoint, at 28-days (7-days versus 28-days were voted on equally as often as the top two choices by 65% of panelists) (Figure 2). One (5%) panelist voted to assess mortality before 7-days, one (5%) voted for 14-days, and three (15%) voted for in-hospital mortality at any time as their primary preference. Selected

Table 1. Representative comments regarding earlier time-points to assess mortality.

24-hours	72-hours	7-days
Early 24-hour deaths best reflection of resuscitation interventions *… early death typically due to hemorrhage.* *Prehospital care would most accurately be reflected in near term mortality (within 24 hours) where times further out would increasingly factor in in-hospital management.* *24-hour mortality relates to the acute EM/resuscitation phase.* *24-hour mortality is most likely to reflect the influence of prehospital interventions… and reflects the initial operative management.* *Majority of trauma deaths occur within 24-hours and more likely reflect prehospital interventions.* *Hemorrhagic death occurs within 3-6 hrs. of injury. TBI death occurs 24-72 hrs. after injury. In reality there are very different time lines for the different disease states…* *The recent NIH recommendation settled on 6-hour mortality as the best outcome for hemorrhage-specific deaths. However, since this study is representing prolonged field care, extending to 72 hours outcome is probably reasonable…The earlier deaths would include hemorrhage and severe TBI…*	*If hemorrhage and TBI relevant then 72 hours would be best…* *72-hours best to evaluate appropriate EM care in those with survivable injuries* *Given this is a prehospital outcomes study, I think that 24 is too short (gets at the resuscitation and terminal injuries) and 7 is too long (gets into the ED and hospital interventions).* *Interventions in the ED are likely to be directed at immediate life threats-loss of airway, decompensated shock, large or tension pneumothorax, severe extremity hemorrhage, etc. Failure to correct these may result in a very early death…However, the 24-hr. time point most accurately reflects ED and prehospital care. I believe the 72-hr. mortality may be indicative of how effective efforts at hemorrhage control were.* *… my concern with 24 hours is that may reflect underlying injury that is resistant to the effect of any prehospital/ED care. To me, 3-5 days is probably the most reasonable, as I think 7 days is getting beyond the ED and more into post-ED care.* *24h may reflect burden of disease (i.e.; non-survivable injuries). 72h will capture effects of prehospital/ED care. 7d presents too many confounding variables for accurate assessment of prehospital/ED care.* *There is a significant second mortality peak on day #3 post-trauma resuscitation.*	*… (72-hours) is a little early to really capture the multi system organ failure deaths.* *… 7 days good to witness combination of emergency and early trauma care (7-d preferred since that's what most studies used).* *To capture the theoretical most common sequelae of PFC resuscitation (end-organ failure, sepsis, coagulopathy), 24 hours is simply too soon. 7 days will optimize any unpredicted 2nd and 3rd order morbidities while still controlling for the pre-hospital and early resuscitation interventions.* *I think anything less than 5 days would not reflect optimal management in the ED (i.e. hypotensive episodes in severe TBI, multi-organ failure after significant oxygen debt). 28 and 30 are great but often a reflection of complications beyond the control of Prehospital/Early Resuscitation care.* *7 days will provide a slightly longer and more complete time end-point that should be more comparable to other countries. While 24-hrs or 72-hrs may be ok for hemorrhagic shock and early TBI mortality, these are too soon for a heterogeneous group of trauma patients.*

Figure 2. Mortality time points for traumatic brain injury (N=20). Each bar shows the proportions of votes for that item (N=20), ranging from the top choice (i.e., "1-best", darkest shade) to the bottom choice (i.e., "6–worst", lightest shade).

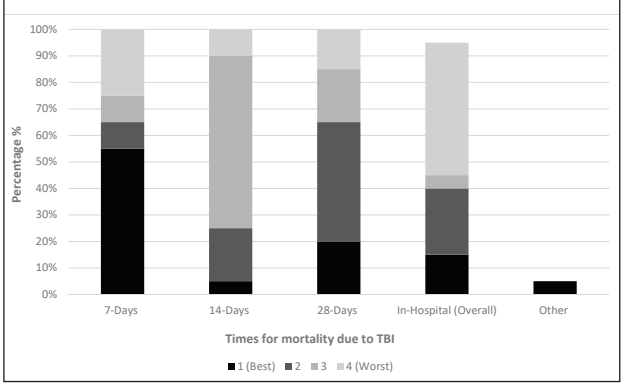


Table 2. Representative comments regarding time-points to assess traumatic brain injury (TBI) mortality.

7-days	28-days
Death from severe TBI occurs within the first few days, after that you will capture many deaths from pneumonia, respiratory failure, and other organ failure. *7 day best for tbi associated mortality, 28 days next most appropriate.* *TBI mortality tends to have a bimodal distribution in terms of mortality, either within a day or so, or weeks.* *While 7d mortality is more temporally related to prehospital care, I am unsure if that is truly reflective of mortality due to prehospital care…* *In general, the longer the length of stay, the less likely the death is directly related to lack of prehospital care…there will be exceptions to this line of thinking…* *The effect of acute care on TBI mortality is more pronounced in the short term. But its effects on morbidity may be more pronounced later on.* *7 days is long enough for the deaths from acute physiologic derangements to be manifest. It will also capture those that had catastrophic injuries and were completely non survivable- unfortunate because those are going to be fatalities regardless of ED care.*	*TBI often lingers and may die even long after ICU discharge while awaiting final down referral* *28 days to keep consistency with previous studies. In hospital may be more easily obtained but will be dependent on discharge resources, limiting generalizability.* *In-hospital mortality is most common outcome for all trauma in US, so comparable, but crude and with different LOS reflects large variability of time surveillance. Need at least 1 month to assess effect of TBI.* *TBI mortality is often delayed and subsequent to other variables (iatrogenesis, days in hospital, quality of upper airway assessment/protection to prevent aspiration)*

Table 3. System for categorizing trauma deaths.

Mechanism of Injury (MOI)	
Category	**Definition**
Firearm	a firearm related injury
Struck/hit	blunt trauma by person or object
Stabbing or cut	inflicted by a human or object
Vehicular Injury	occupant, ejected occupant, or pedestrian
Fall	from ground level or height (not from a vehicle)
Thermal	fire, flames or heat
Choking/hanging	circumferential blunt trauma to neck
Iatrogenic	complications from care
Other	none of above categories
Unknown	pending investigation or unknown
Cause of Death	
Single blunt force injury	
Multiple blunt force injury	
Single penetrating injury	
Multiple penetrating injury	
Blast	
Thermal	
Other	
Iatrogenic	
Unknown	
Mechanism of Death	
Main category	**Sub-categories**
Catastrophic tissue destruction	• Total body (physical dismemberment) • Brain • Cardiac • Open pelvis • Extremity amputation • Abdominal aorta • Thoracic aorta • Incineration • Other (major vessel, liver, trachea)
CNS (central nervous system) injury	• Brain • Brain stem • High cervical spine (at or higher than C3)
Hemorrhage or exsanguination	• Truncal • Extremity • Junctional
Multiple organ failure + Sepsis	• Brain • Cardiac failure • Coagulopathy • Liver failure • Pulmonary failure • Renal failure • Sepsis
Comorbidities	• A significant underlying (medical) disease that directly caused death
Other	• Airway • Breathing • Lung (i.e., penetrating lung injury impairing airway & breathing with hemorrhage) • Cardiac tamponade • Tension pneumothorax • Pulmonary Embolism • Full thickness burns/incineration • Physiologic collapse • Sequalae of injury • Other (including iatrogenesis)
Unknown	• No cause identified

comments from the panel on 7- versus 14-day mortality are in Table 2. One panelist commented:

"The aim of your study is short-term mortality outcomes. The best way to review TBI outcomes (especially with respect to disability) is longer term, which is beyond the scope of this study. Rather keep the TBI outcome scoring simpler and accept the associated limitations than making your study impossible."

Panelists supporting 7-days explained that a shorter outcomes period best reflects the effect of early (i.e. prehospital and ED) resuscitation and helps delineate early survivable versus non-survivable head injuries. Panelists justified 28-days because TBI patients may die long after admission, and 28-days allows comparisons to other TBI studies.

*Item 5) A System for Categorizing Trauma Death*s: First, the panel agreed on semantics for three key terms for death categorization (Table 3), as follows:

- Mechanism of injury (MOI): determined by what created the injury (100% consensus).
- Cause of death (COD): the injury or disease that produces a physiologic derangement that results in death (95% consensus).
- Mechanism of death (MOD): the physiological derangement produced by the COD that results in death (100% consensus).

Next, the panel reached consensus on the contents we proposed within each subsection of the categorization system: MOI (100%), COD (95%) and MOD (85%). Panelists had a few minor concerns and suggestions, summarized as follows:

- MOI subsection: Delineate the difference between "Struck/hit" and "Vehicular injury" in the codebook. Split "Vehicular injury" into "MVC (occupant)", "Auto vs pedestrian", and "Other".
- COD subsection: "Clearly define iatrogenic in the codebook."
- MOD subsection: "MOF can occur in the absence of sepsis and this seems to unnecessarily restrict this category." "… extremity amputation is only catastrophic if it encroaches on the torso."

The final categorization system presented in Table 3.

Item 6) Phases of Care in Trauma Resuscitation: The panel reached consensus (90%) regarding the concept of assigning trauma interventions to pre-determined standard phases of care. Additionally, 90% of panelists agreed with five standardized phases of care that were presented (i.e., initial resuscitation, damage control surgery, intensive care, definitive surgery and

post-intensive care). The panel did advise that prehospital and emergency department resuscitative interventions should be differentiated within the initial resuscitation phase: "You should split out prehospital from initial in-hospital resuscitation as these are two (mostly) different groups with different training, tools, and thinking." Since the specific location or unit of a procedure can vary across health systems, the standard phases of care beyond initial resuscitation are agnostic to the physical location in which they were performed (e.g., an emergent craniostomy may be performed in the emergency department and not the operating room). The final standardized phases and definitions of care are as follows:

> [1] Initial resuscitation phase (initial resuscitation which includes primary & secondary resuscitation [e.g. TCCC, ATLS, PHTLS], and damage control resuscitation [to prevent the lethal triad: hypothermia, acidosis and coagulopathy])
>
> [1a] Prehospital phase,
>
> [1b] Emergency Department phase;
>
> [2] Damage control surgery phase (includes initial or abbreviated surgery to control hemorrhage and contamination);
>
> [3] Intensive care phase (ICU and on-going care for physiological restoration through active rewarming, correcting coagulopathy and acidosis);
>
> [4] Definitive surgery phase (definitive repair of injuries temporized during damage control surgery that usually starts 24-48 hours following initial surgery);
>
> [5] Post-intensive care phase (In-hospital care beyond ICU care and definitive surgery phase i.e. in-hospital supportive and recuperative care).

Item 7) Pre-existing conditions and comorbidities: The panel reached unanimous consensus (100%) that the US National Trauma Data Standard (NTDS)[29] list of comorbidities should be used for the study. Additionally, panelists proposed that several relevant comorbidities should be added to the NTDS list in consideration of the South African burden of disease and contemporary evidence-based trauma risk factors. The following additional pre-existing conditions and comorbidities reached consensus: anemia (90%), hepatitis (95%), HIV/AIDS (85%), malnutrition (90%), obesity (95%), peptic ulcer disease (80%), prior traumatic brain injury (95%), and tuberculosis (90%). The following did not reach consensus: connective tissue disease (20%), osteoporosis/osteopenia (70%), paraplegia (70%), porphyria (60%), quadriplegia (65%), and hemiplegia (60%). Panelists justified including the additional comorbidities as follows: "South Africa is a community with high rates of HIV and TB…"; "Hepatitis may increase the risk of bleeding disorders due to impaired liver function"; "Preexisting anemia in trauma is not well described & is worthy of investigation"; "Obesity is an increasing problem & merits description in the context of trauma"; " DoD in particular may be interested in the clinical course of trauma patients who have suffered previous TBI…"; and "Adjust this list to accommodate comorbidities found in the region of study."

Item 8) Trauma Severity Scores: The panel reached consensus (90%) in favor of a hybrid (i.e., anatomic and physiologic) trauma scoring system instead of an anatomic or physiologic trauma scoring system. We presented the panel with hybrid scores that had the best reported performance characteristics, which included the Kampala Trauma Score (KTS); Mechanism, Glasgow Comma Scale, Age, Blood Pressure score (MGAP); and the Trauma-related injury severity score (TRISS).[30-32] Panelists agreed that hybrid scoring systems provide the benefits of both anatomic and physiologic systems. A few panelists who supported hybrid scores cautioned us to anticipate missing or inaccurate GCS scoring, emphasized the importance of consistent application of hybrid scoring, and underscored concerns with obtaining with accurate anatomic scoring for patients who die in ambulance. The two panelists who did not support use of hybrid trauma scores explained that combined scores have limitations in children and the elderly, and that separately assessing anatomic and physiologic scores could be more helpful.

Discussion

The modified Delphi process proved a pragmatic methodology to allow a multi-disciplinary panel of experts to agree on, and contextually tailor, critical variables needed to conduct the EpiC study.[22,24] EpiC is a combat-relevant epidemiologic study to assess morbidity and mortality due to timeliness of resuscitation in a resource-constrained, international civilian setting.[20,21] We will use outputs from the expert panel in EpiC in the following way: We will assess death within 7-days of injury; we will assess multi-organ failure using SOFA scores measured early (at day 3) and late (at day 7); we will assess TBI mortality at early (within 7-days) and late (at 28-days) time points; we will use a hybrid (i.e., anatomic and physiologic) injury severity scoring tool; we will capture comorbidities according to an expanded NTDS list; we will assign all resuscitative trauma interventions to one of five standardized phases of trauma care; and we will code all deaths according to a novel trauma death categorization system.

Our planned use of expert-ratified variables to conduct a combat-relevant research study internationally is a contemporary approach to filling scientific gaps in trauma

care. In general, it is extremely challenging to study research on critical injury, particularly from the point of injury.[33] Even more challenging is studying trauma in a combat theater, where research is further constrained by a hostile environment and lack of accurate documentation.[34] While combat-relevant studies in US civilian populations have contributed important findings, these have faced considerable limitations including differing injury profiles among US civilians, relatively short durations and distances to definitive care in the US, and low caseloads which hamper study enrollment.[35-40] Lessons learned from global health can help.[41] For example, revolutionary advances with HIV and tuberculosis treatments were realized through ethically-responsible research conducted in ideal settings outside the US conducted by US-sponsored research collaboratives.[41] The DoD-sponsored EpiC study, as an example, embodies these principles by bringing together US and South African researchers, sponsored by the US DoD, to study combat-relevant trauma in an ideal international setting featuring a high prevalence of critical injuries, post-injury mortality rates, resource-limited care, prolonged durations of care, and a stage-wise progression of care through a tiered trauma care system.[42-45] Combined, these features make the Western Cape exceptionally combat-relevant for trauma research.[46]

Aside from benefiting the EpiC study, the expert panel consensus outputs also help to advance thinking around time-based trauma resuscitation research. Specifically, our consensus process directly builds upon a landmark report from a 2008 meeting of physicians, ethicists, and statisticians from academia, industry, and several governmental health organizations who concluded that new, earlier time points were needed for prehospital and emergency department focused trauma resuscitations studies.[47] Endpoints for resuscitation and hemorrhage control studies have traditionally been 28- or 30-day mortality, which are arbitrary and convenient, rather than biologically-based. Our expert panel outputs help to advance the body of knowledge on this topic—the panel considered the existing military and civilian evidence, in addition to the context and objectives of our study, to recommend several early endpoints for conducting a trauma resuscitation research study. The consensus findings from this modified Delphi process may be useful for early trauma resuscitation research by others, in military or civilian application in the US and internationally. Moreover, this study informs the larger DoD-funded effort and ensures that our epidemiology study has maximal applicability and efficacy in policy making.

Importantly, our study offers the opportunity for the US-based EpiC investigators to work with South Africa collaborators and stakeholders, including forensic pathologists, to ensure the project satisfies local needs and informs local trauma care improvements while benefiting the DoD. This collaboration sets the framework for a platform for future DoD-supported investigations that improve the science of trauma care relevant to the combat setting while simultaneously building up research infrastructure in South Africa and improving the care delivered via a data-driven approach.

Limitations

The modified Delphi process did not occur as a concurrent group meeting, which may have limited the richness of discussions and limited the perspectives or opinions provided. Additionally, since we presented focused issues for consensus-building, it is possible there was additional input we failed to solicit, although we provided opportunities for many comments, including those that were off topic. Last, the multi-disciplinary panel did not include a forensic pathologist although we included multiple experts who had conducted mortality and preventable mortality studies.

Conclusion

We successfully used a modified Delphi process to reach expert consensus on customized variables relevant for conducting time-based trauma resuscitation research in a resource-constrained international setting. The panel ratified combat-relevant contemporary definitions and end-points including mortality, multiple-organ failure, head injury outcomes, injury severity scoring, and trauma comorbidities. Outputs will be critical for conducting the EpiC study and may benefit other groups conducting trauma resuscitation research.

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Comparing the Sensitivity of a Low Frequency Versus a High Frequency Probe in the Detection of Pneumothorax in a Swine Model

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Abstract

Background: Correct diagnosis of pneumothorax in trauma patients is essential. Under-diagnosis can lead to development of life-threatening tension pneumothorax, but overdiagnosis leads to placement of unnecessary chest tubes with potential related morbidity and pain. It is unclear from previous work if there is a benefit to switching from the phased array (low frequency) probe to the linear (high frequency) probe. Is the improvement in image quality worth the time lost changing probes?

Methods: We compared the sensitivity and specificity of a low frequency and high frequency ultrasound probe for the detection of pneumothorax. Images were obtained using swine models and were interpreted by Emergency Medicine residents, attendings, and physician assistants.

Results: We found a specificity of 89% and sensitivity of 99% for the low frequency probe and specificity of 96% and sensitivity of 99% for the high frequency probe. There was a statistically different specificity between the two probes, suggesting that the linear probe may be the superior probe for confirming the presence of pneumothorax.

Conclusion: We conclude switching to the linear probe for the thoracic portion of the Extended-Focused Assessment in Trauma will lead to more accurate diagnosis of pneumothorax and decreased false-positive exams.

Introduction

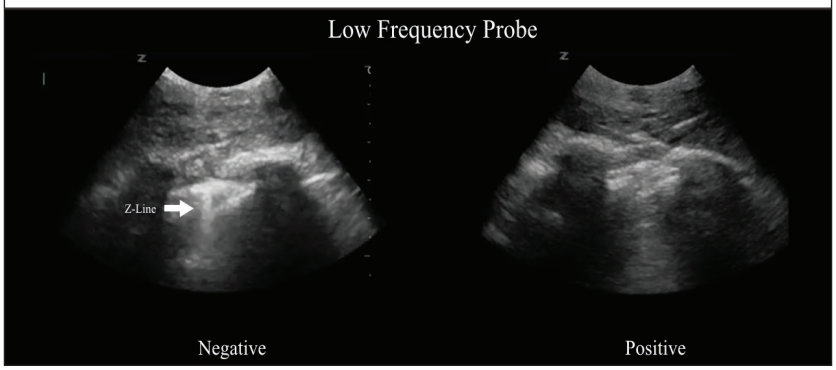
Tension pneumothorax is one of the leading causes of preventable battlefield death.[1] Pneumothorax is present in 20% of all patients presenting with trauma and up to 50% of patients with severe chest trauma.[2,3] The traditional approach to the diagnosis of pneumothorax includes the use of an initial single view supine chest x-ray (CXR) followed by a thoracic computed tomography (CT) scan in stable patients.[4] This approach can be difficult to replicate in a deployed environment where CXR may be only intermittently available and CT often requires an evacuation.

In the field or in a Role 1 facility medical providers may perform bilateral needle decompressions (NCD) to preemptively treat for tension pneumothorax. While this is a completely reasonable approach in the absence of any advanced imaging, it can lead to severe complications, including failure to evacuate a pneumothorax due to insufficient catheter length, damage to vascular structures or the introduction of an infection or iatrogenic pneumothorax.[5,6] Placement of an NCD also leads to the placement of a tube thoracostomy (TT), which is independently associated with an increased incidence of pneumonia and retained hemothorax in one study evaluating a military population.[7] Ultrasound may be useful as a type of portable imaging which could identify which soldiers need NCD or TT in the pre-hospital or Role 1 environment.[8]

Ultrasound has a sensitivity of 86-98% for pneumothorax, compared to 28-75% for the traditional single view CXR, with both ultrasound and CXR having a specificity of greater than 95%.[9] Given its portability and accuracy, ultrasound offers significant benefits for the

diagnosis of pneumothorax in the operational setting.[10,11]

Figure 1. Example of low frequency probe images.



Diagnosis of pneumothorax on lung ultrasound is straightforward and relies on the visualization of the "pleural line" which consists of the visceral and parietal pleura. The pleural line is seen as a horizontal, hyperechoic (bright white) line just beneath the ribs, when looking at an intercostal space in a sagittal plane. Lung sliding, which is seen during a respiratory cycle as the parietal and visceral pleural move adjacent to one another, is visualized as movement of the pleural line. Additionally, the presence of Z-lines, described as vertical hyperechoic artifacts (short white lines) arising from the pleural line, indicate that subpleural lung parenchyma is present. The absence of lung sliding and the absence of Z-lines indicates a separation of the visceral and parietal pleura by air, such as in a pneumothorax.[12-17]

Previous studies and reports have used both high and low frequency probes for the identification of pneumothorax, with the gold standard being either CXR or CT.[9,11,18] Some experts have recommended using the high frequency probe due to better delineation of small superficial structures, such as the pleura, while others recommend using a low frequency phased array or curvilinear probe.[15,17] Emergency Medicine (EM) physicians, however, may prefer the lower frequency probe because it was likely just used for the abdominal portion of the E-FAST exam or because they are avoiding loss of time while switching probes. *The Advanced Trauma Life Support 10th Edition* remarks only that ultrasound can be used for the evaluation of pneumothorax without recommending a specific probe.[19]

One previous meta-analysis combined a wide variety of studies using ultrasound for the diagnosis of both traumatic and non-traumatic pneumothorax in the emergency department (ED) and intensive care unit (ICU). In that study, the authors reported a pooled sensitivity of the high frequency probe of 82.2% compared to 76% for the low frequency probe.[20] A second single-center study directly compared the performance of a high frequency probe compared to a low frequency probe for the evaluation of different lung pathologies, including pneumothorax, in an intensive care unit. Interpretation of the studies was performed by a pulmonologist. The authors reported that the high frequency probe had a sensitivity of 83% and a specificity of 100%, while the low frequency probe had a sensitivity of 67% and a specificity of 100%.[21] No previous attempt has been made to directly compare high and low frequency probes for the evaluation of pneumothorax by EM physicians and EM physician assistants (EMPAs) or isolated to the detection of traumatic pneumothorax. In this study, we address the ability of EM physicians and EMPAs to interpret ultrasound clips and diagnose pneumothorax with a low frequency prove vs. high frequency probe.

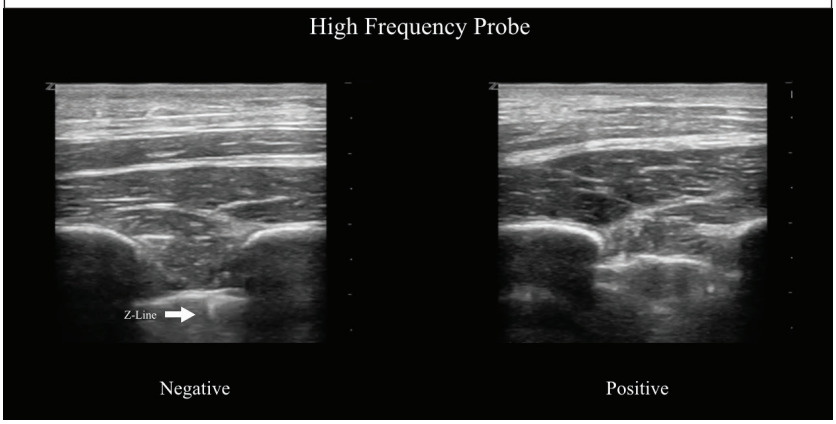
Methods

This was a prospective randomized study evaluating the ability of EM Physicians and EMPAs to evaluate video clips demonstrating the presence or absence of pneumothorax. A research protocol was reviewed and approved by the San Antonio Military Medical Center Institutional Review Board. A separate animal use protocol, as well as the research protocol, were reviewed and approved by the Lackland Veterinary Service and Institutional Animal Care and Use Committee. Six-second video clips of the right hemithorax of a swine model were obtained using a cart-based portable ultrasound. Clips were obtained with the curvilinear C1-4 MHz probe and the linear array L10-5 MHz probe. Clips demonstrating normal lung findings were obtained with both probes on a normal swine model. Following the acquisition of these clips, a needle was inserted into the thoracic cavity and 5mL/kg of air was instilled. Ultrasound was used to confirm the creation of a pneumothorax as agreed upon by RC and MM, both of whom are ultrasound experts. Both had completed 12-month ultrasound fellowship. RC is a Registered Diagnostic Medical Sonographer and MM is the Program Director for an Ultrasound Fellowship. The animal was under general anesthesia with appropriate pain control during the entirety of this time. Twenty clips showing pneumothorax were obtained and were reviewed for quality assurance by RC and MM. Example clips are shown in Figure 1 and Figure 2.

A slide show consisting of 10 high frequency and 10 low frequency clips was constructed. Six negative and 4 positive clips were included for each probe to replicate

normal clinical settings where negative exams are more common than positive exams. Clip order was randomized using a random number generator (www.random.org/integer). Associate investigators AB and JC enrolled a convenience sample of EM residents and faculty and EMPA residents and faculty. Participants were asked to interpret each slide on a tablet and record their answers on the datasheet (appendix A). Data was collected from each participant individually to ensure that participants did not share answers. The initial goal was to enroll 50 study participants. A total of 55 participants were enrolled in the study and completed the quiz and data collection sheet. Each interpreted clip was counted as an observation for purposes of the sensitivity and specificity calculation for a total of 1,100 observations. Participants were asked to complete a short questionnaire regarding their experience and ultrasound training as well as confidence with each probe. Confidence was recorded using a visual analog scale (Appendix A).

Figure 2. Example of high frequency probe images.



Responses were collated using a spreadsheet program and interpreted using statistical software. Confidence Intervals for sensitivity and specificity for each probe type were calculated using Wilson's Method for Exact Confidence Limits. Wilcoxon's Kruskal Wallis Test was performed for each demographic question to compare overall percent correct. Linear regression was used to analyze potential correlation between level of confidence and percentage of correct answers.

Results

The 55 participants were enrolled in the study, which met the initial goal of 50 participants. There were 23 EM residents, 1 EM ultrasound fellow, and 26 EM faculty were enrolled. 3 EMPA residents and 2 EMPA faculty enrolled. All 55 participants stated they had at least 16 hours of bedside ultrasound training. Forty-six participants stated that they completed a one-month rotation during residency which included the performance of 250 ultrasound exams with quality assurance as well as 20 hours of asynchronous education. This included education on the evaluation of pneumothorax with ultrasound. Four participants reported completion of advanced ultrasound training. There was no correlation between the level of training or level of confidence and percentage of correct answers (Tables 1 and 2). After consultation with the statistician, one participant was removed from the final analysis of confidence analysis because the participant's answers were extreme outliers. The participant in question circled "0' on the Visual Analog Scale for confidence for both the low and high frequency probe. While this didn't change the results in favor of either probe, it did significantly skew the final results for both probes and was an extreme outlier when compared to all other results.

Table 1. Correlation between provider type and training, and percent correct.

Factor	Level	Number	Percent Correct	Lower 95%	Upper 95%	Kruskal Wallis p-val
Provider Type	EMPA	5	98.0%	94.6%	101.4%	0.279
	Faculty	27	96.1%	94.6%	97.6%	
	Resident	23	93.9%	90.9%	97.0%	
1 month US Training	N	9	98.3%	96.4%	100.3%	0.068
	Y	46	94.8%	93.1%	96.5%	
Advanced US Fellowship	N	51	95.4%	93.8%	97.0%	0.406
	Y	4	95.0%	95.0%	95.0%	

Table 2. Correlation between confidence and percent correct.

Confidence in Probe Method	R-Squared	Prob>|t|
Linear	0.012	0.4299
Phased Array	0.036	0.1669
Curvilinear	0.029	0.2151

Table 3. Low and high frequency probe sensitivity and specificity.

Probe Type	Sensitivity	Specificity
Low	99.1% (97.8-100%)	89.7% (86.4-93.0%)*
High	98.6% (97.1-100%)	96.4% (94.3-98.4%)*

** Specificity was significantly lower for Low Probe Type vs High Probe Type p<0.001. Sensitivity was not significantly different between probe types p = 0.65.*

The low frequency probe was determined to have a sensitivity of 99.1% (95% CI, 97.8-100%) and specificity of 89.7% (95% CI, 86.4-94%). The high frequency probe

was determined to have a sensitivity of 98.6% (95% CI, 97.1-100%) and specificity of 96.4% (94.3-98.4%). The sensitivity of the high and low frequency probes was not statistically different (p=0.65). There was a statistical difference between the specificity of the probes (p=0.0011) with the high frequency probe determined to have a higher specificity (p=0.006) (Table 3).

Discussion

This study demonstrated an overall high level of sensitivity for the diagnosis of pneumothorax with both the high and low frequency probe with a significantly higher specificity with the high frequency probe. The sensitivity of both probes was near 100%. This was higher than in previous literature, likely because our design involved recorded clips under ideal circumstances.[16,22] This suggests that both the high and low frequency probe could be used to rule out pneumothorax. However, the high frequency probe had a significantly higher specificity which was likely due to multiple false-positive readings with the curvilinear probe. We suggest that this had two basic causes. First, and likely most important, the higher resolution of the linear probe allowed for more accurate interpretation of the clips. Secondly, the participants were aware that the study was evaluating for the diagnosis of pneumothorax and may have overcalled the diagnosis based on this knowledge. We suggest that the same pressure would be present in any patient presenting with concern for pneumothorax. Participants overall showed a preference for the linear probe based on recorded comments. Several participants wrote on the datasheet comments regarding both probes, with comments such as "It's the best" and "Best resolution but less convenient" recorded for the high frequency probe. The low frequency probe was described as "convenient" by one participant. However, the recorded level of confidence did not correlate with the degree of accuracy with any significance.

We found no correlation between advanced training and increased accuracy. All participants stated they had received at least 16 hours of training. Residents and EMPA residents at our facility go through a 16-hour introductory course which includes a lecture and hands-on education on lung ultrasound, and all attendings are EM physicians who have received training in point of care ultrasound. We conclude from this that EM physicians and EMPAs who have completed training similar to the introductory course used at our site can use ultrasound to evaluate for pneumothorax. This correlates with previously published data which reported greater than 95% sensitivity and specificity for pneumothorax after basic training.[23] We suggest that in operational environments it is reasonable to train all members of the care team to perform this important exam. Future studies should be performed to evaluate the amount of time required to switch from the low frequency probe to the high frequency probe and if this time leads to a significant effect on patient outcomes.

There were several limitations to our study. The clips collected were on an adult porcine model. The chest wall of a pig differs from a human in that the ribs are closer together and the thorax is longer with regards to the rest of the body. We evaluated image interpretation but not image acquisition. It is possible that it is easier to gather the pertinent images with the low frequency probe which would factor in the decision on which probe to use. This question could be addressed in future studies. Finally, this was a single-center study in which the majority of the participants had participated in a 16-hour in-house course that included the diagnosis of pneumothorax using the high-frequency probe. It is not known if these results would be generalizable to a provider in a deployed environment with minimal formal training.

Conclusion

We found the linear probe had a significantly higher specificity for the diagnosis of pneumothorax. Placement of an unnecessary chest tube causes significant pain to a patient and may lead to further unwanted downstream effects, such as empyema. Accurate diagnosis leads to the best patient care, and so we conclude a high frequency probe should be used for the evaluation of pneumothorax wherever possible.

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Appendix

Appendix 1. Data collection sheet.

Study Participant Self-reported Data

Date:_____

Y N Have you completed at least 16 hours of bedside ultrasound training? This training includes, but is not limited to, the intern ultrasound course.
Y N Have you completed a formal one month block of emergency ultrasound training as part of your formal emergency medicine curriculum?
Y N Have you completed advanced training in point of care ultrasound such as RDMS certification or an ultrasound fellowship?
What level of provider are you? (Circle one of the answers below)
Resident EMPA Resident Fellow Faculty EMPA faculty

Image Interpretation

	Positive	Negative
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Visual Analog Scale

Which transducer do you use most frequently for the detection of pneumothorax? (Circle one of the answers below)
Curvilinear Linear Phased-Array Other - please describe:
Why? (Circle one of the answers below)
That's how I was trained It is most convenient It doesn't really matter.

Please place a mark on the line below to indicate your level of confidence in each transducer to diagnose pneumothorax. A mark at the **0** point indicates a **very low** level of confidence and a mark at the **10** point indicates a **very high** level of confidence.

High Frequency Linear Probe
0 10
l----------l
Low High

Phased Array Probe
0 10
l----------l
Low High

Curvilinear Probe
0 10
l----------l
Low High

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Ultrasound at the Role 1: An Analysis of After-Action Reviews from the Prehospital Trauma Registry

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Abstract

Background: Ultrasound is a portable and adaptable imaging modality used widely in the care of trauma patients. The initial exam, known as the "Focused Assessment in Trauma (FAST) exam focused on the evaluation for hemoperitoneum and hemopericardium. In recent years, the exam has expanded to include evaluate for thoracic pathology, including pneumothorax, and is now known as the "Extended Focused Assessment in Trauma" (E-FAST) exam.

Methods: We reviewed after-action reviews (AAR) from the Joint Trauma System Prehospital Trauma Registry from 2013-2014 in which the use of an ultrasound exam was noted. Given the largely unstructured nature of the AARs, we selected relevant information from the free text available.

Results: Our initial dataset contained 705 casualties, of which we identified 45 cases containing the key words with AAR data for review: 39 cases involved the use of the FAST exam, three explicitly described the use of pulmonary ultrasound and they were categorized as E-FAST exams, two cases described the use of point of care echo to evaluate for cardiac standstill, and two cases described the use of ultrasound to evaluate for vascular injury. Of those with vital signs documented, 25% (11) reported at least one episode of tachycardia (≥120/min) and 16% (7) with at least one episode of systolic hypotension (<90mmHg). Of the 45 cases reviewed, six were recorded as equivocal, which we interpreted to indicate more training in either performance or interpretation of the exam was needed.

Conclusions: Our findings suggest that training in both the FAST exam and E-FAST has the potential to improve patient care for military trauma patients. A performance improvement system would enable real-time confirmation of findings and feedback for training and quality improvement.

Keywords: prehospital, ultrasound, combat, military, role 1, trauma

Introduction

Background: The Focused Assessment with Sonography in Trauma (FAST) exam is an essential part of the evaluation of the unstable trauma patient. Initially described more than 20 years ago, the early use of ultrasound focused on patients presenting with blunt abdominal trauma and focused on evaluating free fluid.[1,2] The first adopters proved the usefulness of point of care ultrasound (POCUS) in these patients, and ultrasound was increasingly incorporated into trauma guidelines.[3-5] The advantages of an exam that could be performed at the bedside of an unstable patient were quickly recognized, and the exam evolved into the "Extended" Focused Assessment with Sonography in Trauma (E-FAST) adding an evaluation for pneumothorax, in addition to hemoperitoneum, pericardial effusion, and hemothorax. When used appropriately as a triage tool and "rule-in" test, the E-FAST is an essential part of the care of trauma patients and has been incorporated into the Advanced Trauma Life Support System guidelines.[6]

Initially, "portable" ultrasounds were only portable compared to the machines found in radiology suites

and not practical for use outside of a fixed facility. However, the technology rapidly evolved, and soon portable ultrasounds were approximately the size of a laptop and suitable for the operational environment. Military medical providers quickly recognized the value of a portable diagnostic device to evaluate traumatic injuries and incorporated the use of the E-FAST exam into patient evaluations during combat operations in Iraq and Afghanistan.[7] Joint Trauma System (JTS) guidelines recognize the use of the E-FAST exam in the evaluation of critically ill trauma patients in both fixed facilities and the prehospital environment.[8,9] The E-FAST can provide a surgical team with information regarding injuries prior to the operating room, as well as allowing emergency physicians to reverse leading causes of early death, such as a tension pneumothorax. For thoracic trauma, the E-FAST has proved invaluable with extremely high sensitivity (86-98%) and specificity (97-100%) in the evaluation for pneumothorax, which far exceeds that of the single view supine chest x-ray (CXR) at 28-75%.[10] Ultrasound is at least comparable to the single view supine CXR in the evaluation of hemothorax with a sensitivity of 96% and specificity of 100%.[11,12]

The role of ultrasound continues to expand with recent use of this modality for confirmation of placement of a resuscitative endovascular balloon occlusion of the aorta (REBOA) catheter.[13] Although it is beyond the scope of this article focused on the use of ultrasound for trauma, recently there has been increased interest in the use of ultrasound for evaluation of disease non-battle injuries.[14] The advent of relatively inexpensive, highly portable handheld ultrasounds has pushed the use of ultrasound forward all the way to the point-of-injury.[15-17] Military physicians and physician assistants (PAs) have preliminarily investigated the potential for training medics to perform ultrasound, including the E-FAST with good results in early trials.[18] Despite the widespread use of ultrasound during military operations over the past 20 years, there is little data on the actual use at the Role 1.

Goal of this Study: We sought to perform an assessment of after-action reviews from the Prehospital Trauma Registry (PHTR) to identify how ultrasound is being utilized at Role 1 medical treatment areas and identify possible areas for improvement.

Materials & Methods

Ethics: The US Army Institute of Surgical Research regulatory office reviewed protocols and determined it was exempt from institutional review board oversight. We obtained only de-identified data.

Data Acquisition: The Joint Trauma System (JTS) collected AARs for combat casualties injured in the Afghanistan theater of operations between January 2013 and September 2014, which were then subsequently entered into the Prehospital Trauma Registry (PHTR) system. We have previously described our methods for AAR reviews.[19] We analyzed commentary from a free text comment section within the AAR using the search terms "ultrasound," "us," "fast." We then reviewed the free text reports to obtain data on the results when documented, along with any complications or technical problems encountered. We reported data in a descriptive format and supplemented by selected quotes taken from the sources to illustrate key themes. Investigators reviewed the AARs for relevance prior to study inclusion.

Prehospital Trauma Registry Description (PHTR): The JTS PHTR is a data collection and analytic tool designed to provide near real-time feedback to commanders. As previously described, the primary purpose of this tool is to improve casualty visibility, augment command decision-making processes, and direct procurement of medical resources.[20] Additionally, this tool seeks to reduce morbidity and mortality through performance improvement in the areas of primary prevention (tactics, techniques, and procedures), secondary prevention (personal protective equipment), and tertiary prevention (casualty response system and TCCC). The US Central Command (CENTCOM) JTS Prehospital Directorate collected TCCC cards and TCCC AARs and transferred information from these documentation tools into the PHTR.[21]

Data Analysis: We performed all analyses using standard statistical software. We present limited quantitative data metrics using descriptive statistics. For vital sign data, we defined hypotension as <90 mmHg systolic, and tachycardia as ≥120 per minute. If more than one vital sign was documented, we used the lowest recorded systolic or the maximum reported heart rate.

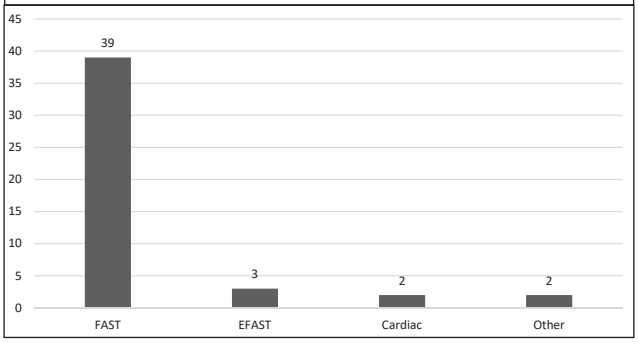
Results

Our initial dataset contained 705 casualties, of which we identified 45 cases with AAR data for review (Table 1). One was eliminated as the case description did not include the use of point of care ultrasound. Thirty-nine cases involved the use of the FAST exam. Three cases explicitly described the use of pulmonary ultrasound and they were categorized as E-FAST exams. Two cases described the use of point of care echo to evaluate for cardiac standstill. Two cases described the use of ultrasound to evaluate for vascular injury, one through direct visualization of flow in the popliteal artery and

Table 1. Demographics of included cases.

Sex	Male	100% (44)
Affiliation	US forces	5% (2)
	Host nation	95% (42)
Battle status	Battle injury	100% (44)
	Non-battle injury	0% (0)
Evacuation priority	Urgent	86% (37)
	Priority	11% (5)
	Routine	2% (1)
Mechanism of injury	Explosive	30% (13)
	Fall	0% (0)
	Firearm	69% (30)
	Other	2% (1)

Figure 1. Types of exams performed.



one through the performance of an Ankle Brachial Index (Figures 1-2). Of those with vital signs documented, 25% (11) reported at least one episode of tachycardia (≥120/min) and 16% (7) with at least one episode of systolic hypotension (<90mmHg). As initially planned, investigators reviewed the cases and provided expert feedback. Pertinent quotes are included in Table 2.

Discussion

All of the experts remarked on the relatively high level of indeterminate or equivocal scans. Previous literature has shown a rate of 4-10% rate of equivocal EFAST exams when performed in an appropriate patient population.[22,23] The rate demonstrated in this population was 15%, higher than expected. The experts concluded that it was likely the sonographer performing these exams had difficulty either performing or interpreting the exam, potentially due to a lack of adequate training. The difficulty with window acquisition was also reflected in multiple AARs documenting the inability to adequately interrogate the splenorenal view or left-upper quadrant. Historically the left upper quadrant (LUQ) view is more difficult given the smaller size of the spleen, causing the view to be more posterior and cephalad than the right upper quadrant (RUQ) as well as the proximity of the view to the stomach, which in a non-fasting trauma patient, may cause gas artifact overlying the spleen. In one study, 6% of the positive FAST exams reviewed were positive only in the LUQ.[24] This small percentage of patients with isolated positive LUQ is important, as this changes the patients management and evacuation decision, especially from locations where advanced imaging and an operating room are not readily available.

It is also unclear what type of quality assurance process was being used, if any, to ensure ongoing E-FAST skill proficiency. While the E-FAST exam is relatively easy to learn, it is difficult to learn to do well without performing multiple exams with constructive feedback from ultrasound experts.[25] The cases reviewed were from Role 1 Basic Aid Stations (BAS), and based on the personnel included in the reviews, it is likely that many of the exams were performed by Physician Assistants or medics.

Half of our expert reviewers (MM, AB, and JC) also identified that several cases in which the AAR noted that hemoperitoneum was "ruled out" by E-FAST. The E-FAST is a relatively insensitive exam with reported sensitivities ranging widely from 42-74% and cannot be used to eliminate the possibility of hemoperitonium.[23,26] These cases may indicate a gap in understanding how to interpret the results of the E-FAST exam.

Another area of concern identified by our expert panel was the relatively few cases of a pulmonary ultrasound being performed or documented. As previously discussed, pulmonary ultrasound is remarkably sensitive and specific for hemothorax and pneumothorax.[11,12] One issue that was independently identified by several of our reviewers described a patient undergoing a diagnostic pleural aspiration to evaluate for pneumothorax. The patient received an invasive procedure for which pulmonary ultrasound may be able to aid in diagnosis. In another case, the AAR reviewer remarked, "When (the) patient was delivered to BAS continuing to have shortness of breath, fluid continued to be heard on exam—ultrasound forgone on route of (sic) chest tube placement." It is unclear why the ultrasound was forgone, but nonetheless it may have added in the evaluation.

On a different note, a common theme identified by our expert reviewers was the appropriate use of serial FAST exams. Serial exams would be ideal for inclusion into a triage protocol when evacuating multiple casualties. We also noted a trend among several cases in which a serial FAST exam could have been beneficial, such as one with a significant change in clinical status. Serial FAST exams are not routinely performed; however, in prolonged field care settings this technique may be helpful as blood or fluid can accumulate in the

Figure 2. Results of Focused Assessment with Sonography in Trauma (FAST) and Extended-FAST (E-FAST) exams.

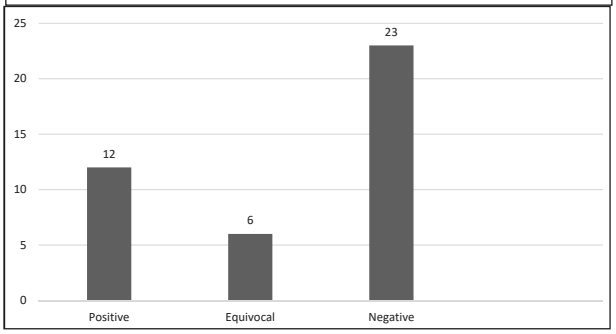


Table 2. Select comments from the free text responses highlighting challenges noted by Role 1 medical personnel.

Table 2 – Select comments lifted from the free text responses highlighting challenges noted by Role 1 medical personnel
"No signs of pneumothorax based on vitals, physical exam, ultrasound of chest. No hemothorax or hemoperitoneum present during FAST-E (sic). FOB (Forward Operating Base) COC (Chain of Command) called Dust Off MEDEVAC (Medical Evacuation) Urgent without cause."
"FAST exam was equivocol (sic) with possible fluid at Morrison's (sic) pouch and around the bladder, splenorenal/splenodiaphramatic (sic) junction difficult to appreciate."
'When patient (sic) was delivered to BAS continuing to have SOB, fluid continued to be heard on exam - ultrasound forgone on route of (sic) chest tube placement."
In discussing improvements in the care of a traumatic cardiac arrest, the recommendation was to "confirm absence of cardiac activity with ultrasound earlier."
"Unable to find a source of bleed using FAST US (ultrasound) and pleural aspiration"

abdomen over time, improving the test characteristics of this diagnostic test.

There were several limitations to our study. This database review was limited to the recorded AARs, and it is likely that there were cases which were not recorded in which ultrasound was used. A system with fields for documentation would likely capture more useful data instead of relying on free text. It would also allow for more quantifiable analyses. We had no access to the original images to assess for false positives and false negatives or assess the quality of imaging. A near-real-time system would aid in quality assurance and performance improvement. All the patient records reviewed survived long enough to be evaluated by the medical response team, introducing a survival bias. Knowing which machines and types of ultrasounds were available would also be of assistance in developing training methods for obtaining and maintaining skills. Future investigations should focus on the review of images and interpretations to assess potential knowledge gaps, which could be improved through training.

Conclusion

Our findings suggest that training in both the FAST exam and E-FAST has the potential to improve patient care for military trauma patients. A performance improvement system would enable real-time confirmation of findings and feedback for training and quality improvement.

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A Descriptive Analysis of Battlefield First Responder and Combat Lifesaver Interventions during the Role 1 Phase of Care

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Abstract

Background: Battlefield first responders (BFR) are the first non-medical personnel to render critical lifesaving interventions for combat casualties, especially for massive hemorrhage where rapid control will improve survival. Soldiers receive medical instruction during initial entry training (IET) and unit-dependent medical training, and by attending the Combat Lifesaver (CLS) course. We seek to describe the interventions performed by BFRs on casualties with only BFRs listed in their chain of care within the Prehospital Trauma Registry (PHTR).

Methods: This is a secondary analysis of a dataset from the PHTR from 2003-2019. We excluded encounters with a documented medical officer, medic, or unknown prehospital provider at any time in their chain of care during the Role 1 phase to isolate only casualties with BFR medical care.

Results: Of the 1,357 encounters in our initial dataset, we identified 29 casualties that met inclusion criteria. Pressure dressing was the most common intervention (n=12), followed by limb tourniquets (n=4), IV fluids (n=3), hemostatic gauze (n=2), and wound packing (n=2). Bag-valve-masks, chest seals, extremity splints, and nasopharyngeal airways (NPA) were also used (n=1 each). Notably absent were backboards, blizzard blankets, cervical collars, eye shields, pelvic splints, hypothermia kits, chest tubes, supraglottic airways (SGA), intraosseous (I/O) lines, and needle decompression (NDC).

Conclusions: Despite limited training, BFRs employ vital medical skills in the prehospital setting. Our data show that BFRs largely perform medical interventions within the scope of their medical knowledge and training. Better datasets with efficacy and complication data are needed.

Keywords: prehospital, combat, battlefield, first, responder, tactical, casualty

Introduction

Background: Prompt medical treatment of combat injuries and evacuation to higher echelons of care is vital to warfighter survival. From 2001 to 2011, Eastridge et al. reported that 4,013 of 4,596 (87.3%) US combat fatalities in Iraq and Afghanistan occurred before the service member reached a military treatment facility (MTF). Furthermore, 24% were potentially survivable (PS).[1] The study investigators used a liberal definition for PS, and these 976 cases included both clearly preventable deaths, as well as those that could only have been prevented by optimal medical knowledge and care immediately available at the point of injury.

The most common causes of potentially preventable death are, in order: hemorrhage, airway obstruction, and tension pneumothorax.[2] Tactical Combat Casualty Care (TCCC) standardizes initial prehospital assessment and treatment on the battlefield, intentionally addressing these three primary concerns using the MARCH protocol. MARCH stands for Massive hemorrhage, Airway management, Respiration and breathing, Circulation, and Hypothermia prevention.[3]

TCCC trains all combatants under the current paradigm of 4 levels or tiers. The first two tiers (all combatants and Combat Lifesavers) are designated for non-medical personnel. Tiers 3 and 4 are focused on those individuals

with a primary duty/specialty to provide medical care: combat medics, hospital corpsman, and those with equivalent or higher levels of medical training whose primary role is rendering aid. The first two tiers can be grouped into the category of Battlefield First Responders (BFRs), as their primary job focuses on something other than rendering medical aid (i.e. infantry or mechanics). Their medical training includes the basic, rudimentary instruction provided at initial entry training (IET, a term which includes Basic Combat Training and Advanced Individual Training) in all services (Tier 1), as well as informal, unit-dependent medical training. The BFR level also includes those who have attended the Combat Lifesaver (CLS) course. CLS course builds on the TCCC principles taught in IET and exposes students to additional medical techniques. Its graduates are Tier 2 providers, able to stabilize severely wounded casualties until dedicated medical personnel are available.[3] In fact, from 2001 to 2010, BFRs placed 42% of tourniquets applied to the 75th Ranger Regiment's combat casualties. The importance of adequate BFR training is underscored by the fact that 94% of the unit's casualties receiving tourniquets during this period ultimately survived their wounds.[4]

Table 1. Description of prehospital trauma registry casualties treated exclusively by battlefield first responders (January 2003 to May 2019), n=29.

Demographics	**18-25 years**	34% (10)
	26-33 years	41% (12)
	34-41 years	10% (3)
	42-49 years	0% (0)
	50-57 years	0% (0)
	58-65 years	0% (0)
	66+ years	3% (1)
	Unknown age	10% (3)
	Male	100% (29)
Mechanism of Injury*	**Explosive**	55% (16)
	Firearm	24% (7)
	Fragmentation	10% (3)
	Fall	3% (1)
	Other	6% (2)
Rank	**Enlisted**	82% (24)
	Officer	3% (1)
	Unknown	13% (4)
Affiliation	**US Conventional Forces**	44% (13)
	US Special Operations Forces	37% (11)
	Unknown	3% (1)
Battle Status	**Battle**	93% (27)
	Non-Battle	7% (2)
Country	**Afghanistan**	96% (28)
	Iraq	3% (1)

**If a casualty experienced more than one mechanism of injury, all were included.*

Goals of this Investigation: We will seek to characterize casualty interventions performed by BFRs by isolating combat casualties that had only a BFR in their chain of care.

Methods

We submitted protocol H-19-018 to the US Army Institute of Surgical Research (USAISR) regulatory office who determined to be exempt from institutional review board oversight. Data sharing agreement 19-2186 was submitted and executed with the Defense Health Agency (DHA) prior to submitting a request for data to the Joint Trauma System (JTS). We obtained de-identified data on all casualties captured by the PHTR prior to May 2019. We also requested outcome data on PHTR casualties linkable to the DoDTR. In compliance with new DHA requirements regarding de-identified data, an age range replaced exact patient age.

Prehospital Trauma Registry (PHTR): The JTS PHTR is a data collection and analytic tool designed to provide near-real time feedback to commanders. The US Central Command JTS Prehospital Directorate collected TCCC cards and TCCC After-Action Reviews (AARs) and input these data into the PHTR. As previously described, the PHTR improves casualty visibility, augments command decision-making processes, and informs medical resource procurement. The PHTR's goal is to reduce morbidity and mortality through improved performance in primary (tactics, techniques, and procedures), secondary (personal protective equipment), and tertiary (casualty response system and TCCC) prevention.[5,6] The origins of the PHTR have previously been described.[7,8]

Department of Defense Trauma Registry (DoDTR): The DoDTR, formerly known as the Joint Theater Trauma Registry, is the DoD's data repository for trauma-related injuries.[9-15] The DoDTR records data on demographics, injury-producing incidents, diagnoses, treatments, and outcomes following injuries for US and non-US military and civilian casualties from the point of injury to final disposition.

Data Analysis: All analyses were performed using digital solutions and data visualization tools. We quantified continuous variables using the mean with standard deviations (SD); ordinal variables using the median with interquartile ranges; and nominal variables using sample number and frequencies. We reviewed our dataset for a reported provider type, including only those with a BFR recorded in the chain of care. Data were excluded if a medical officer, medic, unknown, or nothing was documented.

Results

Our initial query of the PHTR identified 1,357 casualty encounters, with the majority occurring from January 2003 through May 2019. BFRs were the sole provider(s) reported in the chain of care for 29 cases (Table 1). All 29 were male: most were enlisted (82%) service members, and 93% sustained their injuries in combat. Afghanistan (96%) was the most common geographic location of injury. Explosive injury was the most common mechanism (55%), followed by firearm (24%), fragmentation (10%),

Table 2. Interventions administered to prehospital trauma registry casualties treated exclusively by battlefield first responders (January 2003 to May 2019, 29 total casualties).

Massive Hemorrhage	Pressure dressing	41% (12)
	Limb tourniquet	14% (4)
	Hemostatic gauze	6% (2)
	Wound packing	6% (2)
Airway Management	Bag-valve-mask	3% (1)
	Nasopharyngeal airway	3% (1)
Respiration and Breathing	Chest seal	3% (1)
	Chest needle decompression	0% (0)
Circulation	IV fluids	10% (3)
	Intraosseous access	0% (0)
Hypothermia prevention	Hypothermia prevention maintenance kit	0% (0)
Post-MARCH (**M**assive hemorrhage, **A**irway management, **R**espiration and breathing, **C**irculation, **H**ypothermia prevention)	Extremity splint	3% (1)
	Backboard	0% (0)
	Blizzard blanket	0% (0)
	Cervical collars	0% (0)
	Eye shield	0% (0)
	Pelvic splint	0% (0)

Table 3. Description of Prehospital Trauma Registry casualties treated exclusively by battlefield first responders (January 2003 to May 2019) and linked to the Department of Defense Trauma Registry, n=21.

Military Operation	**Afghanistan (Operation Enduring Freedom)**	66% (14)
	Afghanistan (Operation Freedom's Sentinel)	28% (6)
	Iraq (Operation Inherent Resolve)	5% (1)
Injury Severity Score#	**Composite ISS**	5 (1-10)
	ISS ≤ 15	85% (18)
	ISS 16-25	5% (1)
	ISS > 25	9% (2)
Serious Injuries – Abbreviated Injury Scale 3+	**Extremities**	14% (3)
	Head/neck	9% (2)
	Thorax	9% (2)
	Abdomen	0% (0)
	Face	0% (0)
	Skin/superficial	0% (0)
Outcome Data	**Discharged Alive**	95% (20)

ISS = Injury severity score
#presented as median and interquartile range

and fall (3%); unspecified mechanisms comprised 6% of injuries.

Pressure dressing application (n=12) was the most common BFR intervention performed during combat operations in these 29 patients (Table 2). Limb tourniquet application (n=4), IV fluids (n=3), hemostatic gauze application (n=2), and wound packing (n=2) followed in frequency. The remaining BFR interventions included bag-valve-mask ventilation, chest seal placement, extremity splint application, and nasopharyngeal airways (NPA) placement (n=1 each). Several interventions were notably absent from our dataset, including backboards, blizzard blankets, cervical collars, eye shields, pelvic splints, and hypothermia kits. Additionally, there were no recorded instances of BFRs administering chest tubes, supraglottic airways (SGA), intraosseous (I/O) lines, or needle decompression (NDC).

Of the 29, 21 were linkable to the DoDTR for injury severity and outcome data (Table 3). The median injury severity score (ISS) was 5 (IQR 1-10). For those with injuries ≥ 3 on the abbreviated injury scale (AIS), injury to the extremities predominated (14%), followed by head/neck and thorax (9% each), with 95% (n=20) surviving to discharge.

Discussion

Our data indicate that BFRs perform a wide array of interventions. Other than three instances of IV administration, these interventions fall within the current guidelines of TCCC Tier 1 and 2 medical providers. Though the patients in our dataset did not suffer major trauma according to ISS (conventionally defined as ISS > 15), those treated solely by BFRs boasted a high degree of survivability.

In a study of patient outcomes after casualty evacuation (CASEVAC) from 2007-2017 during Operation Iraqi Freedom (OIF), all Afghanistan combat operations and Operation Inherent Resolve (OIR) casualties were not categorized by a TCCC medical provider. However, survival to discharge in our patient population (95%) was similar to all casualties undergoing CASEVAC from OIF (100%, n=3), Afghanistan (97%, n=241), and OIR (94%, n=233) from 2007-2017. Of note, the median ISS in our study (5, IQR 1-10) was lower than each of the three CASEVAC casualty cohorts (OIF ISS=10, IQR 4-43; Afghanistan ISS = 9, IQR 5-17; and OIR ISS = 9, IQR 5-13).[16] This is likely because those that were more severely injured also had a combat medic or medical officer involved in their chain of care. Additionally, they may not have survived long enough to be captured in the PHTR since the registry does not consistently capture those that die prehospital.

A 2018 study evaluated the survivability of casualties wounded in Afghanistan who passed through Role 2 facilities from February 2008 to September 2014. A Role 2 MTF possesses damage control resuscitation and surgical capabilities. That study did not correlate provider level, though did note that prehospital providers were involved in the chain of care—13,398 prehospital interventions were performed in the patient population. Of the 12,352 casualties with outcome data, 11,815 (96%) survived to discharge, a frequency that supports our data.[17]

TCCC guidelines require that qualified BFRs demonstrate competency in tourniquet, hemostatic dressing, and pressure dressing applications to control massive

hemorrhage in the prehospital setting.[18] Our data support this; all three interventions were recorded in our patient population suggesting that these skills will be put to use. Notably, BFRs treating patients with massive hemorrhage in our dataset did not use any interventions, like junctional tourniquets, that would be considered inappropriate for their level of training. For massive external hemorrhage injuries where limb tourniquet use is either contraindicated or impractical, BFRs commonly pack wounds with hemostatic dressings like Combat Gauze.[3,19] Pressure dressings frequently accompany massive hemorrhage injuries, as reflected in our data.[20]

Proper limb tourniquet use is a TCCC cornerstone. It is effective and easily taught to nonmedical personnel.[21] Special Operations Forces (SOF) units like the 75th Ranger Regiment, with a penchant for innovation and adaptability, rapidly implemented TCCC guidelines (first published in 1996). Demonstration of the effectiveness of TCCC early in the conflict following 2001 showed stark contrast to medical data from some conventional forces. By 2011, preventable prehospital death incidence in the 75th Ranger Regiment fell, remarkably, to zero.[4,22] As a result of early TCCC success, Combatant Commands required conventional units to adopt TCCC principles. These units experienced similar drops in preventable combat deaths as tourniquet use soared.[1,23,24] For example, a Baghdad combat support hospital estimated that proper tourniquet use saved 31 lives over a 6-month period in 2006.[22]

According to TCCC guidelines, BFRs must be capable of repositioning casualties to manage compromised airways. Bag-valve-mask ventilation and NPA placement interventions are limited to those personnel who have successfully completed the CLS course. No BFRs airway interventions should be attempted above this level of training—our dataset showed only NPA (n=1) and bag-valve-mask ventilation (n=1).

Our patient population was similar in age, gender, and mechanism of injury to a study evaluating prehospital airway management in 28,222 DoDTR casualties from January 2007 to August 2016. Provider level was not indicated. NPA (n=17) was the least common airway intervention in Afghanistan yet boasted the best overall outcomes. However, providers favored intubation (n=883), cricothyrotomy (n=178), and SGA (n=27) despite lower percentages of patients surviving to discharge.[25] Intubation (Tier 4 and higher), cricothyrotomy (Tier 3), and SGA (Tier 3) all require training specific to dedicated medical personnel, and equipment not included in Gen I or Gen II Individual First Aid Kits (IFAKs). Conversely, NPAs are readily available in both IFAKs, and their proper use is taught in the CLS course.[18,26] However, we noted only one instance of use. Given the high survival rate and survival bias inherent to the registries, it may be that no other insertions were indicated.

Most interventions during this phase of MARCH require medical training received only by dedicated medical personnel (Tier 3 and higher).[18] Thus, TCCC expects BFRs to reassess and appropriately mark previously-placed tourniquets, and accurately document injuries and interventions via the TCCC Card (DD Form 1380) during this phase.[3,27] However, our dataset reported three instances of IV fluid administration (Table 2).

This portion of MARCH depends largely on the tactical situation. Ideally, BFRs will protect casualties from the elements, swap out wet clothing, and wrap patients in anything that retains heat.[3] While BFRs did not deploy hypothermia prevention maintenance kits in our dataset, IFAKs do not include these kits. Therefore, hypothermia prevention was not necessarily overlooked; it is possible that BFRs used other means to address this, or that such casualties were treated by dedicated medical personnel and thus disqualified from our study. It is also possible that the intervention was simply not needed.

After completing the MARCH sequence, BFRs may provide supplemental interventions, like addressing penetrating eye trauma and burns, administering analgesia and antibiotics, and assembling splints. This only occurs when time and enemy situation permit after the MARCH sequence has been completed.[3] These parameters may help explain the low eye shield use and extremity splint application in our dataset. However, we lack significant granularity with regards to the exact injuries, so it remains unclear if anyone had an indication for these interventions but were not performed.

Limitations: This study has several limitations. First, under-documentation of battlefield casualties via DD1380 TCCC Cards continues to plague the US military and limit our data collection. One study found that only 3.3% of PHTR casualty encounters from January 2013 through September 2014 primarily drew their data from completed TCCC Cards.[8] This likely contributed to our small sample size, which in turn may have manifested as under or overrepresentation of at-large BFR interventions in our data. Additionally, the PHTR does not always capture Role 1 casualties who expire prior to arrival at a Role 2 or higher level MTF. This inherent PHTR survival bias, paired with the strict inclusion/exclusion criteria we used to ensure we only considered casualties treated exclusively by BFRs, makes it possible that additional BFR-only prehospital care was rendered and not scrutinized. Finally confounding variables that may have impacted level of care like battlefield situation

were neither available nor examined.

Conclusion

Our study demonstrates that BFRs provide a wide range of vital medical interventions in combat. Periodic reassessments of training and equipment like ours are necessary to ensure that BFRs perform interventions in the most rapid and effective ways. Future studies should determine whether or not to omit less frequently administered interventions from formal BFR curricula with matching materiel solutions.

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Comprehensive Decision Support for Prehospital Combat Casualty Care: The Airway Clearance Model

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Abstract

Airway management is a foremost priority for combat medics treating battlefield casualties, as a compromised airway is the second leading cause of potentially survivable death on the battlefield, accounting for 1 in 10 preventable combat deaths. Effective suction is a critical component of airway clearance. However, currently available commercial devices are too heavy and bulky for combat medics to carry, and/or lack sufficient power to be useful. Clinical decision support systems (DSS) can close the gap between existing commercial devices and their clinical use and enhance combat medic clinical performance by providing the right "tooth-to-tail" tools to accomplish the task of clearing the airway. Our DSS approach will provide a focused, real-time set of guidelines and recommendations that are tailored to the combat medic. Our proposal will create a knowledge-based algorithm and clinical guideline regarding the use of suction, delivering to the combat medic the "right information, to the right person, in the right format, through the right channel at the right time."

Introduction

Airway management is a foremost priority for combat medics treating battlefield casualties, as a compromised airway is the second leading cause of potentially survivable death on the battlefield, accounting for 1 in 10 preventable combat deaths.[1] Airway management starts with inspection, clearing any obstructions from the airway, and, if necessary, placing an endotracheal tube to secure the airway.[2,3] Effective suction is a critical component of airway clearance.[4] However, currently available devices are too heavy and bulky for combat medics to carry and/or lack sufficient power to be useful.[5] A recent report by Schauer et al underscores the infrequent use of portable suction in combat.[6] Another study by Blackburn et al further underscores that advanced airway interventions including suction are not used (or are used inappropriately) in many situations requiring urgent field airway management.[7] The industry has not responded to this capability gap, with companies continuing to produce models using 1970s technology.[8] In essence, suction is a critical gap in prehospital combat casualty care. Moreover, it is likely that many casualties may not need immediate intubation when adequate suctioning and positional maneuvers are used—this is especially relevant to combat situations where one medic or one medical officer must care for multiple casualties at a time.

Effective suction is a crucial component of airway management. Indeed, Tactical Combat Casualty Care (TCCC) guidelines recommend the use of suction.[9,10] In prolonged care situations, periodic suction is also important for preventing the serious problem of pulmonary aspiration. Unfortunately, the prehospital combat provider has neither the equipment nor the information needed to provide critical airway suction for multiple reasons: a) current devices are unsuitable for austere settings, and b) evidence-based guidelines and training recommendations are not tailored for the combat environment. Thus, there exist simultaneously materiel and doctrine gaps that deprive wounded soldiers of the best available technology to clear the airway.

Using decision support systems (DSS), we will outline a "tooth-to-tail" approach that encompasses many of the

components within and beyond the military to ensure high quality and effective care of the battlefield casualty. To describe this paradigm, we will use airway clearance with suction as the illustrative example.

Relevant Military Environment

Care of the wounded on the battlefield presents many unique challenges as compared to the civilian environment. Combat medics often provide care in no light or low-light conditions, surrounded by the chaos of combat, and with the limited dexterity that accompanies bulky body armor, gloves, and heavy equipment. Far-forward medical care is also limited by available resources, which often is only what a combat medic can fit in the aid bag.[6] Furthermore, the complicated battlespace that has expanded across the Middle East and the vast expanses of Africa and Asia have mandated the development of a prolonged field care (PFC) model to address the challenges of prolonged hold and transport times.[11,12] Future battlefield prehospital emergency airway clearance devices must take these environmental constraints into consideration.

During immediate care of a trauma patient, securing the airway is a top priority after hemorrhage control. Optimized airway devices are among the top five in a comprehensive list of battlefield research and development priorities by the Defense Health Board, yet the challenge of airway management has received little investment compared to other causes of preventable battlefield death such as exsanguinating hemorrhage and traumatic brain injury.

The leading cause of airway deaths on the battlefield is maxillofacial injuries.[13] Due to deformed facial features from injuries such as fractures, swollen tongues, or debris blocking the airway, suctioning and intubation can be difficult. These atypical presentation scenarios are challenging for combat medics, who receive relatively limited training in intubation. The Registry of Emergency Airways at Combat Hospitals study (REACH) shows that prehospital cricothyrotomies are performed ten times more often on the battlefield as compared to civilian trauma systems. (5.8% vs. 0.5%).[14] An attributed major reason for this dramatically higher rate of surgical airways was poor visualization of the injured airway due to current inadequate suction devices available on the battlefield. Effective suction would aid in the ability to clear the airway, assess the need for securement through intubation, and visualize the glottal opening for proper cannulation.

Surveys conducted by our group established that the current medical suction technologies available to far-forward medical personnel are not sufficiently effective, being either insufficiently powerful (for manual devices) or far too bulky (for powered systems).[8] For the civilian market, Kozak et al reported on a survey of paramedics, stating that paramedics typically elected to leave suction equipment behind more than 75% of the time despite its critical importance for airway management, a finding attributed to both suboptimal function and weight of the available units.[5] We propose to close this information gap by outlining a decision support system focused on suction use in the prehospital combat environment.

Decision Support Systems

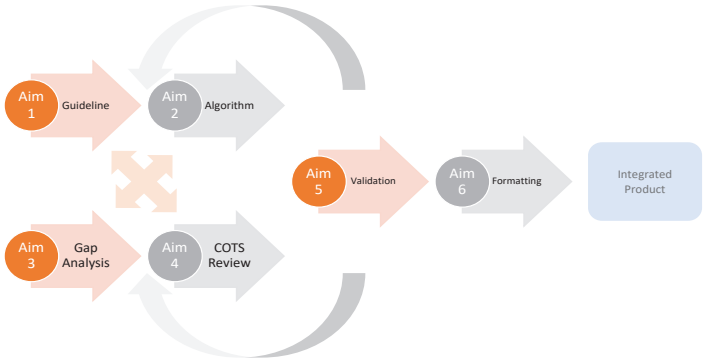
Computer-based decision support systems (DSS) have been used in the fields of defense, environment, finance, business strategy, and public policy since the 1970s. Unfortunately, the use of DSS in healthcare as they apply to clinical decision-making has been lacking as compared to these other industries. Comprehensive DSS include selection, procurement, fielding, use, and quality improvement (QI) of the intervention. The testing and QI of devices in the military combat environment is especially important as safety and efficacy cannot be assumed, in contrast to the often-applied interventions in routine DSS. Continual evaluation and improvement are especially important in clinical DSS as algorithms and guidelines frequently change. This is particularly evident in the military setting, where the medical director role is more diffuse, requiring a balance between Surgeon General recommendations, Department of Defense (DoD) and TCCC guidelines, medical officer supervision, and local commander directives. As such, DSS development should follow a 3-part cycle which should be frequently re-visited: initiation, analysis, and delivery. Effective user training that addresses both individual as well as organizational needs is also critical.[15]

Our DSS approach will extend the usual acquisition and training channels with a focused set of guidelines and recommendations that are tailored to the end-user, in this case the combat medic. By integrating the process with the selection, procurement, testing, validation, and training with the clinical use of the device (from user feedback and data obtained from the Pre-Hospital Trauma Registry (PHTR), a component of the DoD Trauma Registry),[16] a stronger and more useful set of decision support can be obtained.

Our proposal focuses on creating a knowledge-based algorithm and clinical guideline regarding the use of suction in the combat setting, delivering the "right information, to the right person, in the right format, through the right channel at the right time."[17,18] More than just

collating existing information, we endeavor to synthesize this information in order to help the end-user in their clinical decision-making with airway compromise.

Figure 1. Schema of the flow of specific aims showing parallel development of Aims 1&2 and 3&4 with feedback and iterative development. COTS, commercial-off-the-shelf (product).



The output should start out as a text-based product that can be used in standard document form (e.g., paper, text file, or pdf). This provides a common platform for use in traditional textbooks and manuals, website narratives, and it can be configured as a DSS downloadable application for existing hand-held devices/phones that combat medics already carry. The general principles of DSS development will ensure quality and future compatibility with other guidelines and algorithms.[17,19-20] The output of each specific aim will feed into the next specific aim in sequence combined with parallel and iterative development as appropriate (Figure 1).

Suction DSS

The overall objective of the proposal is to create and validate a set of algorithms and guidelines and to identify and test existing commercial suction devices to provide decision support to combat medics in the application and use of suction on the battlefield.

Step 1: Create an evidence-based guideline on a) the use of suction for airway clearance in far-forward combat scenarios, and b) pulmonary aspiration prevention for prolonged care scenarios. The guideline should be evidence-based, and the output intended to guide training and clinical care. This can be initiated by systematically searching, reviewing, and critically appraising the relevant literature, and synthesize the information into a clinical guideline for prehospital combat care.

Step 2: Generate an airway suction decision algorithm(s) for use by combat medics. This clinical algorithm should be rule-based and formatted for input into the TCCC approval process. Developing guidelines into rule-based prehospital clinical workflow will highlight critical actions, decision nodes, and options for higher levels of care. Clinical algorithms provide an intuitive link between evidence-based guidelines and rule-based clinical practice.[15,17,21] Using accepted methods, the guidelines developed in Specific Aim 1 will be developed into a clinically useful and effective algorithm.[18-21]

Step 3: Conduct a capability gap analysis of prehospital suction device requirements and create a best-available or improvised device algorithm for use until a preferred suction device is procured. The output of this analysis should provide interim recommendations on selecting suction devices and inform the military acquisition system of the requirements generation process. Engineering analysis that focuses on medical device requirements for battlefield use of suction devices would include a detailed review of commercially available powered and manual suction devices.

Step 4: Conduct a detailed review of commercially available powered and manual suction devices and identify product(s) with potential application to the prehospital combat environment. The review should include engineering analysis of manufacturer's specifications and capabilities. The output would be a short list of devices recommended for physical testing. If interim devices can be identified, these could be fed into the decision support algorithm of Step 3. Testing using relevant standards such as liquid flow rates with a variety of relevant fluids including mimics of blood and vomitus. The general standard is for air flow rates which do not have clinical or practical relevance to the intended use of a prehospital suction device. Instead, we recommended liquid flow rates using different fluid viscosities, solid particle lifting capacity, and obstruction (clogging) resistance.[22] The end-product of this step is a rank-order of devices according to key performance indicators and adherence to specification criteria.

Step 5: Validate all developed components (guidelines, algorithms, and recommendations) using expert and user review. This could be realized using structured and semi-structured qualitative methods to examine all decision support components. A broad-based team of military medical and engineering experts and users would be empaneled to facilitate the process.

Step 6: Format the components into an integrated

knowledge-based product that is usable by combat medics in the field. Either a text-based system (e.g., written protocol) or a more sophisticated electronic application format is envisioned as the output of the system.

Step 7: Continual quality assessment of the DSS to include the utilization of appropriate quality improvement tools.[23] To ensure continued relevance any clinical DSS requires continual updating. New devices, manufacturer's recommendations, clinical reports, after-action reviews and similar events will require periodic synthesis and revision of the DSS.

Integration & Execution: A best practice approach requires the contribution and participation of all elements in the process: the procurement and logistics experts who purchase and evaluate the device, training personnel who teach the use of suction and create training content, and clinicians including experienced combat medics and airway management experts such as emergency physicians. Leadership of the process should rest with the senior (determined by education and experience, not military rank) clinician and advised by an expert in DSS creation and dissemination. Funding for the process need not be onerous and could, for example, represent <10% of the estimated procurement contract.

Conclusion

Decision support systems (DSS) are a potentially important component in the clinical use of a medical device. We describe an integrated version of DSS that incorporates the entire life cycle of the device from procurement to patient outcomes with suction devices used by medics in the far-forward combat environment. If implemented, this approach can lead to smarter logistics, more focused training, and evidence-based clinical outcomes on the battlefield and improved care of the prehospital combat casualty.

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Combat Medic eFAST with Novel and Conventional Portable Ultrasound Devices: A Prospective, Randomized, Crossover Trial

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Abstract

Background: Extended Focused Assessment with Ultrasonography in Trauma (eFAST) reliably identifies non-compressible torso hemorrhage (NCTH), a major cause of battlefield death. Increased portability of ultrasound enables eFAST far forward on the battlefield, and published data demonstrate combat medics can learn and reliably perform ultrasound exams. One medical company developed an ultrasound device with an intuitive graphical user interface (GUI) and novel, finger-worn transducer with built-in linear and phased arrays, referred to as the novel device. We evaluated combat medic eFAST performance between the novel and conventional device.

Methods: This was a prospective, randomized, crossover trial completed at a single US military installation. Subjects were US Army combat medics with no previous ultrasound experience. Subjects performed an eFAST on a live human and a simulation model with both devices after a brief training intervention. Our primary outcome was time in seconds for eFAST completion, limited to 600 seconds. Secondary outcomes included diagnostic accuracy, technical adequacy using a validated task-specific checklist, and end-user appraisal of device ease-of-use with 5-point Likert items. This study was approved by the local institutional review board.

Results: Forty subjects volunteered, most were male (67.5%), less than 36 years old (95.0%), and grade E-4 or below (75.0%). Subjects performed a total of 160 eFAST scans (80 novel, 80 conventional). We found no significant difference in time for eFAST completion between the novel and conventional devices (391 seconds [95% CI 364, 417] versus 352 seconds [95% CI 325, 379]; $p = 0.71$). We also found no significant differences between the novel and conventional devices with respect to diagnostic accuracy (91.5% versus 89.2%; $p = 0.28$) and technical adequacy (75.0% versus 72.5%; $p = 0.28$). However, we did find that subjects favored the image quality of the novel device (4.3 versus 3.6; $p < 0.01$), while favoring the conventional transducer (3.8 versus 4.3; $p = 0.04$).

Conclusion: Combat medic eFAST performance utilizing both devices did not differ with respect to time to completion, diagnostic accuracy, and technical adequacy. Medics with limited ultrasound experience performed diagnostically accurate eFAST after a brief training intervention. Future research should assess learning gaps and skill retention in order to guide development of US military ultrasound training programs for combat medics.

Keywords: ultrasound, FAST, medic, combat, trauma, military, POCUS

Introduction

Background: During the recent conflicts in Afghanistan and Iraq, non-compressible torso hemorrhage (NCTH) was the most common cause of preventable death on the battlefield and required surgical intervention.[1-4] Extended focused assessment with sonography in trauma (eFAST) reliably diagnoses non-retroperitoneal NCTH, and if performed far forward on the battlefield may enable rapid diagnosis and evacuation of casualties with NCTH to surgical facilities.[5-9] Multiple, previous studies demonstrate combat medics can learn and reliably perform diagnostically accurate ultrasound examinations for pulmonary, soft tissue, and musculoskeletal structures.[10-13] A recent study reported combat medics completed timely and diagnostically accurate eFAST after a short training intervention.[14]

Figure 1. Novel device.

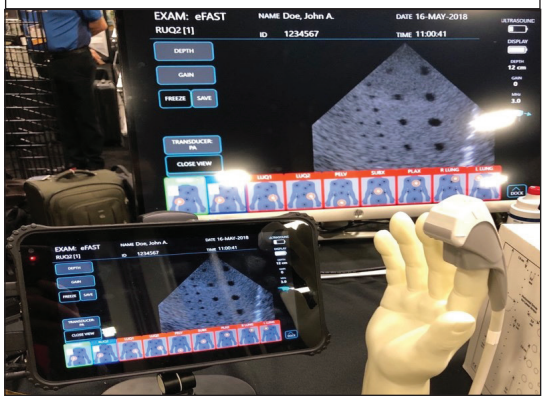


Figure 2. Conventional device.

With recent advances in technology, ultrasound devices may now be portable and rugged enough for battlefield utilization.[7,15-16] A medical company developed a handheld ultrasound device specifically for battlefield medic use. This device couples an intuitive graphical user interface (GUI) and a finger-worn ultrasound transducer with built-in linear and high-frequency arrays. Although ultrasound device and transducer miniaturization are often considered advantageous, their impact on ultrasound exam performance remains unclear, particularly amongst novice sonographers in the austere combat setting. The purpose of this study was to evaluate combat medic eFAST performance with the novel device in comparison to a widely available portable conventional ultrasound device.

Goals of this Study: We compare combat medic eFAST completion times utilizing novel and conventional ultrasound devices. Secondarily, we evaluate diagnostic accuracy, technical adequacy, and end-user impressions of device ease-of-use, between devices.

Methods

Study Oversight & Design: The US Army Regional Health Command-Pacific Institutional Review Board approved this prospective, randomized, crossover trial protocol. All subjects were consented.

Subjects & Materials: We conducted all study activities within the Medical Simulation Training Center at Joint Base Lewis-McChord, WA. We utilized a classroom for all standardized instruction and a simulated aid station for practical training and testing. The simulated aid station was indoors, temperature-controlled, and with optimal lighting for interpretation of eFAST images displayed on device GUI.

We enrolled subjects from locally assigned military units. Our inclusion criteria included medics (military occupational specialty 68W or 18D) on active duty status 18-54 years old. We excluded subjects who were pregnant or reported previous formal ultrasound training—defined as a 1-month ultrasound training program, an ultrasound fellowship, or diagnostic medical sonographer training. We sought medics with minimal ultrasound training to avoid potential confounding from device or exam experience. All investigators have emergency medicine residency training. Investigators Jonathan D. Monti, DSc PA-C; LTC Aaron J. Cronin, DSc PA-C; and LTC Michael D. Perreault, MD completed emergency ultrasound fellowship training. All investigators dressed in civilian attire to preclude undue influence from military rank and status.

We utilized two portable ultrasound devices. The first was a prototype manufactured by a medical company referred to as the novel device. The novel device utilizes a finger-worn transducer with built-in linear and high-frequency arrays, thereby eliminating the need to connect multiple, separate transducers during the performance of an eFAST (Figure 1). The novel device is connected by cable to a GUI that employs an intuitive menu system with prompts specifically designed to guide the user through eFAST execution. The second device used was widely available during the time of this study, referred to as the conventional device. The conventional device also possesses a single transducer with built-in linear and high-frequency arrays; however, these two arrays are situated on opposite ends of the transducer as opposed to one end, and it is not designed to be worn on the finger (Figure 2). The conventional device transducer is also connected by cable to its GUI that also utilizes a menu-driven system, which includes eFAST but without prompts to guide the sonographer through eFAST execution.

We used two models for eFAST training and testing.

One was the ultrasound "FAST Exam Real Time Ultrasound Training Model". The ultrasound models produce realistic sonographic images (Figure 3). We utilized these models to generate abnormal ultrasound findings; however, the ultrasound models do not replicate lung physiology and cannot produce sonographic lung sliding. After we manipulated the ultrasound models to create the desired abnormalities, two different investigators performed eFAST on them to validate expected exam findings before subjects tested. The other models were living humans without medical or surgical histories that would produce abnormal eFAST findings. Since these models could not produce abnormal eFAST findings, we did not use them to measure diagnostic accuracy. We incorporated living human models into our study to provide normal eFAST pulmonary findings and evaluate for differences in eFAST performance between living and simulated tissue.

Figure 3. Ultrasound Focused Assessment with Ultrasonography in Trauma (FAST) model.

Study Protocol: After consenting and enrolling subjects, a single investigator (JM) provided all medics with a standardized, 60-minute lecture on eFAST in a classroom setting. Afterwards, we utilized a random number sequence generator to randomize subjects into one of two groups. Group 1 trained and tested on the novel device first and then repeated the same on the conventional device. Group 2 trained and tested on the conventional device before the novel device.

By groups, subjects moved to the simulated aid station for device orientation, eFAST exhibition, and eFAST practice exams on a living human model and an ultrasound model. Investigators demonstrated GUI operation and transducer handling before performing an eFAST on both models for training benefit. Then each subject performed a practice eFAST on both models while being observed by an investigator who provided real-time feedback. After all subjects completed both practice eFAST scans, subjects returned to the classroom before testing so that investigators could manipulate the ultrasound models. Then, investigators tested each subject individually on the device they just trained, one eFAST per model. After all subjects tested, we provided an hour-long break for lunch before repeating the same sequence of events, except this time with the other ultrasound device. After the second iteration of training and testing, all subjects completed a survey in the classroom before being released from the study.

Table 1. Subject demographics.

Characteristics [n (%)] (n=40)	
Gender	
Male	27 (67.5)
Female	13 (32.5)
Age (years)	
18-36	38 (95.0)
37-54	2 (5.0)
Grade	
E2	6 (15.0)
E3	2 (5.0)
E4	22 (55.0)
E5	5 (12.5)
E6	4 (10.0)
E7	1 (2.5)
Years of Service	
0-2	21 (52.5)
3-5	12 (30.0)
6+	7 (17.5)

Outcomes: The primary outcome for our study was time to complete an eFAST in seconds. Time started when the subject touched the ultrasound transducer and ended when the medic stated the exam was complete or when the maximum allotted time of 600 seconds elapsed. We recorded incomplete exams (i.e. any of the five views were omitted) as the maximum time. We did not include incomplete exams or exams reaching the time limit in our time analysis. We selected 600 seconds as the time limit based on the results of previous research on combat medics performing eFAST.[14,17]

Our secondary outcomes included diagnostic accuracy, technical adequacy, and device ease-of-use appraisals. For diagnostic accuracy, we only used the manikin ultrasound models. We required participants to vocalize "normal" or "abnormal" in each of the five eFAST views. Study investigators assessed the participants' responses as diagnostically correct or incorrect by comparing them to the preset ultrasound model conditions.

We assessed technical adequacy by utilizing a modified version of an image quality checklist validated for FAST (Appendix 1).[14,18] An investigator watched a single participant conduct an eFAST and recorded performance of 22 total items. We assessed technical adequacy by total scores; however, in order for an eFAST to be considered technically adequate, 9 of the 22 items (indicated by an asterisk (Appendix 1)) had to be performed since they are considered critical to maximize the sensitivity of detecting abnormalities.[14,18]

We used 5-point Likert items (1=most difficult, 5=easiest) to evaluate medic ease-of-use impressions between devices (Appendix 2). We utilized survey questions validated in previous research on medical eFAST performance.[14]

Statistical Analysis: We utilized statistical software to analyze study data. We used a t-test to analyze study data and for crossover effects. We report continuous

Table 2. eFAST time, diagnostic accuracy, and technical adequacy, by device.

	Novel	Conventional	p-value
Time (seconds)	391 95% CI 364, 417	352 95% CI 325, 379	0.71
Diagnostic Accuracy (%)	91.5 95% CI 86.9, 96.0	89.2 95% CI 83.3, 95.1	0.57
Technical Adequacy (%)	75.0 95% CI 63.5, 86.4	72.5 95% CI 60.5, 84.4	0.28

Table 3. Survey results, by device.

Ease-of-use… (Likert 1-5)	Novel	Conventional	p-value
Transducer	3.8 95% CI 3.4, 4.1	4.3 95% CI 4.0, 4.6	0.04
GUI	4.3 95% CI 4.0, 4.6	4.2 95% CI 3.9, 4.6	0.61
Image Quality	4.3 95% CI 4.0, 4.5	3.6 95% CI 3.2, 3.9	<0.01
Device Overall	4.1 95% CI 3.8, 4.3	4.1 95% CI 3.9, 4.4	0.72
Confidence to Perform eFAST	4.2 95% CI 3.9, 4.5	4.4 95% CI 4.1, 4.6	0.31

variables as means with standard deviations and ordinal data as proportions with 95% confidence intervals. We defined statistical significance as $p < 0.05$. We performed pre-study power analysis with a beta of 0.80 and alpha of 0.05 to detect a clinically meaningful difference of 30 seconds between devices, utilizing a time for conventional eFAST completion derived from the results of previous research.[14] Our power analysis determined a sample size of 146 eFAST scans (73 per group) was required.

Results

From April to May of 2019, 40 combat medics volunteered. All 40 were enrolled, none were excluded, and none withdrew early from the study. Most subjects were male (67.5%), less than 36 years old (95.0%), grade E-4 or below (75.0%), with less than 6 years of military service (82.5%) (Table 1). Subjects performed a total of 160 eFAST exams (80 novel, 80 conventional). Six of 160 (3.8%; 3 novel, 3 conventional) eFAST scans exceeded the time limit and were excluded from comparative time analysis. A total of 794 of 800 (99.25%) possible views were available for secondary outcome analysis.

We found eFAST times between the novel and conventional devices were not statistically significant (391 seconds [95% CI 364, 417] versus 352 seconds [95% CI 325, 379]; p = 0.71) (Table 2). Diagnostic accuracy between devices did not differ significantly (91.5% [95% CI 86.9%, 96.0%] versus 89.2% [95% CI 83.3%, 95.1%; p=0.57). Technical adequacy did not differ significantly between devices (75.0% [95% CI 63.5%, 86.4%] versus 72.5 [95% CI 60.5%, 84.4%]; p=0.28). We did, however, find that subjects favored the image quality of the novel device (4.3 [95% CI 4.0, 4.5] versus 3.6 [95% CI 3.2, 3.9]; p<0.01), and that subjects preferred the conventional transducer (3.8 [95% CI 3.4, 4.1] versus 4.3 [95% CI 4.0, 4.6]; p=0.04) (Table 3). Analysis of crossover effects demonstrated the treatment effects observed were valid.

Discussion

In this study we evaluated combat medic performance and appraisal of device ease-of-use for eFAST. Subjects favored the novel device's image quality and the conventional device's transducer, while endorsing similar assessments for the GUI, device as a whole, and confidence to perform the eFAST. Time for eFAST completion, diagnostic accuracy, and technical adequacy did not differ between the novel and conventional devices. However, we did find that the majority of subjects completed diagnostically accurate eFAST in a timely manner.

On average, combat medics completed the eFAST in less than 6.5 minutes with either device. This finding is consistent with previous similarly designed study results, that also incorporated the novel transducer (but not GUI).[14] The time in our study, however, is almost double that reported for out-of-hospital eFAST performed by physicians (3.5 minutes).[19] The longer time we observed is likely explained by the difference in subjects between studies. Brun, et al.'s study incorporated emergency medicine physicians with US training and experience, while we enrolled US naïve combat medics who underwent a brief training intervention.[19] This difference in time may be of little clinical significance in the prehospital, combat setting where a positive eFAST may significantly reduce time to surgical intervention by expediting medical evacuation directly from the point-of-injury. Future studies with combat medics performing eFAST in a simulated combat environment may be beneficial.

Combat medic eFAST diagnostic accuracy was approximately 90% with both devices, despite technical adequacies of roughly 74%. Both of these findings are consistent with the results of a previous study for combat medic performed eFAST.[14] Previously published studies evaluating combat medic performance of soft tissue and pneumothorax ultrasound exams also demonstrated high diagnostic accuracies.[10,11,13] Our findings coupled with published data on combat medic ultrasound performance suggest combat medics possess the capacity to learn and perform clinically useful eFAST despite less-than-thorough technical evaluations. This, in turn, indicates sustained eFAST utility despite technical skill degradation.[20] Currently, the US military does not offer ultrasound training and/or ultrasound skill sustainment for combat medics. Future studies assessing eFAST retention and knowledge gaps may enable development of

training and sustainment programs for combat medics.

Novel medical devices may offer design benefits over existing options; however, the end-user's operating environment, technical expertise, and clinical experience may negate these apparent advantages. With the exception of image quality, medics seemed to have preferred the conventional over the novice device based on several factors. Despite the unique design of the novel finger-worn, dual array transducer, medics reported the conventional transducer was easier to use. During training and testing, we observed several medics remove the novel transducer from their right index finger and hold it in their hand instead. This most commonly occurred at the outset of the eFAST when the medic, standing on the patient's right, began scanning the right upper quadrant of the abdomen. In order to place the low-frequency array in the proper position the medic had to internally rotate their right upper extremity and direct the palm of their hand down. This awkward position could have been avoided by donning the transducer on the left index finger, standing on the patient's left side, or at the head of the bed; however, virtually all medics opted to hold the device with their right hand and remain in the same position relative to the patient throughout the eFAST. We suspect this awkward positioning while using the novel transducer donned on the finger partially explains the lack of preference for the novel device. Our findings suggest either device may be employed by combat medics for eFAST.

Our study has several important limitations. First, the manikin ultrasound model used to assess diagnostic accuracy does not replicate such normal human physiology as respiration, diaphragmatic movement of the liver and spleen, and cardiac activity. Of particular importance, all lung examinations were abnormal since lung sliding was not possible, and many medics likely recognized this. However, we required all subjects to visualize the pleural lining at three separate intercostal spaces on each side of the thorax and vocalize their findings in order to reduce any artificial impact on time for eFAST completion.

We incorporated living human models to overcome simulation model shortfalls to measure time for eFAST completion. Our subjects performed eFASTs in a simulated aid station that does not mimic the far forward battlefield environment. Therefore, our findings likely do not translate to point-of-injury eFAST performance. However, we chose this setting to eliminate as many potential confounders as possible. We did not require subjects to wear the novel transducer on the finger during its use. This limits the findings of our study as it pertains to its intended use as a finger-worn device; however, the manufacturer explicitly states the novel transducer can be held (not worn) based on user preference. Finally, subjects in our study came from a single US Army installation comprised entirely of combat medics. Consequently, our findings are not generalizable to the all medics in the US Army and sister services.

Conclusion

Combat medic eFAST performance across devices did not differ with respect to time to completion, diagnostic accuracy, and technical adequacy. Medics with limited ultrasound experience performed diagnostically accurate eFASTs after a brief training intervention. Future research should assess learning gaps and skill retention in order to guide development of US military ultrasound training programs for combat medics.

APPENDICES

Appendix 1. Task specific checklist used to evaluate technical adequacy.

US Military Medic eFAST Performance with Novel vs Conventional Portable Ultrasound Devices: a Prospective, Randomized, Crossover Study. PI: Perreault

Identifier:_____

Hepatorenal Space				
	Live VScan	**Phantom V**	**Live Novel**	**Phantom Nov**
Orient image-liver left, kidney right	Y / N	Y / N	Y / N	Y / N
Depth-image ends just below kidney	Y / N	Y / N	Y / N	Y / N
Sets gain appropriately	Y / N	Y / N	Y / N	Y / N
*Visualize liver/kidney interface	Y / N	Y / N	Y / N	Y / N
*Visualize caudal tip of the liver	Y / N	Y / N	Y / N	Y / N
Score	/5	/5	/5	/5
Diagnostic Accuracy		Go / No Go		Go / No Go

Splenorenal Space				
Orient image-spleen left, kidney right	Y / N	Y / N	Y / N	Y / N
Depth-image ends just below kidney	Y / N	Y / N	Y / N	Y / N
Sets gain appropriately	Y / N	Y / N	Y / N	Y / N
*Visualize spleen/kidney interface	Y / N	Y / N	Y / N	Y / N
*Visualize diaphragm/spleen interface	Y / N	Y / N	Y / N	Y / N
Score	/5	/5	/5	/5
Diagnostic Accuracy		Go / No Go		Go / No Go

Pelvis				
Depth-image ends 3-6cm below bladder	Y / N	Y / N	Y / N	Y / N
Sets gain-compensates for PAE	Y / N	Y / N	Y / N	Y / N
*Visualize bladder in long and sweep	Y / N	Y / N	Y / N	Y / N
*Visualize bladder in trans and sweep	Y / N	Y / N	Y / N	Y / N
Score	/4	/4	/4	/4
Diagnostic Accuracy		Go / No Go		Go / No Go

Pericardium				
Orient image-apex right (SX) or apex left (PL)	Y / N	Y / N	Y / N	Y / N
Depth-image ends below pericardium	Y / N	Y / N	Y / N	Y / N
Sets gain-blood in ventricles black	Y / N	Y / N	Y / N	Y / N
*Visualize ant. and post. pericardium	Y / N	Y / N	Y / N	Y / N
Score	/4	/4	/4	/4
Diagnostic Accuracy		Go / No Go		Go / No Go

Thorax				
*Appropriate transducer-linear array	Y / N	Y / N	Y / N	Y / N
Depth-pleural interface near mid-depth	Y / N	Y / N	Y / N	Y / N
Sets gain appropriately	Y / N	Y / N	Y / N	Y / N
*Visualize pleural line at 3 IC spaces	Y / N	Y / N	Y / N	Y / N
Score	/4	/4	/4	/4
Diagnostic Accuracy		Go / No Go		Go / No Go

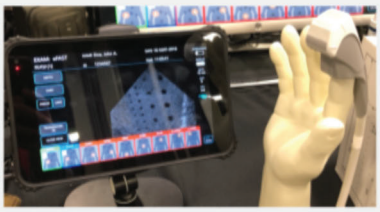
Total Exam Time			

* Denotes Critical Criteria in determining adequacy of exam

Appendix 2. Survey used to assess end-user device ease-of-use.

PARTICIPANT NUMBER / IDENTIFIER _____

NOVEL SYSTEM RATING



1. Please rate the NOVEL SYSTEM'S **Transducer**

Very Easy 5	Somewhat Easy 4	Neutral 3	Somewhat Difficult 2	Very Difficult 1

2. Please rate the NOVEL SYSTEM'S **Graphical User Interface** (Tablet Screen Interface)

Very Easy / Intuitive 5	Somewhat Easy 4	Neutral 3	Somewhat Difficult 2	Difficult / Not Intuitive 1

3. Please rate the NOVEL SYSTEM'S **image quality**

Highest Quality 5	Good Quality 4	Neutral 3	Suboptimal 2	Lowest Quality 1

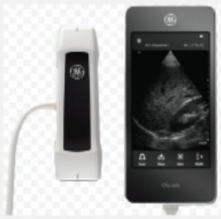
4. Please rate your **confidence in performing a complete eFAST exam** (obtaining all req'd views) with the Novel System

Very Confident 5	Somewhat Confident 4	Neutral 3	Not Very Confident 2	No Confidence 1

5. Please rate the NOVEL DEVICE's **overall performance**

Best 5	Good 4	Neutral 3	Soboptimal 2	Worst 1

CONVENTIONAL SYSTEM RATING



1. Please rate the V-Scan's **Transducer**

Very Easy 5	Somewhat Easy 4	Neutral 3	Somewhat Difficult 2	Very Difficult 1

2. Please rate the V-Scan's **Graphical User Interface** (Tablet Screen Interface)

Very Easy / Intuitive 5	Somewhat Easy 4	Neutral 3	Somewhat Difficult 2	Difficult / Not Intuitive 1

3. Please rate the V-Scan's **image quality**

Highest Quality 5	Good Quality 4	Neutral 3	Suboptimal 2	Lowest Quality 1

4. Please rate your **overall confidence in performing a complete eFAST exam** (obtaining all req'd views) with the V-Scan

Very Confident 5	Somewhat Confident 4	Neutral 3	Not Very Confident 2	No Confidence 1

5. Please rate the V-Scan's **overall performance**

Best 5	Good 4	Neutral 3	Suboptimal 2	Worst 1

Please include any additional comments on the systems' features that you preferred or disliked

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16 Years of Role 1 Trauma Care: A Descriptive Analysis of Casualties within the Prehospital Trauma Registry

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Abstract

Background: Most battlefield deaths occur in the prehospital setting prior to reaching surgical and hospital care. Described are casualties captured by the Joint Trauma System (JTS) in the Prehospital Trauma Registry (PHTR) module of the Department of Defense Trauma Registry (DoDTR), from inception through May 2019.

Methods: The JTS was queried for all PHTR encounters and associated data from inception (January 2003) through May 2019. The PHTR captures data on Role 1 prehospital care which encompasses treatment prior to arrival at a Role 2 with or without forward surgical team or Role 3 combat support hospital. Two unique patient identifiers were used to link DODTR outcome data to each PHTR encounter. Descriptive statistics were used to analyze the data.

Results: We obtained a total of 1,357 encounters from the PHTR. Of these encounters, we successfully linked 52.2% (709/1357) to the DODTR for outcome data. Encounters spanned from 2003 to 2019, with most (69.5%) occurring from 2012 to 2014. Many casualties were in the 18-25 (25.5%) or 26-33 (27.0%) age ranges, male (99.2%), injured by explosive (47.1%) or firearm (34.8%), enlisted (44.8%), and US military conventional (24.1%) and special operations (23.9%) forces. Of those linked to the DODTR, demographics were similar, most casualties sustained battle injuries (87.1%), the majority of which survived (99.1%).

Conclusions: We described 1,357 encounters within the PHTR, most of which were US casualties and casualties injured by explosives. This renewed effort by the JTS to capture more casualties for inclusion into the registry has nearly doubled the proportion of available encounters for analysis. This analysis lays the foundation for in-depth analyses targeting areas for optimizing Role 1 prehospital combat casualty care.

Keywords: prehospital, trauma, registry, military, combat

Introduction

Background: Over the past 18 plus years of overseas contingency operations, more than 60,000 US service members have sustained injuries and approximately 7,000 have died.[1] A comprehensive study of nearly 57,000 of these injured US military service members indicated that critically injured casualties accounted for approximately 16% of casualties and 90% of deaths.[2] Previous studies of injury survivability have also shown that approximately 90% of battlefield fatalities occur in the prehospital setting and 19-28% of prehospital deaths have injuries deemed potentially survivable.[3-5] Consequently, optimized prehospital care and transport likely offer the most potential for improving survival on the battlefield. However, optimization of prehospital efforts requires objective data to guide performance improvement.[6-9]

Early in the course of recent conflicts, the US military established the Joint Trauma System (JTS) and a data repository, now known as the Department of Defense Trauma Registry (DODTR), to improve combat casualty care.[10,11] Although the DODTR is the US military's premiere source for combat injury and treatment data, it previously included data only on those casualties that arrived alive to a military hospital, and it focused

primarily on hospital-based interventions.[12] To improve capture of prehospital injury and treatment data, the JTS created a standalone database called the Prehospital Trauma Registry (PHTR)[13] modelled after efforts from the 75th Ranger Regiment.[14] The PHTR has since become a submodule to the DODTR.

The PHTR receives data from three primary sources: (1) Tactical Combat Casualty Care (TCCC) cards, (2) TCCC after-action reports (AARs), and (3) JTS Trauma Resuscitation Records.

Although the commander of US Forces-Afghanistan mandated use of the TCCC card and the TCCC AAR for all combat casualties in Afghanistan starting in July 2013, the new TCCC Card (DD Form 1380) did not officially replace the old Field Medical Card (DD Form 1380 also available with the DA form 7656, 1991 edition) throughout the DoD until June 2014.[15] The Committee on TCCC (CoTCCC) approved the TCCC card and designed it to specifically capture TCCC recommended interventions.[15,16] Although currently on just a Department of the Army form obtainable through the JTS website along with other the other documentation forms,[17] the TCCC AAR serves as an additional method to capture prehospital data.[15] The JTS created the Trauma Resuscitation Record (DD Form 3019) to standardize initial hospital injury and treatment documentation. Hospital or forward surgical team personnel complete the Trauma Resuscitation Record upon casualty arrival, and it includes a section for documenting care provided and conveyed by prehospital medical evacuation personnel. Additionally, the form facilitates performance improvement and follow-on care throughout the trauma system.[15]

Previous PHTR analyses examined data spanning January 2013 to September 2014.[13,15] Subsequently, the JTS expanded the PHTR data set through renewed efforts to capture and consolidate more TCCC data from current prehospital care, and from historical prehospital care previously documented but now added to the registry. The goal of this current study was to provide an updated analysis and description of casualties captured within the Prehospital Trauma Registry from inception through May 2019. Secondarily, we seek to lay the foundation for future analyses from this data to optimize care delivery at or near the point of injury (POI) and perform hypothesis generating analyses that help guide high quality, prospective research, development, testing, and evaluation.

Methods

Data Acquisition: Protocol was submitted to the US Army Institute of Surgical Research regulatory office on behalf of this study and determined to be exempt from institutional review board oversight. The data sharing agreement was submitted and executed with the Defense Health Agency (DHA) prior to submitting a request for data (Appendix) to the JTS. Requested and obtained were de-identified data on all casualties captured by the PHTR prior to May 2019. Also requested were outcome data on PHTR casualties linkable to the DODTR. Due to new DHA requirements regarding deidentified data, only an age range, and not a specific age, was provided for each patient.

Prehospital Trauma Registry (PHTR): The JTS PHTR is a data collection and analytic tool designed to provide near-real time feedback to commanders. As previously described,[18] the primary purpose of this tool is to improve casualty visibility, augment command decision-making processes, and direct procurement of medical resources. Additionally, this tool seeks to reduce morbidity and mortality through performance improvement in the areas of primary prevention (tactics, techniques and procedures), secondary prevention (personal protective equipment) and tertiary prevention (casualty response system and TCCC).[19] The US Central Command JTS Prehospital Directorate collected TCCC cards and TCCC AARs and transferred information from these documentation tools into the PHTR. We have previously described the origins of the PHTR.[13,15]

Department of Defense Trauma Registry (DODTR): The DODTR, formerly known as the Joint Theater Trauma Registry, is the DoD's data repository for trauma-related injuries.*20-26* The DODTR includes documentation regarding demographics, injury-producing incidents, diagnoses, treatments, and outcomes following injuries. The registry includes data on US and non-US military casualties as well as US and non-US civilian casualties from the point of injury to final disposition. The DODTR is primarily comprised of patients admitted to a hospital with an injury diagnosis using the International Classification of Disease 9th Edition (ICD-9) between 800-959.9, near-drowning/drowning with associated injury (ICD-9 994.1) or inhalational injury (ICD-9 987.9) and trauma occurring within 72 hours from presentation to a facility with surgical capabilities.

Data Analysis: All analyses were performed using commercially available database software and statistical analysis software. Continuous variables were described through means and standard deviations, ordinal variables through medians and interquartile ranges, and nominal variables through numbers and percentages. Blood pressures documented as systolic over diastolic (e.g. 120/80 mmHg) or systolic obtained by palpable pulse (e.g. 90/palpation) were both considered as evidence of blood

pressure evaluation. Respiratory rates documented as either quantitative (e.g. 15 per min) or qualitative (e.g. agonal) were also considered as evidence of respiratory evaluation.

Results

PHTR—Casualties & Data: A total of 1,357 casualty encounters were obtained from the PHTR (Table 1). Of these PHTR casualty encounters, 52.2% (709/1357) were linked to the DODTR (Table 2). Casualty data spanned from January 2003 through May 2019, with most (69.5%; 943/1357) occurring from 2012 to 2014, followed by 2016 to 2018 (Figure 1). Casualty data were absent from 2005 to 2007, and from 2009 to 2010. Casualties were primarily in the 18-25 and 26-33 age ranges (52.6%; 714/1357), male (99.2%; 1347/1357), injured by explosive (47.1%; 640/1357) or firearm (34.8%; 473/1357), enlisted (44.8%; 609/1357), US military conventional and special operations forces (48.0%; 652/1357), classified as wounded in action (86.7%; 1177/1357), and injured in Afghanistan (94.5%; 1283/1357).

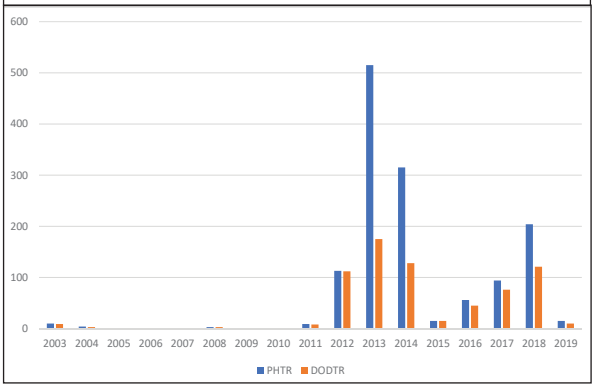
A total of 65.8% (894/1357) of patient encounters had documentation of prehospital provider type. From these 894 encounters, there were 1,396 patient-provider interactions to include care delivered by non-medic first responders (12.2%; 171/1396), medics (56.4%; 787/1396), and medical officers (31.4%; 438/1396). The most documented treatment interventions were for hemorrhage control and included pressure dressings and limb tourniquets (Table 3). Junctional tourniquets and supraglottic airways were documented the least. Most encounters included documentation of all vital signs. The most documented vital sign was for neurologic determination of level of consciousness through Alert, Verbal, Pain, Unresponsive (AVPU), and the least was for determination of pain through the numeric rating scale (Table 4).

Table 1. Description of casualties and data found in the Prehospital Trauma Registry, n=1357.

Demographics	**18-25 years**	25.5% (347)
	26-33 years	27.0% (367)
	34-41 years	8.0% (109)
	42-49 years	2.9% (40)
	50-57 years	<1% (8)
	58-65 years	<1% (5)
	66+ years	<1% (2)
	Unknown age	35.2% (479)
	Male	99.2% (1347)
Mechanism of Injury*	**Explosive**	47.1% (640)
	Firearm	34.8% (473)
	Fragmentation	4.7% (64)
	Ground Vehicle Mishap	3.9% (54)
	Aircraft Mishap	<1% (12)
	Burn	<1% (11)
	Blunt, unspecified mechanism	<1% (10)
	Structure collapse	1.1% (16)
	Environmental exposure	<1% (8)
	Drowning	<1% (1)
	Fall	2.8% (38)
	Other	5.0% (68)
Rank	**Enlisted**	44.8% (609)
	Officer	3.6% (50)
	Civilian	7.5% (102)
	Unknown	43.9% (596)
Affiliation	**US Conventional Forces**	24.1% (327)
	US Special Operations Forces	23.9% (325)
	US/NATO civilian personnel	2.9% (38)
	Host civilian personnel	<1% (2)
	Host military forces	29.5% (401)
	NATO forces	<1% (4)
	Unknown	19.1% (260)
Battle Status#	**Battle**	87.1% (1182)
	Non-Battle	12.9% (175)
Outcome	**Alive**	12.8% (175)
	Wounded in Action, Died of Wounds	<1% (6)
	Wounded in Action, Lived	86.2% (1171)
	Unknown	<1% (3)
	Killed in action	<1% (2)
Country	**Afghanistan**	94.5% (1283)
	Iraq	5.0% (68)
	Syria	<1% (6)

**Casualties could have more than one mechanism of injury documented.*
#battle status is designed if the injury was sustained while engaged in direct combat with the enemy.

Figure 1. Prehospital Trauma Registry (PHTR) entries by year along with corresponding volume of matches to the Department of Defense Trauma Registry (DoDTR) (number of entries versus the year).



DODTR—PHTR Linked Casualties & Data: Of the 709 PHTR casualty encounters linked to the DODTR, most were in the 18-25 and 26-33 year age ranges (82.1%; 582/709), male (98.7%; 700/709), injured by explosive (52.6%; 373/709) or firearm (31.8%; 226/709), US military (68.4%; 485/709), located in Afghanistan (91.1%; 646/709), with a low median composite injury severity score (ISS) of 5, and most survived to hospital discharge (97.4%; 691/709). Of the 709 casualties linked to the DODTR, 39 received whole blood, 187 received packed cells, 148 received fresh frozen plasma, and 71 received platelets. The number of PHTR to DODTR matched encounters are illustrated by year in Figure 1.

Table 2. Description of casualties and data linked from the Prehospital Trauma Registry to the Department of Defense Trauma Registry, n=709.

Demographics	**18-25 years**	41.6% (295)
	26-33 years	40.4% (287)
	34-41 years	11.8% (84)
	42-49 years	4.3% (31)
	50-57 years	<1% (6)
	58-65 years	<1% (5)
	66+ years	<1% (1)
	Male	98.7% (700)
Mechanism of Injury*	**Explosive**	52.6% (373)
	Firearm	31.8% (226)
	Ground Vehicle Mishap	4.3% (31)
	Blunt, unspecified mechanism	1.2% (9)
	Fall	3.9% (28)
	Aircraft Mishap, Rotary Wing Aircraft	1.4% (10)
	Machinery injury	1.1% (8)
	Pedestrian injury	1% (6)
	Other	2.5% (18)
Patient Category	**US military forces**	68.4% (485)
	NATO/non-NATO partners	17.3% (123)
	Contractor	2.5% (18)
	Host nation (military/civilian)	10.8% (77)
	US government civilian	<1% (6)
Military Operation	**Afghanistan (Operation Enduring Freedom)**	59.8% (424)
	Afghanistan (Operation Freedom's Sentinel)	31.3% (222)
	Iraq (Operation Inherent Resolve)	6.3% (45)
	Iraq (Operation Iraqi Freedom)	2.5% (18)
Injury Severity Score#	**Composite ISS**	5 (2-14)
	ISS ≤ 15	78.5% (557)
	ISS 16-25	11.2% (80)
	ISS > 25	10.1% (72)
Serious Injuries – Abbreviated Injury Scale 3+	**Head/neck**	9.8% (70)
	Face	<1% (3)
	Thorax	11.2% (80)
	Abdomen	6.3% (45)
	Extremities	22.4% (159)
	Skin/superficial	1.9% (14)
Total Blood Products#	**Whole blood (n=39)**	0 (0-0)
	Packed red cells (n=187)	0 (0-1)
	Fresh frozen plasma 148	0 (0-0)
	Platelets 71	0 (0-0)
Outcome Data#	**Discharged Alive**	97.4% (691)
	Total Hospital Days	4 (2-12)
	ICU Days	0 (0-4)
	Ventilator Days	0 (0-1)

ISS = Injury severity score.
**any category with 5 or less events was placed into other.*
#presented as median and interquartile range.

Table 3. Frequency of interventions.

Hemorrhage	**Hemostatic agent**	17.3% (235)
	Pressure dressing	30.6% (415)
	Limb tourniquet	24.7% (335)
	Junctional tourniquet	0.9% (12)
	Wound packing	3.7% (50)
Airway	**Nasopharyngeal airway**	2.7% (37)
	BVM	2.4% (33)
	Endotracheal tube	4.8% (65)
	Cricothyrotomy	2.3% (31)
	Supraglottic airway	0.7% (10)
Breathing	**Needle decompression**	5.2% (70)
	Chest seal	11.3% (154)
	Chest tube	3.5% (47)
Circulation	**IV fluids**	32.2% (437)
	Intraosseous access	6.8% (92)
Disability	**Backboard**	1.8% (24)
	Blizzard blanket	10.2% (139)
	Hypothermia kit	19.5% (264)
	Ready heat	4.6% (63)
	Eye shield	1.8% (24)
	Pelvic splint	1.4% (19)
	Extremity splint	13.6% (185)

Discussion

In this analysis, we present a renewed effort by the JTS to expand capture of data within the PHTR from our previously published 705 casualties to the 1,357 noted in this dataset.[15] Of note, in our previous dataset JTS linked only 190 of the 705 (26.9%) from the PHTR to the DODTR for more comprehensive outcome data such as survival to hospital discharge and blood products administered. In the current dataset presented here, the JTS linked 709 of the 1,357 (52.2%) to the DODTR—this is nearly a double proportion that were linkable for outcome data compared to our previously published data.[15] The JTS relies on deterministic linkage that requires 2 positive identifiers which remains challenging in countries with different languages, especially in Afghanistan with multiple local dialects. Even minor spelling differences in names can preclude linkage, so this finding is greatly improved compared to our previous data request likely due to the inclusion across more than one theater of operation and more US personnel.

Table 4. Vital signs documentation within the Prehospital Trauma Registry.

Heart rate	85.9% (1166)
Blood pressure	77.2% (1047)
Respiratory rate	81.1% (1101)
Pulse oximetry	61.0% (828)
AVPU	87.8% (1191)
GCS	51.8% (703)
Pain	22.4% (304)

Improvements in combat casualty care require data-driven solutions that optimize care delivery. The Role 1 phase of care has always lacked reliable data. As such, the renewed efforts by the JTS represents the importance within the DoD in making improvements. The renewed effort to capture data for entry into the PHTR started approximately 2016. The attempts at retrospective capture are quite limited as many of these records are likely destroyed, missing, or otherwise unaccounted for. Moreover, the mandates for data capture have varied throughout the wars with more progressive requirements as the theaters became more seasoned and developed. This likely explains the multiple gaps noted within registry capture, namely 2005-2007 and 2009-2010. Previous analyses revealed multiple areas for improvement in prehospital care; however, these findings were limited to a single military operation over a short time period.[17,27] This new attempt to capture PHTR data encompasses multiple military operations in multiple theaters of operation over a longer span of time.[17,27-31] Moreover, nearly one-third had a medical officer involved in their Role 1 care highlighting the need for targeting improvements from all levels of medical personnel including the officers. As previously noted, the data mandate has evolved, as have documentation methods including multiple iterations of the TCCC cards. Additionally, the TCCC-specific AAR did not come about until several years into the war. These invaluable tools likely would have added

data capture earlier in the wars in parallel with the performance improvement mandates but instead represent limitations in the currently available data. Other limitations include the lack of situational information that is not captured in any of the Joint Trauma System registries or capture of casualties that died before reaching medical personnel. We still have the major gap in capture of those that were killed in action for which they are not captured in the DODTR nor is a TCCC card or AAR generated.[15] One possible solution that has been previously used through a DoD-funded effort was the use of prospective data collection personnel in the combat theaters at medical facilities that would capture data on casualties brought in.[32] Such a system greatly—albeit temporarily—aided in high quality data capture.

A 2019 publication evaluated 56,763 US military casualties from the recent conflicts.[33] Our dataset only captures 652 US military casualties, which is approximately 1% of this population. It is unlikely that every one of the 56,763 casualties received medical evaluation and care in the prehospital setting, or that all required immediate interventions. Nevertheless, we suspect that prehospital care documentation and data capture remains incomplete, and that a data collection priority moving forward must be better prehospital documentation and data capture for all casualties ranging from minor wounds to critically wounded so as to improve the full gamut of care delivered to casualties seen and treated at the Role 1 phase of care. Moreover, the 2017 National Defense Authorization Act specifically required optimization of performance improvement methods to improve military health readiness in the deployed setting. Specific to this dataset, we plan to perform the following analyses *a priori*:

1. Time-based trends assessing changes in interventions based on TCCC changes, theater guidance, etc.
2. Outcomes based on interventions at the POI.
3. Outcomes associated with medical provider type (e.g. battlefield first responder, medic, medical officer).
4. Outcomes based on evacuation methods.
5. Contemporary TCCC guideline adherence.

Conclusion

We described 1,357 encounters within the PHTR, most of which were US casualties and casualties injured by explosives. This renewed effort by the JTS to capture more casualties for inclusion into the registry has nearly doubled the proportion of available encounters for analysis. This analysis lays the foundation for in-depth analyses targeting areas for optimizing Role 1 prehospital combat casualty care.

Acknowledgements

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Sports Injuries among Deployed US Service Members between October 2001 and December 2018

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Abstract

Background: Sports injuries are an important non-battle cause of attrition and morbidity among deployed US service members (SMs). Injuries secondary to sport may cause physical disability and prolonged periods of limited duty days. Our objective was to provide a descriptive analysis of sports injuries sustained by US SMs which may assist in the preventive strategies and thereby decrease their burden on the deployed force.

Methods: Using the Department of Defense Trauma Registry's (DoDTR) data between October 2001 and December 2018, a retrospective cross-sectional analysis was conducted. We reported summary statistics of injury characteristics and care provided, stratified by geographic location.

Results: We found 1,578 causalities with sport injuries (4.9% of DoDTR); 1,081 (68.5%) in Iraq and Syria and 497 (31.5%) in Afghanistan. Most casualties had mild injuries (injury severity score: 1-9; n=1,514; 95.9%) and most sustained injuries in the lower extremities (n=741; 47%) followed by upper extremities (n=430; 27.2%). Most injuries were caused by a striking force (n=827; 52.4%) followed by overexertion (n=444; 28.2%), and 512 casualties (32.4%) had a fall incident. About 833 casualties (52.8%) received at least one surgery, and 931 casualties (59%) were hospitalized for two days or more. One casualty died of wound (0.1%).

Conclusions: Sports injuries continue to be an important source of morbidity and attrition and require disproportional medical attention, relative to their mild severity, representing a significant burden to the deployed health care system and impact combat readiness. Further research addressing the prevention of sports injury among deployed US SMs is needed.

Introduction

The injuries sustained in sports activities among US service members (SMs) are an important cause of morbidity in non-battle settings. Sports and physical activities and regular exercise are essential for the readiness of US SMs and their overall health.[1-3] However, such injuries incurred from participation in sports activities (e.g., musculoskeletal injuries and concussion) may cause physical disability and prolonged periods away from the duty requirements of the SMs affecting their readiness for deployment. Therefore, understanding the risks of sports participation should be understood and mitigated before engaging in sports activities. Although military sports injuries, being in non-battle settings, are analogous to those sustained in civilian settings, their impact may extend beyond missed duty days and disability and may hinder the military mission. Since deployment readiness is a function of each SM's ability to perform their duty, it is paramount to understand the characteristics and extent of injuries occurring during sports activities in the deployed environment.

Previous studies demonstrate that the rates of injuries occurring from sports among active duty Army personnel during the period 1989-1994 were 38 and 18 per 10,000 person-years for men and women, respectively. Men lost an average of 13 days per injury and women lost an average of 11 days per injury.[4] During a similar period (1990-1994) for the same population, sports injuries were the third leading cause of injuries for men (17%) and the fifth leading cause for women (9%) in

the 25 largest US Army military occupational specialties.[5] In 2008, a survey was conducted among active-duty SMs concerning injuries sustained in the previous year. Of 10,692 SMs responded, 49% sustained an injury from any cause; 52% of them had an exercise or sports activities-related injury.[6] This further shows the importance of sports injuries in the young US SMs' population. Between January 2003 and December 2014, 697 SMs sustained sports injuries which accounted for 6.8% of all non-battle casualties during that period.[7]

The Defense Health Agency Joint Trauma System (JTS)[8-10] hosts and maintains the Department of Defense Trauma Registry (DoDTR). Since 2001, the DoDTR, which was formerly known as the Joint Theater Trauma Registry (JTTR), has been collecting data on traumatic injuries sustained by any patient treated in US medical treatment facilities alongside demographic information and the care provided to them.[9,11] The DoDTR has been utilized to conduct evidence-based performance improvement as well as supports multiple aspects of trauma research. Results from research and performance improvement projects help to develop and promulgate clinical practice guidelines, relevant policies, and interventions to improve clinical care and prevention methods to better serve US uniformed personnel. The DoDTR contains data on sports injuries in the deployed setting that may provide a reliable source to help us identify the characteristics and the trends of sports injuries among deployed US SMs in recent years. An up-to-date description of sports injuries sustained by US SMs in deployed settings will not only provide a better understanding of the nature these injuries but will inform preventative measures which could decrease attrition in the deployed environment.

Methods

In this study, we conducted a retrospective cross-sectional analysis for the period from October 2001 and December 2018 using the Department of Defense Trauma Registry (DoDTR). The DoDTR, which is maintained by the Joint Trauma System (JTS), serves as a comprehensive US military trauma registry that contains data collected from abstracted medical records of trauma casualties who were admitted and treated in US military treatment facilities (MTFs). Sports injuries were defined as injuries sustained during sport recreational activities and physical training (e.g. combatives). These injuries were identified using the e-codes for sports injuries from the International Classification of Diseases 9th Revision (ICD-9) and 10th Revision (ICD-10) or identified in the DoDTR with sports as the mechanism of injury and confirmed by injury narrative.

The inclusion criteria of the study were (1) active duty US SMs; (2) sustaining non-battle traumatic sports injuries; and (3) injuries sustained while being deployed to one of the following US military operations: Operation Enduring Freedom (OEF), Operation Freedom's Sentinel (OFS), Operation Iraqi Freedom (OIF), Operation New Dawn (OND), and operation Inherent Resolve (OIR).[12] A full review of records from the Armed Forces Medical Examiners System was conducted to ascertain non-battle deaths incurring due to sports injuries. The population of the study was divided into two groups based on geographic location: (1) those sustaining sports injuries while deployed in Afghanistan (i.e. OEF and OFS); and (2) those occurring in Iraq and Syria (i.e. OIF, OND, and OIR).

A descriptive summary of patient demographics and sports injury characteristics was reported, and the results were stratified by geographic location. The Abbreviated Injury Scale 2005 (AIS) was used to identify injured body regions and calculate the overall Injury Severity Score (ISS).[13] Counts and percentages were reported for categorical variables, while mean and standard deviation (SD) or median and interquartile range (IQR) were reported for continuous variables. The Chi-square test or Fisher's exact test when warranted were used for categorical variables and Student's t-test for continuous variables was used. The proportions of sports injury casualties per year and geographic location were reported to both: (1) all US SMs DoDTR casualties, and (2) all US SMs non-battle casualties. The specific cause of injury of these non-explosive mechanisms was reported in five groups: (1) fall, not secondary to other mechanisms; (2) overexertion; (3) striking force: struck by or against an object, with or without a confirmed subsequent fall; (4) traffic-related injury (on- or off-road; e.g., cycling accidents); and (5) other or unknown mechanism of injury. We also reported the type of sport involved in the sports injuries per geographic location. The length of hospital stay was reported in days by geographic location and divided into three groups: (1) one day or less; (2) two to seven days; (3) more than a week of hospitalization. The number of surgical procedures performed, the proportions of US casualties receiving them, and the proportions of the casualties receiving the three most performed surgical procedures were reported per year and geographic location. This study (IRB#: DHQ-2023) was deemed as research that does not include human subjects by the Defense Health Agency Human Research Protection Office.

Results

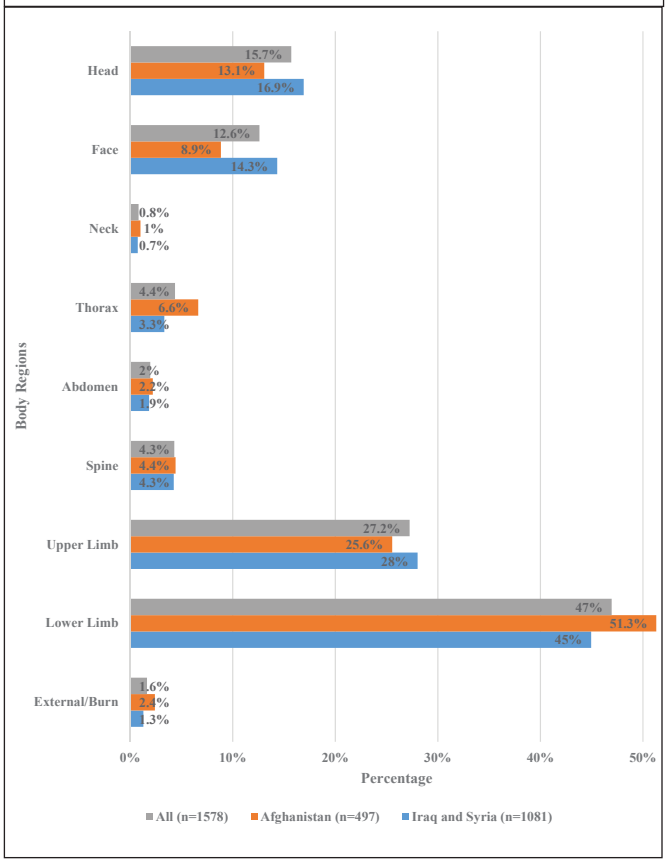
Out of 32,350 US SMs admitted to US MTFs in the DoDTR who sustained traumatic injuries during the

Table 1. Demographic characteristics of deployed US service members sustaining sports injuries from October 2001 to December 2018 per geographic location.

Characteristics	Afghanistan [a] n=497 (31.5%)	Iraq and Syria [b] n=1081 (68.5%)	Total n=1578	*p*-value [c]
Age (in years)				0.2156
Mean (SD [d])	29.5 (7.8)	28.5 (7.4)	28.8 (7.5)	
18-24	163 (32.8%)	404 (37.4%)	567 (35.9%)	
25-34	207 (41.7%)	444 (41.1%)	651 (41.3%)	
35-44	105 (21.1%)	195 (18.0%)	300 (19.0%)	
45-59	232 (4.4%)	38 (3.5%)	60 (3.8%)	
Gender				0.2115
Female	23 (4.6%)	67 (6.2%)	90 (5.7%)	
Male	474 (95.4%)	1014 (93.8%)	1488 (94.3%)	
Military Service				<0.0001
Air Force	64 (12.9%)	85 (7.9%)	149 (9.4%)	
Army	311 (62.6%)	846 (78.3%)	1157 (73.3%)	
Coast Guard	-	1 (0.1%)	1 (0.1%)	
Marine	93 (18.7%)	99 (9.1%)	192 (12.2%)	
Navy	29 (5.8%)	50 (4.6%)	79 (5.0%)	
Military Rank				<0.0001
Enlisted E1-E3	87 (17.5%)	202 (18.7%)	289 (18.3%)	
Enlisted E4-E6	266 (53.5%)	656 (60.7%)	922 (58.4%)	
Enlisted E7-E9	68 (13.7%)	69 (6.4%)	137 (8.7%)	
Officer O1-O3	39 (7.9%)	98 (9.1%)	137 (8.7%)	
Officer O4-O6	24 (4.8%)	43 (3.9%)	67 (4.3%)	
Officer O7-O9	2 (0.4%)	-	2 (0.1%)	
Warrant W1-W3	9 (1.8%)	11 (1.0%)	20 (1.2%)	
Warrant W4-W6	1 (0.2%)	2 (0.2%)	3 (0.2%)	
Unknown	1 (0.2%)	-	1 (0.1%)	
Predominant Injury Type				0.3181
Blunt	481 (96.8%)	1024 (94.7%)	1505 (95.4%)	
Multifactorial	4 (0.8%)	12 (1.1%)	16 (1.0%)	
Penetrating	5 (1.0%)	15 (1.4%)	20 (1.2%)	
Other	3 (0.6%)	6 (0.6%)	9 (0.6%)	
Missing	4 (0.8%)	24 (2.2%)	28 (1.8%)	
Injury Severity Score				0.8676
Median (IQR [e])	4 (4-4)	4 (2-4)	4 (2-4)	
Mild: 1-9	476 (95.8%)	1038 (96.1%)	1514 (95.9%)	
Moderate: 10-15	9 (1.8%)	22 (2.0%)	31 (2.0%)	
Severe: 16-25	7 (1.4%)	9 (0.8%)	16 (1.0%)	
Critical: 26-75	4 (0.8%)	10 (0.9%)	14 (0.9%)	
Missing	1 (0.2%)	2 (0.2%)	3 (0.2%)	
Final Discharge Status				0.4976
Alive	497 (100%)	1080 (99.9%)	1577 (99.9%)	
Dead	-	1 (0.1%)	1 (0.1%)	

a Includes: Operation Enduring Freedom and Operation Freedom's Sentinel. b Includes: Operation Iraqi Freedom, Operation New Dawn, and Operation Inherent Resolve. c p-value obtained from Chi-square test or Student's t-test. d SD: Standard Deviation. e IQR: Interquartile Range.

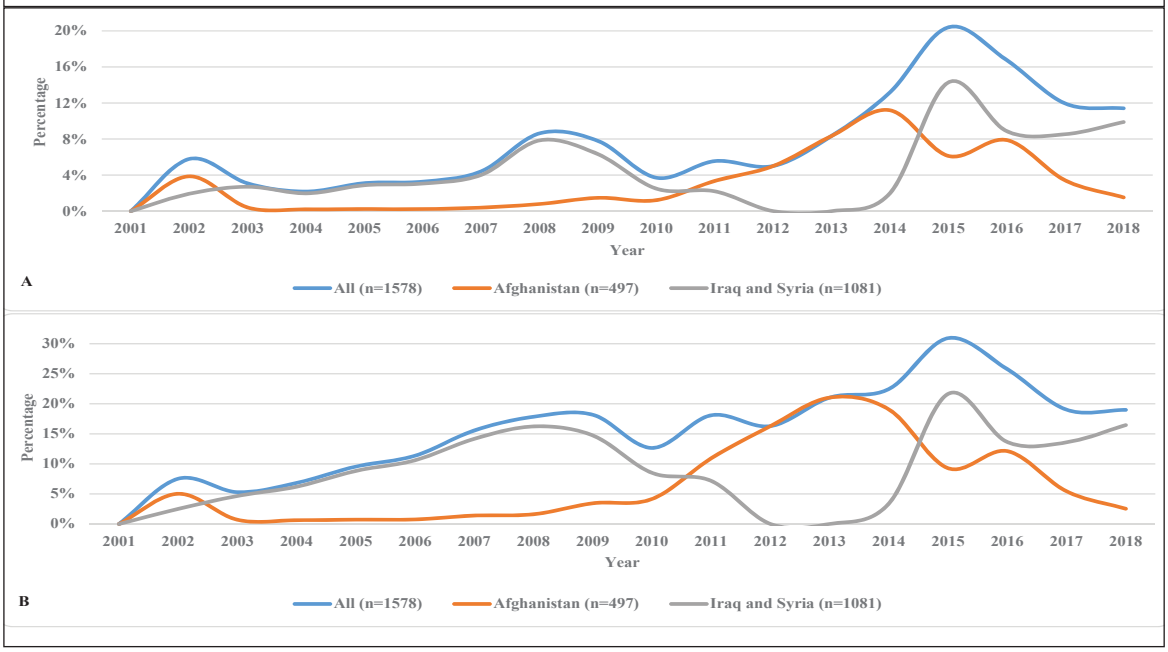
Figure 1. Proportions of deployed US service members sustaining sports injuries from October 2001 to December 2018 per anatomical body region and geographic location.



study period, there were 1,578 casualties (4.9%) who met the inclusion criteria of the study. These casualties accounted for 13.2% of all US SMs casualties who sustained non-battle injuries (out of 11,971). Approximately two-thirds (n=1,181; 68.5%) of all sports casualties occurred in Iraq or Syria, while the remaining casualties (n=497; 31.5%) occurred in Afghanistan. The largest age group was those between 25 and 34 years old at the time of injury (n=651; 41.3%), followed by those 24 years old or younger (n=567; 35.9%). Female casualties represented 5.7% (n=90) of all casualties. The vast majority of the casualties included in the study belonged to the US Army (n=1,157; 73.3%). The Army had more casualties in Iraq and Syria (78.3% vs. 62.6%), while the Marines and the Air Force sustained more casualties in Afghanistan (18.7% and 12.9% vs. 9.1% and 7.9%, respectively). Most casualties were junior and mid-grade enlisted SMs, belonging to E1-E6 ranks (n=1,211; 76.7%). The sports injuries sustained were predominantly blunt (n=1,504; 95.4%) and had mild severity on the injury severity score scale (ISS: 1-9; n=1,514; 95.9%). The median severity was 4 (IQR: 2-4), which was the same for both geographic locations. There was one sport related death (<0.1%) that occurred in Iraq in 2003 due to a fall while running. The demographic characteristics of the studied SMs are presented in Table 1.

Lower extremities were the most affected body region with 47% of casualties (n=741) sustaining lower extremity injury (Figure 1). A higher proportion of casualties sustained lower extremity injury in Afghanistan than in Iraq and Syria (51.3% vs. 45%). The upper extremities were the second most prevalent body region injured (n=430; 27.2%). The head (n=248; 15.7%) and face (n=199; 12.6%) were the third and fourth most affected body regions. The proportion of sport injury casualties to all US SMs casualties in the DoDTR was the highest in 2015 (n=30; 20.4%), even though there were more casualties in 2008 (n=199; 8.6%). There were no casualties in 2001; after 2001, the lowest proportion occurred

Figure 2. Proportions of deployed US service members sustaining sports injuries from October 2001 to December 2018 per year and geographic location. A: To all US service members in the Department of Defense Trauma Registry. B: To all US service members with non-battle injuries.



in 2004 with only 2.2% (n=87) of all casualties in the DoDTR (Figure 2-A). Almost one-third (n=30; 30.9%) of all non-battle US SMs casualties occurring in 2015 sustained sports injuries. After 2001, the lowest proportion to non-battle casualties was in 2003 with 74 casualties (5.4%) (Figure 2-B). Most casualties before 2011 and after 2014 were occurring in Iraq, while between 2011 and 2014, they were mostly occurring in Afghanistan.

More than half of sport casualties sustained injuries caused by a striking force where they were struck against or by an object (n=827; 52.4%) (Table 2). A higher proportion of casualties experienced this mechanism in Iraq and Syria than in Afghanistan (n=617; 57.1%; vs. n=210; 42.3%). Overexertion was the second highest occurring mechanism of injury (n=444; 28.2%). Overexertion occurred in a higher proportion in Afghanistan compared to Iraq and Syria (n=194; 39%; vs. n=250%; 23.2). The sports activity in which most casualties occurred were basketball (n=344; 21.8%) followed by sports categorized as football (which includes American football, flag football, powderpuff football, ultimate Frisbee, and rugby) which accounted for 18% (n=284) of casualties. In Iraq and Syria, football varieties were more frequent than in Afghanistan (n=217; 20.1%; vs. n=67; 13.5%). The complete list of injured SMs per type of sport is shown in Table 3.

Table 2. Causes of sports injuries for deployed US service members sustaining sports injuries from October 2001 to December 2018 per geographic location.

Cause of Injury	Afghanistan n=497 (31.5%)	Iraq and Syria n=1081 (68.5%)	All n=1578 (%)
Fall	67 (13.5%)	154 (14.2%)	221 (14.0%)
Overexertion	194 (39.0%)	250 (23.2%)	444 (28.2%)
Struck by/against an object	210 (42.3%)	617 (57.1%)	827 (52.4%)
With Confirmed Fall	75 (15.1%)	216 (20.0%)	291 (18.4%)
Without Confirmed Fall	135 (27.2%)	401 (37.1%)	536 (34.0%)
Traffic on/off road	10 (2.0%)	26 (2.4%)	36 (2.2%)
Other/Unknown	16 (3.2%)	34 (3.1%)	50 (3.2%)

Around 50.8% (n=801) of casualties stayed in the hospital between 2-7 days, 41% (n=647) stayed for one day or less, and 8.2% (n=130) stayed for more than one week. Approximately half of the casualties in our study required surgical procedures (n=833; 52.8%). There were a total of 1,226 surgical procedures performed during the study period in US MTFs; 815 (66.5%) surgeries were performed on casualties injured in Iraq and Syria and 411 (33.5%) in Afghanistan. Most surgeries performed before 2011 were on casualties injured in Iraq, and after 2011, most surgeries were performed on those injured in Afghanistan. From 2004 to 2016, between 49.4% (n=77) and 73.6% (n= 39) of all sports casualties received at least one surgical procedure. Among those who required surgical procedures, more than 4 in 5 (n=690; 82.8%) had orthopedic surgeries, which remained the type of surgical procedures most performed between 2003 and 2017.

Discussion

Table 3. Counts of deployed US service members sustaining sports injuries from October 2001 to December 2018 per type of sport and geographic location.

Sport	Afghanistan n=497 (31.5%)	Iraq and Syria n=1081 (68.5%)	All n=1578 (%)
Basketball	111 (22.3)	233 (21.6)	344 (21.8)
Football Varieties [a]	67 (13.5)	217 (20.1)	284 (18.0)
Wrestling/Martial Arts/Combative Training	76 (15.3)	103 (9.5)	179 (11.3)
Weight Lifting	60 (12.1)	62 (5.7)	122 (7.7)
Running/Jogging/Hiking	44 (8.9)	72 (6.7)	116 (7.4)
Baseball/Softball/Stickball/Kickball	22 (4.4)	72 (6.7)	94 (6.0)
Volleyball	23 (4.7)	39 (3.6)	62 (3.9)
Physical Training/Workout	25 (5.0)	36 (3.3)	61 (3.9)
Soccer	18 (3.6)	42 (3.9)	60 (3.8)
Boxing	6 (1.2)	26 (2.4)	32 (2.0)
Biking/Cycling	7 (1.4)	23 (2.1)	30 (1.9)
Diving/Swimming	1 (0.2)	13 (1.2)	14 (0.9)
Dodgeball	6 (1.2)	8 (0.7)	14 (0.9)
Other/Unknown	31 (6.2)	135 (12.5)	166 (10.5)

Sports activities are important for the physical wellbeing of US SMs, teambuilding for unit cohesion, and combat readiness by fostering endurance, communication and physical stamina. However, sports injuries are an important non-battle source of morbidity which affects SMs' active duty days and mission readiness in the deployed environment. Sports injuries accounted for 13.2% of all non-battle injuries in the combat theater, which is higher than the previous findings by Le et al for the period between 2003 and 2014. This rise in sports injury casualties is likely due to that our study included a longer study period (2001 to 2018) and that the proportions of sports casualties were higher in these later years not included in the said previous work (Figure 2). We also used extensive inclusion criteria based on mechanism of injury, e-codes, and narratives. We identified three key findings in this analysis: (1) sports injury casualties differed across geographic locations in (a) demographics; (b) trend per year; and (c) mechanism of injury and (d) type of sport; other key findings were (2) the extremities were the most prone for injury, followed by the head and face; and (3) sports injuries contributed to higher healthcare costs and limited duty days as measured by surgical procedures performed and length of hospital stay.

The casualties in both geographic regions manifested different characteristics in their demographics. Those sustaining sports injuries in Iraq and Syria were younger, included more female casualties, and were disproportionately serving in the Army. On the other hand, a higher proportion of casualties sustaining injuries in Afghanistan were serving in the Marines and Air Force, compared to those in Iraq and Syria. Sports injury casualties occurred in the two geographic regions in an alternating trend. Before 2011 and after 2014, there were more casualties in Iraq, corresponding to the total number of deployed SMs in that region. In contrast, most of the casualties that occurred between 2011 and 2014 were in Afghanistan. This alternating trend can be attributed to operational tempo and accordingly the differences in the number of deployed US SMs in either geographic location. Compared to casualties in Iraq and Syria, the proportion of casualties sustaining sports injuries due to overexertion was significantly higher in Afghanistan. In contrast, a higher proportion of casualties sustained injuries due to a striking force in Iraq and Syria. This finding is corroborated with the type of sport in which the casualties were engaged in both geographic locations. A higher proportion of casualties sustaining injuries in Iraq and Syria were in sports that included one of the varieties of football, where there is an increased possibility of striking by or against an object. While those in Afghanistan sustained sports injuries that were caused by repetitive and straining activities resulting in overexertion, like weight lifting, combat-based sports, and running.

The lower extremities were the most prone to injuries, followed by the upper extremities. This finding is characteristic of injuries associated with physical activity and is similar to other findings by previous.[4,6] However, more than one-quarter of all casualties sustained sports injuries in the head or face. An injury to the head might have latent consequences that will appear or exacerbate later (e.g., concussion). An important concern to consider here is that a mild severity trauma to the extremities (e.g., strain or bruise) or the head, although it might not result in long hospitalization, it will affect the wellbeing of the individual and combat readiness.

Sports and physical activities are considered essential for SMs' wellbeing and physical fitness. However, despite sustaining predominantly injuries of mild severity, over half of sports casualties required surgical procedures and almost 3 in 5 casualties needed a hospitalization of two days or more. This high proportion of required surgical procedures and hospitalization alludes to the nature of sports injuries and the affected body regions. In absence of direct costs related to sports injuries, this information provides an understanding of the continuous financial burden resulting from such injuries. The mechanisms

of injury related to sports injuries are associated with a higher chance of injuries that limits physical activities. Examples of such injuries are orthopedic injuries (e.g., fracture, avulsion, dislocation, and joint strains), muscular and soft tissue injuries (e.g., compartment syndrome, muscle spasm, and muscle contusion or muscle bruises), and other conditions that are not readily apparent like concussions. Preventive and cautionary measures are required when playing sports or participating in physical training to prevent the occurrence of sports injuries. Such preventive measures may include wearing sport-related personal protective equipment at all times when participating in combat-based sports, adequate rest and hydration, avoiding overexertion, and stopping the activity to seek medical attention promptly when there is an indication of potential injury (e.g., bruises, spasms, or dizziness).

The study encountered few limitations related to the nature of data DoDTR that are obtained from abstracted medical records which contain missing information. There was no information available regarding the use of sport-related personal protective equipment, direct and indirect financial burden in terms of medical expenses, or limited or lost duty days associated with these injuries outside of hospital stay (i.e. while in physical therapy). Despite these limitations, this study provides an up-to-date report of the characteristics of sports casualties per geographic location and year. Further work is needed to study sports injuries using other data sources that would include other factors not studied before to expand our knowledge and provide more information that informs injury preventive measures and improved medical care for US service members.

Conclusion

Sports activities are essential for the wellbeing of US SMs; however, sports injuries continue to be an important non-battle source of morbidity and attrition among US SMs in deployed settings. More casualties occurred in Iraq and Syria than in Afghanistan, and the characteristics and trends of these injuries differed between the two geographic locations. Sports injuries required disproportionate hospitalization and medical attention compared to their predominantly mild severity. Further research is needed to maintain a combat ready force in the deployed setting and minimize or eliminate the occurrence of preventable injuries.

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The Impact of Military Emergency Medicine Scholarly Activity

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Abstract

Background: Emergency medicine is recognized as a critical wartime specialty within the US military. Military emergency medicine contributes to medical literature in unique ways not seen with our civilian counterparts. The impact of this contribution, especially regarding innovations in military medicine, has not been previously examined. This study evaluates the numbers of citations for emergency medicine manuscripts published by members of the US military.

Methods: Utilizing the Scopus database, we identified published manuscripts from 2000 to 2020 with an emergency medicine author affiliated with a US military treatment facility. We sorted manuscripts on the number of citations in Scopus and categorized each paper as to whether it addressed military unique topics.

Results: We identified 1,718 manuscripts through Scopus, and based on a 10-citation minimum, we further analyzed 508 manuscripts. After verification of military affiliation, we included 421 manuscripts. The mean number of citations per manuscript was 31.7 ± 40.5; the Mean Cite Score was 4.75 ± 6.17 with a Field Weighted Citation Index (FWCI) of 2.96 ± 6.25. Citation count of publications has been steadily increasing in recent years with significantly more citations for military relevant publications when compared to non-military relevant publications.

Conclusions: These findings highlight the importance of military emergency medicine scholarly activity which has a history of contributions that address specific medical needs of the warfighter and advance the specialty. Military emergency medicine papers have seen rising numbers of citations in the medical literature, particularly those related to military relevant topics emphasizing combat casualty care and military readiness.

Keywords: graduate medical education, emergency medicine, military medicine, scholarly activity, citation analysis

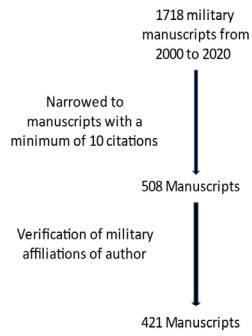
Introduction

Emergency physicians (EPs) are a critical wartime specialty offering unique skills in the care of deployed members of the Armed Forces. EPs have a diverse core knowledge, both hospital and prehospital, making them distinctly well suited for the challenges of the battlefield. Most recently in Operation Enduring Freedom (OER) and Operation Iraqi Freedom (OIF), the military utilized EPs at every echelon of care. EPs fulfill a variety of roles including leadership positions, strategic medical planning, medical engagement missions, advisors and liaisons, special operations units, and patient care in many settings. EPs have also performed significant research that has advanced battlefield care and directly contributed to the Committee on Tactical Combat Casualty Care (CoTCCC).[1] Of note, EP academic contributions included literature related to whole blood transfusion,[2] damage control resuscitation (DCR),[3] resuscitative endovascular balloon occlusion of the aorta (REBOA),[4] and extracorporeal membrane oxygenation (ECMO).[5] Further, many recent military advancements relevant to emergency medicine have translated to the civilian adoption of principles related to DCR and whole blood.[6,7] Within the military services, EPs are one of the most deployed specialties, placing emergency medicine within the top tier of critical specialties.[1,8]

The specialty of emergency medicine, however, is relatively new. While use of ambulances in the battlefield to transport casualties to a centralized care area has occurred since the 1790s, the modern concept of an

emergency department with 24/7 staffing did not emerge until 1961.[9] Due to improved casualty care in the Vietnam War, the US initiated the 1966 Federal Highway Safety Act, which set standards for ambulances and training. Emergency departments in the 1960s were not staffed with specialty trained physicians, and it was not until 1970 that the University of Cincinnati introduced the first emergency medicine residency. Although the American College of Emergency Medicine was established in 1969, emergency medicine was not recognized as a specialty by the American Medical Association until 1972 and was not granted "primary board status" until 1989.[10] The first military emergency medicine residency program opened at Brooke Army Medical Center in 1977, and this is currently the largest emergency medicine program in the Department of Defense (DoD). There are now a total of ten military or military-affiliated emergency medicine residency programs in the country,[11] with several more military emergency medicine departments throughout the world.[12] Faculty and residents of these programs, many of whom have returned from combat with invaluable medical experience, actively contribute to military emergency medicine scholarly activity. This manuscript examines the citation counts for papers published by military emergency physicians during the last two decades.

Figure 1. Manuscript selection.



An initial search for manuscripts authored between 2000 and 2020 by a military affiliated author yielded 1,718 papers. This was narrowed to 508 articles with less than 10 citations. The list was further narrowed to 421 after confirming military affiliation.

Methods

This study met institutional requirements for being exempt from regulatory oversight. Utilizing the Elsevier Scopus database, we conducted a publication search for all journal articles from January 2000 to June 2020 listing an emergency medicine author and affiliation with any US military treatment facility (MTF). We then reviewed the initial list of publications individually to confirm the emergency medicine author had an MTF affiliation. The authors are well versed in the DoD MTFs. We included only journal manuscripts with a minimum of 10 citations and ranked them in order of Scopus citations. We selected this number of citations to limit the analysis to more recognized manuscripts in the medical literature.

From this final group of manuscripts, we obtained information to include the MTF affiliation, Cite Score (based on 2019 rankings), Field-Weighted Citation Impact (FWCI), and SCImago Journal Rank (SJR) as listed in Scopus, and applicability to unique aspects of military medicine.[13] FWCI is an author metric which compares the total citations actually received by a researcher's publications to the average number of citations received by all other similar publications from the same research field. The global mean of the FWCI is 1.0, so an FWCI of 1.50 means the publication was cited 50% more than the world average; whereas, an FWCI of 0.75 means the publication was cited 25% less than world average. CiteScore is the number of citations received by a journal in one year to documents published in the three previous years, divided by the number of documents indexed in Scopus published in those same three years.

The authors reviewed all retrieved abstracts and came to unanimous agreement regarding which manuscripts were military relevant publications. Examples of criteria used to determine military relevance included research involving a primary active duty military population; direct impact on military readiness and training; or direct relationship to combat casualty care to include trauma, critical care, or resuscitation.[14]

We summarized the three scores for comparison (Cite Score, FWCI, and SJR) using means and standard deviations and analyzed using Wilcoxon's method. Trends over the years 2000 to 2020 were compared using standard linear regression. Further analysis included differences between military relevant and other subject matter manuscripts. We performed all statistical analysis using standard software. Several regional areas comprised multiple institutions with military affiliations. These regions included Washington, DC comprising Walter Reed National

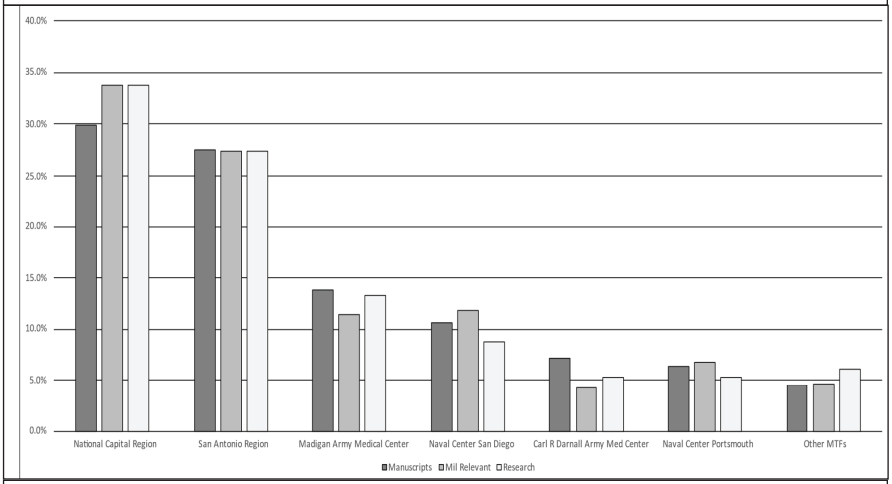
Table 1. Manuscripts based on number of citations.

	Total	10-19	20-39	> 40
N	421	196	131	94
Military Relevant Topic	263 (62.5%)	114 (58.2%)	86 (65.6%)	63 (67.0%)
Citations	31.7 ± 40.5	14.0 ± 2.7	27.4 ± 5.8	74.5 ± 69.3
Field Weighted Citation Index	2.96 ± 6.25	1.84 ± 3.67	2.62 ± 6.21	5.71 ± 9.09
Cite Score	4.75 ± 6.17	3.77 ± 4.90	4.13 ± 2.65	7.64 ± 10.03
SCImago Journal Rank	1.15 ± 1.69	0.91 ± 1.35	0.99 ± 0.74	1.85 ± 2.77

Table 2. Military relevant topics.

Military Topic	N (%)
Trauma	77 (29.3%)
Toxicology	61 (23.2%)
Military Population	52 (19.8%)
Deployment	19 (7.2%)
Military Training	19 (7.2%)
Critical Care	15 (5.7%)
Orthopedic Trauma	10 (3.8%)
Transport	10 (3.8%)
TOTAL	**263 (100%)**

Figure 2. Scholarly activity by region/institution.



Percentage of overall manuscripts based on location along with percentage of overall manuscripts that were 1) military relevant and 2) research-based manuscripts.

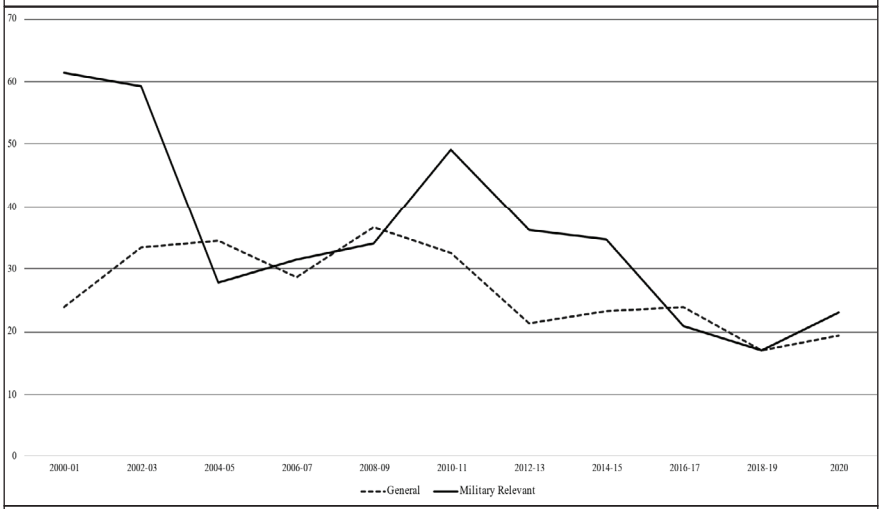
Medical Center (WRNMMC) and Uniformed Services University of the Health Sciences (USUHS), and San Antonio, TX comprising Brooke Army Medical Center (BAMC), Wilford Hall Ambulatory Surgical Center (WHASC). We combined publications with author affiliations from multiple institutions in a single region into a single group for analysis.

Results

From 2000 to 2020, the initial search for manuscripts with authors affiliated with an MTF or "emergency medicine" yielded 1,718 manuscripts from all institutions identified through Scopus. After limiting further analysis to articles with a minimum of 10 citations in Scopus, we identified 508 manuscripts. After verification of author affiliation and MTF to exclude authors without a military affiliation, we analyzed the final group of 421 manuscripts (Figure 1).

Of the 421 manuscripts included, 70.5% (297) had a military treatment facility (MTF) listed as the primary institution (Table 1). Types of manuscripts included 1) clinical research studies: n=185 (43.9%); 2) review articles: n=111 (26.4%); 3) laboratory/animal research: n=53 (12.6%); 4) case reports: n=51 (12.1%); 5) conference proceedings: n=11 (2.6%); 6) clinical practice guidelines: n=7 (1.7%); and 7) letters/editorials: n=3 (0.7%). This group of manuscripts included 263 (62.5%) publications which were directly relevant to military medicine and predominantly related to trauma (29.3%), toxicology (23.2%), and studies in military population (19.8%) (Table 2). Washington, DC, and San Antonio, TX, comprised 29.9% and 27.6% of all manuscripts, respectively (Figure 2). The percentage of overall manuscripts, the percentage of military relevant manuscripts, and percentage of research manuscripts were consistent for each location.

Figure 3. Yearly cite count.

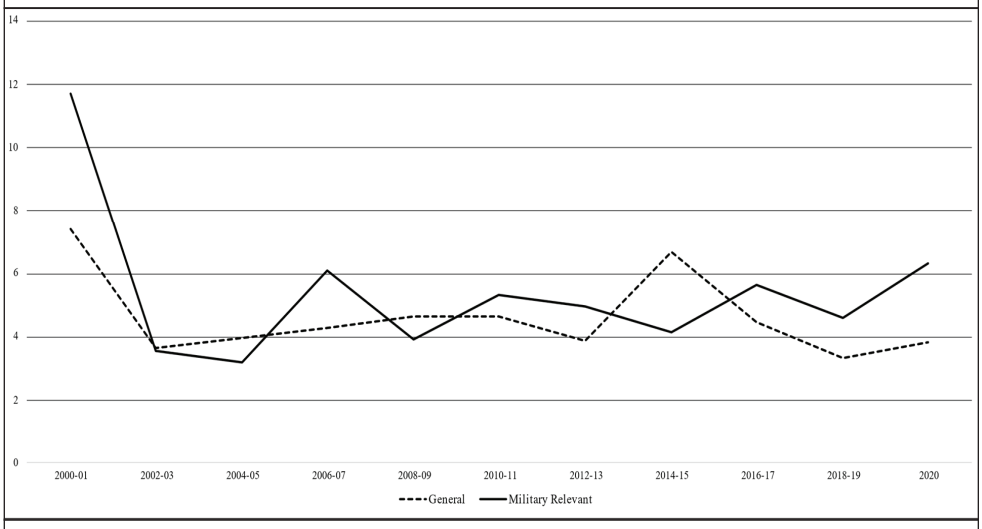


Trend for bi-yearly citation count since 2000 based on reviewed manuscripts that were specifically 1) military relevant or 2) general medicine topics by emergency medicine authors

Further analysis of the findings is based on yearly publications. The citation count (based on 2 year averages) steadily increases beginning in the most recent years with an upward trend for older citations (Figure 3). This is significantly different for military relevant publications.

Further evaluating the impact of military unique publications. Figure 4 depicts the bi-yearly mean Cite Score for military relevant and general subject matter emergency medicine manuscripts, and Figure 5 depicts the FWCI for these groups. The Cite Score and FWCI were higher for military unique manuscripts (Cite Score 2.97 +/- 6.01 and FWCI 4.86 +/- 6.49) compared to non-military unique manuscripts (Cite Score 2.94 +/- 6.65 and FWCI 4.57 +/- 5.59), and there was general consistency with military unique manuscripts on a yearly basis. We identified no differences for either Cite Score or FWCI.

Figure 4. Yearly CiteScore.



Trend for bi-yearly Scopus CiteScore since 2000 based on reviewed manuscripts that were specifically 1) military relevant or 2) general medicine topics by emergency medicine authors.

Discussion

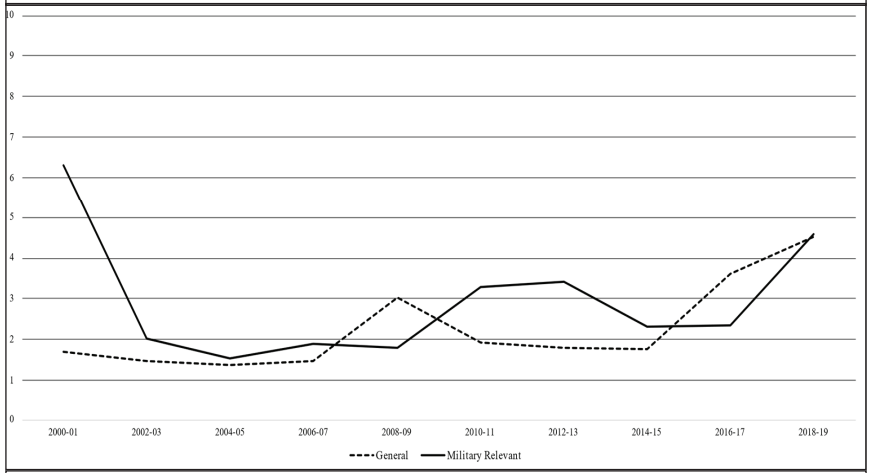
General medical education (GME) research is required to maintain accreditation through the Accreditation Council for Graduate Medical Education (ACGME). The mission of the military researcher is unique, as are the challenges.[15] Some of the challenges faced include staff turnover, staff retention, deployments, budget cuts, and travel restrictions related to conference attendance. Despite the challenges, recent research using Scopus metrics identified the significant academic impact military medical GME has for the advancement of both military and civilian medicine.[13] In that study, among the various specialties, emergency medicine was the fourth most academically productive medical specialty. This present study aimed to identify, for the first time, the academic impact of military emergency medicine GME. Major findings were that research contributions were relatively consistent over the last 20 years, the majority of academic contributions were military relevant, the major research category was trauma, and analysis using Scopus metrics (Cite Score and FWCI) demonstrates the relevance of both the military specific and non-military specific topics to medicine and science in general.

Emergency medicine is a critical wartime specialty, and military emergency medicine in particular, is a field of medicine that provides a unique contribution to medical literature. Emergency medicine faculty and residents from academic military medical centers have produced an array of works with specific military relevance, particularly on topics that emphasize combat casualty care and military readiness. In this study, we identified 421 manuscripts produced between 2000-2020 with at least 10 citations as having been written by authors with a military affiliation. Of these, 62.5% were directly relevant to military medicine, and most of these papers were clinical research studies. Washington, DC, and San Antonio, TX, which are the two larger regions with academic military medical centers, produced 29.9% and 27.6% of all manuscripts, respectively, and the percentage of military relevant manuscripts were consistent for each location. Washington, DC, does not have a DoD sponsored emergency medicine residency but is home to the Uniformed Services University of the Health Sciences. San Antonio, TX, has the largest DoD emergency medicine residency and is located at Brooke Army Medical Center (BAMC). While all emergency medicine residency programs have a requirement to participate in "scholarship," this has a varied interpretation.[16,17] Brooke Army Medical Center has a defined research curriculum with an established scholarly activity requirement for residents and for core faculty, which has increased annual publications since its institution, directly contributing to its academic productivity.[18]

Emergency medicine training programs in the DoD focus heavily on military medicine specific topics emphasizing combat casualty care and military readiness, such as trauma, operational medicine, and toxicology, along with issues affecting the military population. An analysis of the manuscripts reflects the emphasis on important military topics, as trauma (29.3%), toxicology (23.2%), and military population (19.8%) were the most

frequent military topics. Specifically, EPs have made academic contributions on topics including whole blood transfusion,[2] damage control resuscitation (DCR),[3] resuscitative endovascular balloon occlusion of the aorta (REBOA),[4] and extracorporeal membrane oxygenation (ECMO).[5] Additionally, several EPs are fellowship-trained in toxicology, ultrasound, critical care, and wilderness medicine, which is reflected in the diversity of military relevant publications that were reviewed. The academic contributions of EPs directly impact warfighting capabilities, military readiness, and deployed medicine.

Figure 5. Field-Weighted Citation Index (FWCI).



Trend for bi-yearly Scopus Field Weighted Citation Index since 2000 based on reviewed manuscripts that were specifically 1) military relevant or 2) general medicine topics by emergency medicine authors.

Military related studies had a higher Cite Score and FWCI, which may support their applicability to medicine in general. Several studies in our review were specific to austere or deployed medicine, making it interesting that military unique manuscripts had higher Cite Scores and FWCI. This may be due to the medical innovation that often stems from military and austere medicine. It is also worth considering that the medical community in general benefits from the research performed in the military setting, especially in regard to DCR.[14] Several medical advancements including REBOA,[19] modern use of tourniquets,[20] and use of whole blood,[7] which were initially studied in the military setting, have transferred to civilian medicine. The citation count (based on 2-year averages) steadily increases beginning in the most recent years with an upward trend for older citations. This is significantly different for military relevant publications, thus emphasizing the overall importance to emergency medicine.

This present study has several limitations. Articles with significant interest may have been published more recently, and thus have not been cited as frequently as older studies. Additionally, the scores are based on citations and referencing which may not reflect the clinical impact of a scientific work. Moreover, citations represent the importance to academia and publishing may not reflect the impact on clinical practice. In addition, emergency medicine covers a wide range of medical and trauma topics, and several subjects may not have been adequately represented. Future studies are needed evaluating study quality and medical impact. While some studies demonstrate clear military relevance, others may have questionable relevance, leaving some level of subjectivity in making that determination. We further utilized manual assessment of affiliations with MTFs based upon our own knowledge and experience rather than using a systematic algorithm. We further have no measures of interrater reliability to quantify the precision of our study identification methodology. Lastly, our study identification methodology required listing of an affiliation recognized by us as being an MTF or military hospital. Authors may not have listed the institution or errors may have occurred in the listing, especially in the setting of military institutions changing their name. Alternatively, authors may list affiliations with operational units in lieu of local MTFs. As such, we may have not captured those publications.

Regardless of these limitations, this study provides important information concerning military emergency medicine academic contributions for both military and non-military topics. The results support the importance of literature published from military academic emergency medicine programs. Our study reveals that trauma, toxicology, and military populations are vital subjects in military research.

Conclusion

Over the last 20 years, we identified 421 manuscripts with at least 10 citations authored by an EP with a military affiliation. Most of the research performed by military EPs was military relevant and related to trauma, toxicology or military populations. Analysis using Scopus metrics (Cite Score and FWCI) demonstrates the relevance of both the military specific and non-military specific topics to medicine and science in general.

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An Analysis of the Shock Index and Pulse Pressure as a Predictor for Massive Transfusion and Death in US and Coalition Iraq and Afghanistan

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Abstract

Among combat casualties with survivable injuries, the most common cause of mortality is massive hemorrhage. The objective of this study was to identify the accuracy of shock index (SI) and pulse pressure (PP) for predicting receipt of massive transfusion and death on the battlefield. The study searched the Department of Defense Trauma Registry from January 2007 to August 2016 using a series of procedural codes to identify casualties which has been previously described. This is a secondary analysis of casualties analyzing SI. This study analyzed using receiver operating characteristic (ROC) and regression analyses. Within that dataset, there were 15,540 that were US Forces (75.1%), Coalition Forces (14.5%) or contractors (10.3%)—of which, 1,261 (7.9%) underwent massive transfusion. On ROC analyses for SI, this study found an overall optimal threshold at 0.91 with an area under the curve (AUC) of 0.89 with a sensitivity of 0.81 and specificity of 0.87 for predicting massive transfusion. The study found an optimal threshold of 0.91 with an AUC of 0.76 with a sensitivity of 0.67 and specificity of 0.82 for predicting death. On ROC analyses for PP, the study found an overall optimal threshold at 48 with an AUC of 0.71 with a sensitivity of 0.56 and specificity of 0.76 for predicting massive transfusion. The study found an optimal threshold of 44 with an AUC of 0.75 with a sensitivity of 0.60 and specificity of 0.82 for predicting death. SI and PP may accurately predict receipt of massive transfusion and of mortality in a combat casualty population.

Introduction

Background: Among combat casualties with survivable injuries, the most common cause of mortality is massive hemorrhage.[1] Many studies on hemorrhage have attempted to identify predictors of massive transfusion. Early identification of candidates who may need massive transfusion remains particularly important, as early transfusion improves survival in massive hemorrhage.[2-4] In general, clinicians use clinical gestalt developed through experience to determine which trauma patients may require massive transfusion. However, clinical gestalt has been shown to be a poor screening test for massive transfusion.[5] Moreover, it remains unclear how consistent clinical gestalt will apply across all levels of training as blood products get pushed further forward into the hands of medics.

Several objective measures exist to guide the decision whether to initiate massive transfusion. The shock index (SI), defined as heart rate (HR) divided by systolic blood pressure (SBP), predicts mortality and need for blood transfusion.[6] SI outperforms traditional measures in predicting hemorrhagic shock or candidates for massive transfusion, such as heart rate or blood pressure in the emergency department (ED) setting.[7] Other studies have found the SI to be moderately accurate in predicting the need for massive transfusion, with areas under the curve AUC-ROC curves of 0.80 (95% confidence interval (CI), 0.74-0.87) and 0.72 (95% CI, 0.68-0.77) for massive transfusion of one unit of PRBC and three units of packed red blood cells (PRBC) within the first hour, respectively.[8]

Of particular interest to the military healthcare provider

is the performance of these predictive tools in the pre-hospital setting, particularly in the context of combat trauma where access to labs and other physiologic parameters may not exist. SI and pulse pressure (PP) both are useful predictors of pre-hospital massive transfusion for trauma patients, where PP is defined as the difference between systolic and diastolic blood pressure.[9] The utility of the shock index in predicting transfusion is that it requires less technical skill as compared to other scores used to predict massive transfusion, such as the Assessment of Blood Consumption (ABC) score which requires ultrasound data input into the measurement.[10] In battlefield trauma decision-making must be simple and based on data available near the point-of-injury (POI). A predictive system such as the use of SI and PP is simple and does not require data points unavailable at the POI (e.g. ultrasound data, laboratory studies, etc.).

Table 1. Description of casualties within the analysis.

		Overall (15540)	Massive Transfusion Casualties (1261)	Deaths (375)
	Age	25 (22-30)	24 (21-28)	24 (21-29)
	Male	97.5% (15151)	98.6% (1243)	97.5% (365)
Patient Category	**US Forces**	75.0% (11665)	75.2% (949)	76.5% (287)
	Coalition	14.5% (2259)	18.6% (235)	9.8% (37)
	Contractors	10.3% (1616)	6.1% (77)	13.6% (51)
Mechanism of Injury	**Explosion**	61.0% (9481)	83.3% (1051)	60.2% (226)
	Gunshot Wound	15.3% (2393)	14.2% (179)	31.4% (118)
	MVC	6.5% (1020)	0.8% (11)	2.6% (10)
	Other	17.0% (2646)	1.59 (20)	5.6% (21)
Location	**Afghanistan**	70.5% (10960)	75.2% (949)	52.2% (196)
	Iraq	29.4% (4580)	24.7% (312)	47.7% (179)
Injury Score	**Composite**	6 (3-14)	25 (18-34)	26 (20-35)
Outcome	**Survival**	97.5% (15162)	87.4% (1103)	----
Vital sign data*	**Heart rate**	93 (93.2-93.9)	123.5 (121.9-125.1)	101 (96.1-106.4)
	Systolic pressure	128.3 (127.9-128.6)	100.9 (99.2-102.6)	90.3 (85.2-95.4)
	Diastolic pressure	70.7 (70.4-70.9)	55.6 (54.4-56.7)	51.5 (48.3-54.8)
	Pulse pressure	57.7 (57.4-57.9)	45.4 (44.3-46.5)	39.4 (36.4-42.3)
	Shock index	0.7 (0.7-0.7)	1.3 (1.2-1.3)	1.24 (1.15-1.32)

**data presented as mean and 95% CI*

Goal of this Study: This study seeks to analyze SI (<0.9) or PP (>45) as a predictor for massive transfusion and death in a combat trauma population.

Methods

Ethics: The US Army Institute of Surgical Research regulatory office reviewed the protocol and determined it was exempt from Institutional Review Board oversight. The study obtained only de-identified data.

Data Acquisition: The study used a series of ED procedural and diagnostic codes to search for subjects within the Department of Defense Trauma Registry (DoDTR) for the creation of the dataset which we have previously described1. This is a secondary analysis of the previously published data focusing on US forces, coalition forces, and contractors that underwent massive transfusion or died during their initial hospitalization.

Department of Defense Trauma Registry (DoDTR): The DoDTR, formerly known as the Joint Theater Trauma Registry (JTTR), is the data repository for the DoD of trauma-related injuries.[1,2,5-7] The DoDTR includes documentation regarding demographics, injury-producing incidents, diagnoses, treatments, and outcomes following injuries. The registry includes US/non-US military and US/non-US civilian personnel from the point of injury to final disposition during war and peacetime. The DoDTR comprises of patients admitted to a fixed facility Role 3/combat support hospital (CSH) or forward surgical team (FST) with an injury diagnosis using the International Classification of Disease 9th Edition (ICD-9) between 800-959.9, near-drowning/drowning with associated injury (ICD-9 994.1) or inhalational injury (ICD-9 987.9) and trauma occurring within 72 hours from presentation to a facility with surgical capabilities. For the purposes of this data set, we consider the FST, CSH, and Role 3 as the emergency department.

Data Analysis: The study defined serious injuries as those resulting in an abbreviated injury scale of 3 or greater by body region.[8-9] The study compared study variables using a t-test for continuous variables expressed as means with standard deviations, Wilcoxon Rank Sum test for ordinal variables expressed as medians and interquartile ranges, and chi-squared test for nominal variables expressed as numbers and percentages. Vital sign values are based on the lowest documented blood pressure (<90mmHg versus 90 or greater) and the maximum documented heart rate (<120 per minute versus 120 or greater per minute) within the emergency

Table 2. Shock index receiver operating characteristic analysis as continuous variable.

		ROC Threshold	AUC	Sensitivity	Specificity
Massive Transfusion	**Overall**	0.91	0.89	0.81	0.87
	Explosive	0.92	0.90	0.83	0.86
	Gunshot wound	0.91	0.79	0.67	0.82
	Motor vehicle	0.92	0.93	0.90	0.92
Death	**Overall**	0.91	0.76	0.67	0.82
	Explosive	0.91	0.75	0.69	0.89
	Gunshot wound	1.11	0.69	0.52	0.93
	Motor vehicle	0.85	0.95	1.00	0.87

ROC: receiver operating characteristic
AUC: areas under the curve

Table 3. Shock index as binary variable at >0.9 threshold.

		Sensitivity	Specificity	+ Likelihood Ratio
Massive Transfusion	**Overall**	0.76	0.85	5.22
	Explosive	0.78	0.83	4.89
	Gunshot wound	0.62	0.80	3.17
	Motor vehicle	0.90	0.90	9.26
Death	**Overall**	0.49	0.81	2.59
	Explosive	0.50	0.77	2.23
	Gunshot wound	0.47	0.78	2.21
	Motor vehicle	0.50	0.89	4.85

Table 4. Pulse pressure receiver operating characteristic analysis as continuous variable .

		ROC Threshold	AUC	Sensitivity	Specificity
Massive Transfusion	**Overall**	48	0.71	0.56	0.76
	Explosive	48	0.72	0.61	0.76
	Gunshot wound	44	0.64	0.46	0.82
	Motor vehicle	32	0.79	0.54	0.98
Death	**Overall**	44	0.75	0.60	0.82
	Explosive	43	0.75	0.59	0.83
	Gunshot wound	44	0.71	0.61	0.81
	Motor vehicle	30	0.89	0.77	0.99

ROC: receiver operating characteristic
AUC: areas under the curve

department due to limitations in prehospital documentation of vital signs.[10] The study generated receiver operating characteristic (ROC) curves and areas under the curve (AUC). The study calculated odds ratios using logistic regression analysis. The study excluded records from analysis when variables required for that analysis were missing (e.g. if diastolic blood pressure was missing, we excluded that record from analyses involving pulse pressure). We defined a massive transfusion as 10 or more units of packed red cells or whole blood within the first 24 hours.

Results

The initial search from January 2007 to August 2016 captured 28,222 casualties, as previously described. Within that dataset, there were 15,540 that were US forces (75.1%), coalition forces (14.5%) or contractors (10.3%). Of those, the study found that 1,261 (8.1%) underwent massive transfusion and 375 (2.4%) did not survive their initial hospitalization (Table 1).

On ROC analyses for SI, the study found an overall optimal threshold at 0.91 with an AUC of 0.89 with a sensitivity of 0.81 and specificity of 0.87 for predicting massive transfusion. The study found an optimal threshold of 0.91 with an AUC of 0.76 with a sensitivity of 0.67 and specificity of 0.82 for predicting death (Table 2). Based on previous reports, when using a SI threshold of >0.9 for predicting massive transfusion the study found a sensitivity of 0.76, specificity of 0.81, and positive likelihood ratio of 5.22. When predicting death, the study found a sensitivity of 0.49, specificity of 0.81, and a positive likelihood ratio of 2.59 (Table 3).

On ROC analyses for PP, the study found an overall optimal threshold at 48 with an AUC of 0.71 with a sensitivity of 0.56 and specificity of 0.76 for predicting massive transfusion. The study found an optimal threshold of 44 with an AUC of 0.75 with a sensitivity of 0.60 and specificity of 0.82 for predicting death (Table 4). Based on previous reports, when using a PP threshold of <45 for predicting massive transfusion the study found a sensitivity of 0.53, specificity of 0.81, and positive likelihood ratio of 2.83. When predicting death, the study found a sensitivity of 0.69, specificity of 0.79, and a positive likelihood ratio of 3.40 (Table 5).

Table 5. Pulse pressure as binary variable at <45 threshold.

		Sensitivity	Specificity	+ Likelihood Ratio
Massive Transfusion	**Overall**	0.53	0.81	2.83
	Explosive	0.53	0.82	2.95
	Gunshot wound	0.50	0.79	2.44
	Motor vehicle	0.54	0.81	2.86
Death	**Overall**	0.69	0.79	3.40
	Explosive	0.68	0.79	3.28
	Gunshot wound	0.69	0.79	3.36
	Motor vehicle	0.80	0.81	4.25

Discussion

Based on the data analysis, using a SI threshold of >0.9 appears to be consistent in predicting the need for massive transfusion among combat trauma casualties. Studies evaluating SI as a predictor of massive transfusion have traditionally used a cut-off value of 0.97.[18-20] This cutoff value is an agreement with the findings of our study. However, these studies have not described sensitivities, specificities at this cutoff value. This study adds these additional diagnostic test characteristics. One study described sensitivities and specificities for a PP of <45 as a predictor of massive transfusion.[9] Additionally, some studies have used variants of pulse pressure, such as pulse pressure/heart rate to predict massive transfusion and mortality in trauma patients.[8] However, other studies describing pulse pressure as a predictor for massive transfusion and death are scarce. This study adds additional statistical analysis of PP to identify optimal cut off values as predictors of massive transfusion and mortality in trauma patients.

Other studies defining an optimal SI found thresholds of 0.81 with a sensitivity of 0.85 and specificity of 0.64, compared to this study, which found an optimal threshold of 0.91 for a sensitivity of 0.81 and 0.876. The aforementioned study population included patients presenting to an emergency room at a Level I trauma center. Conversely, the patients in this study included patients

who presented to a role 3 military treatment facility or a forward surgical team from prehospital combat settings.

In another study using an SI threshold of 0.9, the sensitivity was 0.54 and a specificity of 0.94, while a threshold of 0.8 had a sensitivity of 0.76 and a specificity of 0.8721. However, the study evaluated trauma patients at a tertiary care facility. Additionally, the clinical endpoints from this study were bleeding requiring a therapeutic measure rather than activation of a massive transfusion protocol or death from exsanguination. In contrast, this study optimizes sensitivity and specificity of the SI to the specific endpoints of massive transfusion and mortality.

One systematic review of the literature of prediction models for massive transfusion identified nine independently validated predictors to include the mechanism of injury, systolic blood pressure, heart rate, hemoglobin, lactate, international normalized ratio (INR), and focused assessment with sonography in trauma (FAST) exam.[22] Other mathematical prediction models include the ABC score, the McLaughlin score, and the Trauma Assessment Severity of Hemorrhage score.[23-25] As mentioned in the study by Demuro, all these scores, while useful, incorporate more advanced modalities that may not always be available in the prehospital combat trauma setting. In contrast, the use of the SI may be a simple calculation that can be done in a prehospital setting, where blood products may be available despite the lack of other advanced modalities incorporated into these prediction scores. Additionally, one study found the SI to be a more accurate predictor of massive transfusion than the ABC score.[10] Together with results of this study, the literature suggests that the SI offers a prognostication tool that is both less cumbersome than the ABC score, but also highly accurate. This suggests its potential for use prior to arrival to an emergency department, particularly in a combat setting.

The PP has been previously identified as an independent predictor for active hemorrhage in trauma patients, with a cut-off of 40 mm Hg for patients between the ages of 16-60 and an increased probability of acute hemorrhage as PP narrows.[26] Pulse pressure is a less reliable tool than the shock index in predicting massive transfusion and mortality as measured by AUROC. However, the authors found that using a PP <45 was less sensitive but equally specific as a SI of >0.9 in predicting the need for transfusion. The PP is more sensitive but similarly specific to SI in predicting death. In one study evaluating the PP as a predictor of massive transfusion, a PP<45 had a sensitivity of 0.73 and specificity of 0.50 in predicting massive transfusion protocol (MTP).[7] However, that study used a much smaller dataset than this study, which found an optimal PP of 48 with a sensitivity of 0.56 and specificity of 0.76 in predicting the need for MTP. Therefore, the PP still proves to be a useful predictive tool for massive transfusion and death.

This study has several important limitations. First, any registry-based study comprises observational data and, by extension, it is possible only to establish correlation and not causality. Moreover, with regards to the outcome of massive transfusion, this study can only establish correlation with receipt of massive transfusion; it is unclear whether any of the patients in this dataset necessarily required massive transfusion. Next, the vital signs in this secondary analysis were all collected within the emergency department rather than at the point of injury. Additionally, because our data lacks date/time stamps, it is impossible to know whether blood pressure and heart rate measurements were taken simultaneously. The fact that all measurements occurred in the ED in a combat setting where prolonged lengths of stay are unusual leads the authors to believe that excessive time did not elapse between measurements, though we cannot prove this is the case. Future research of SI in the deployed setting should strive for simultaneous measurements of these variables. The fact that the data arises from measurements of patients in the ED does somewhat limit the external validity of the results to a prehospital setting. The literature would benefit from additional studies to validate these predictors in a prehospital setting. Pending such data, the authors do believe that the data and results suggest that these predictive models may be useful in a prehospital setting where more complex predictive models of transfusion and death may be too cumbersome to use.

Conclusion

Both the SI and PP accurately predict receipt of massive transfusion and of mortality in a combat casualty population. Given their simplicity, these prediction tools lend themselves to use in a combat setting where decision-making must be quick and without access to technology that a tertiary care center may possess.

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Prehospital Intervention Analysis of Helicopter Crashes in Afghanistan

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Abstract

Background: Based on isolated case reports, military helicopter mishaps often result in multiple critical casualties leading to complicated stabilization and evacuation by healthcare providers. The aim of this retrospective descriptive analysis is to describe the incidence of common prehospital injuries associated with rotary wing crashes in order to improve mission planning and casualty survivability.

Methods: This is a secondary analysis of data from the Prehospital Trauma Registry and the Department of Defense Trauma Registry (DoDTR) from April 2003 through May 2019. We searched within our dataset for all encounters involving aviation crashes.

Results: From April 2003 through May 2019 there were 1,357 casualty encounters in the Prehospital Trauma Registry. There were 12 casualties identified injured by aircraft crash, of which, 10 were linkable to the DoDTR for outcome data. All encounters for this sub analysis occurred in Afghanistan in 2014, all were US military service members, and a majority were enlisted conventional forces. Most prehospital interventions focused on hemorrhage control, to include limb tourniquets (n=3), pressure dressings (n=2), and pelvic splint (n=1). One patient received a cervical collar and two patients received temperature control with a hypothermia kit.

Conclusions: In this case series, hemorrhage control and extremity stabilization accounted for the majority of prehospital interventions. Larger datasets are needed to validate findings and extrapolate it into mission planning.

Introduction

Over the recent past two decades of combat operations, rotary wing airframes have provided crucial transportation for US troop movements on the battlefield as well as aerial support for ground operations. The historical beginning of this mode of troop transport occurred in combat operations in Nicaragua in 1932. The US Marine Corps used a Pitcairn XOP-1 autogiro.[1] From that point forward, rotary wing air assets have become a cornerstone of modern conflict enhancing mission capabilities on the battlefield. However, like all components of combat operations, the use of rotary wing assets implies risk to personnel and equipment. The most significant risk comes by way of potential hazards, injuries, and tragically, on occasion, death to the pilots, aircrew, and their passengers as a result of collisions.

Per the Army Accident Investigations and Reporting regulations, the factors that influence combat rotary wing crashes can be generally divided into three main categories: 1) environmental factors, such as loss of vision or challenges with vertical lift; 2) materiel (equipment) failures such as from improper maintenance or mechanical failure; and 3) human factors such as pilot or flight crew errors or enemy anti-aircraft weapons.[2] These are categorized as the "What Happened" cause factors according to DA PAM 385-40, which also includes further analysis of the systems of support, standards, training, leader and individual as well as further controls, corrective actions and counter measures in place. It is therefore paramount to minimize the risk of potential mishaps, because, unlike fixed wing aircrafts, rotary wing aircraft typically have lower flight altitudes as well as proximity to enemy activity and terrain features. In addition, there are limited inflight escape mechanisms for aircrew members due to the position of the rotors as well as typical cruising altitude. These complicating factors often lead to unique and more severe injury patterns. For medical providers with the responsibility of responding to helicopter crashes or first responders on neighboring aircraft, understanding the types of potentially survivable injuries associated with

Table 1. Prehospital Trauma Registry (PHTR) demographic data (n=12).

Age	18-25	41.7% (5)
	26-33	25.0% (3)
	34-41	16.7% (2)
	Unknown age	16.7% (2)
Sex	Male	100% (12)
Location	Afghanistan	100% (12)
Rank	Enlisted	75.0% (9)
	Officer	25.0% (3)
Force Type	Special Operations	33.3% (4)
	Conventional	66.7% (8)

Table 2. Department of Defense Trauma Registry (DoDTR) data.

Injury Severity Score	Composite	9 (5-18)
Serious injuries by body region	Head/neck	10% (1)
	Face	0% (0)
	Thorax	20% (2)
	Abdomen	0% (0)
	Extremities	20% (2)
	Skin	0% (0)
Outcome data (interquartile range)	Ventilator days	0 (0-2)
	ICU days	0.5 (0-13)
	Hospital days	10 (2-18)
	Survival to discharge	100% (10)

rotary wing crashes increases aircrew survivability through optimum medical care which likely mirror that of other combat-related deaths.

With regards to typical helicopter crash injuries, a civilian autopsy review by Taneja et al found 88% of deaths were a result of various blunt trauma injuries. In this same study, the most common bone fractures were ribs, skull, and facial bones in descending frequency, and the most common organ injuries were brain, lung, and liver respectively.[3] These findings are similar to a case series of a civilian helicopter crash in Scotland with a total of 18 people onboard, where again blunt trauma was the leading cause of death.[4] Chesters et al reported the accident rate per 10,000 missions in the United Kingdom between 1987 and 2013 for helicopter emergency medical services (HEMS) was 0.57.[5] Comparatively, Hinkelbein et al. reported a similar accident rate over a 40 year period in Germany with 43.4% of accidents due to collision with an obstacle during landing, take-off or hovering.[6] While certainly useful for civilian institutions, most of the research available on civilian aviation accidents are difficult to translate to military aviation given different airframes, equipment, and presumably flight plans, which do not incur the inherent risks associated with combat, such as frequent night flights, surface-to-air or air-to-air attacks.

The Korean War proved the utility of helicopters in the support of combat operations through casualty evacuation (CASEVAC) and equipment transport, while the Vietnam War demonstrated helicopters' ability to be deployed in combat operations through the development of air assault units. The increased use of helicopters in the Vietnam War led to an estimated 5,600 helicopter losses and over 5,000 killed in action (KIA) of aircrew members during the war, but there is very limited data on injuries from these accidents.[7] The last large-scale published analysis of the US Army aircrew member injuries occurred nearly 35 years ago during a time of peace and a period that pre-dated many of the current airframes used in combat, limiting the utility of this data greatly.[8] Furthermore, publicly available reports from current ongoing conflicts have only documented singular crashes, most of the time involving a mass casualty event in part due to helicopter troop carrying capabilities, as well as the documented injuries exceeding initial medical responders' capabilities.[9,10] Modern military aviation has placed an increasing focus on improving crew member survivability in crashes with improved equipment, such as landing gear and seats equipped with stroking capability, as well as improved training such as Shallow Water Egress Training (SWET), but few papers exist documenting injury patterns sustained in crashes.

Goal of this Investigation: We seek to describe casualties within the Prehospital Trauma Registry (PHTR) along with associated interventions and outcomes to better understand injury patterns and guide medical personnel for mission planning when responding to helicopter crashes.

Methods

Data Acquisition: We submitted the protocol to the US Army Institute of Surgical Research regulatory office and determined to be exempt from institutional review board oversight. We obtained only de-identified data. The data sharing agreement was submitted and executed with the Defense Health Agency (DHA) prior to submitting a request for data to the Joint Trauma System (JTS). We requested all data within the Prehospital Trauma Registry (PHTR) prior to May 2019 linkable data from the DoDTR to form the initial dataset from which this subanalysis was drawn. Due to the new DHA requirements regarding de-identified data, only an age range, and not a specific age, was provided for each casualty. It is important to note that the only combat theater aviation mishaps are included as CONUS Army occurring mishaps, injuries, and fatalities are more often captured by the Combat Readiness Center (formerly Safety Center) and are not include in the DoDTR currently.

Prehospital Trauma Registry (PHTR): The JTS PHTR is a data collection and analytic tool designed to provide near-real-time feedback to commanders. As previously described, its primary purpose is to improve casualty

visibility, augment command decision-making processes, and direct procurement of medical resources. Additionally, the PHTR seeks to reduce morbidity and mortality through performance improvement in the areas of primary prevention (tactics, techniques, and procedures), secondary prevention (personal protective equipment) and tertiary prevention (casualty response system and TCCC). The US Central Command JTS Prehospital Directorate ordered the collection and transcription of TCCC card and after-action review (AAR) data into the PHTR. This allows for a more complete understanding of the care provided in the Role 1.

Table 3. Prehospital Interventions (n=12).

Major Hemorrhage	
Limb tourniquet	3
Junctional tourniquet	0
Pressure dressing	2
Pelvic splint	1
Airway Management	
Nasopharyngeal airway	0
Supraglottic airway	0
Endotracheal tube	0
Cricothyrotomy	0
Breathing/Respirations	
Needle chest decompression	0
Thoracostomy tube	0
Chest seal	0
Circulation	
Intravenous fluids	0
Intraosseous access	0
Head and Hypothermia	
Cervical collar	1
Spinal backboard	0
Hypothermia kit	2
Extremity (non-hemorrhagic)	
Extremity splint	0

Department of Defense Trauma Registry (DoDTR): The DoDTR, formerly known as the Joint Theater Trauma Registry, is the DoD's data repository for trauma-related injuries. The DoDTR includes documentation regarding demographics, injury-producing incidents, diagnoses, treatments, and outcomes following injuries. The registry includes data on US and non-US military and civilian casualties from the point of injury to final disposition. The DoDTR is primarily comprised of patients admitted to a hospital with an injury diagnosis using the International Classification of Disease 9th Edition (ICD-9) between 800-959.9, near-drowning/drowning with associated injury (ICD-9 994.1) or inhalational injury (ICD-9 987.9) and trauma occurring within 72 hours from presentation to a facility with surgical capabilities.

Data Analysis: In this sub analysis, we searched for all casualties with documented mechanisms of injury by way of aviation mishap. We analyzed the data using standard statistical software. Continuous variables were described through means and confidence intervals (95%), ordinal variables through medians and interquartile ranges, and nominal variables through numbers and percentages. Serious injuries were defined as an abbreviated injury scale by body region of 3 or greater.

Results

A total of 1,357 casualty encounters were obtained from the PHTR from January 2003 to May 2019 as part of the overall data from which this sub analysis was drawn. Within that 1,357, we identified 12 (1%) casualties that were injured by aircraft crash, of which, 10 were linkable to the DoDTR for outcome data. All encounters for this analysis occurred in 2014. All were US military, of which 33% (4) were special operations forces, the rest were conventional forces. Most casualties (75%) were enlisted personnel. All were located in Afghanistan. Complete summary of results is found in Table 1 for PHTR demographics, Table 2 for DoDTR outcomes, and Table 3 for prehospital interventions.

Discussion

In this descriptive analysis, we document the casualties injured in aircraft crashes within the PHTR and the interventions they received documented when linked to the DoDTR. To our knowledge, no prior studies have examined this specific injury mechanism and the associating interventions during the Role 1 phase of care. Surprisingly, only 12 service members in four different crashes were identified as casualties during this time frame, a figure that is likely artificially low due to underreporting of data in these registries, consistent with previous reports of poor TCCC documentation.[11,12] We found that all of the 12 subjects identified were US military adult males injured in Afghanistan in 2014, a majority were under 33 years of age, and most were enlisted. For the 10 patients with data also in the DoDTR, they had an average Injury Severity Score of 9 which is relatively minor, and all survived to discharge which may suggest some inherent survival bias. With regards to the location of serious injuries by body regions, one patient had serious head/neck injuries, two had thoracoabdominal injuries, and two had extremity injuries. Consistent with the locations of serious injuries, limb tourniquets, a cervical collar, and pressure dressings were applied. According to the data, no patients received intubation, cricothyrotomy, chest tubes, chest seals, intra-osseous access, intravenous fluids, or extremity splints for prehospital interventions. This is in stark contrast to the majority of trauma seen on the battlefield, where penetrating trauma and blast injuries oftentimes result in life threatening hemorrhage and airway compromise, injury patterns that were not identified in this study.[13] However, this may be due, in part, to the inclusion bias within the registries in which only those that survived to arrive at a military treatment facility (MTF) with signs of life or on-going interventions. As many of the aircraft crashes likely result in near-instant death for all crew, they would not be captured within the registries since the registries do not capture those killed in action.

Analysis of data from multiple aviation organizations in North America and Europe on rotor-wing crashes focused on the fatal injuries and provide suggestions for prevention of these injuries, most commonly traumatic brain injuries.[3,5,6] However, this does not inform the missions responding to crashes as it only accounts for those that died, not those that required interventions prehospital. A casualty care mission is far different than a body recovery mission both in terms of mission planning and the risks that commanders will assume. This was similarly demonstrated in an analysis of injuries sustained in the US Army helicopters from 1979-1985; 55% of fatalities in potentially survivable crashes were attributed to head injuries for which there is little by way of prehospital interventions aside from airway protection and supportive care.[8] The same study reports that the most common injuries were obtained on the extremities, and while this study does not document type of injury or intervention, our data also shows that the most common treatment provided was for extremity injuries such as tourniquets.

The most extensive data for helicopter survivor injuries and interventions come from case reports of helicopter crashes. We reviewed information from four different helicopter crashes with 71 survivors and 52 injured.[4,9,10,14] The most common injury seen in both critical and non-critical patients were vertebral fractures. Most of these were thoracic and upper lumbar fractures, with only one documented cervical fracture (type 2 odontoid fracture). In a Chinook crash that occurred early in Operation Enduring Freedom, all patients transported to the field hospital were placed in cervical spine immobilizers if the responding medical personnel could not clear their cervical spine at the scene. In these patients, no spinal injuries were ultimately diagnosed, suggesting this may be low yield for those that survive the crash.[10] However, this liberal use of cervical spine immobilization is in line with current recommendations by the Joint Trauma System Clinical Practice Guidelines, but has limited emphasis in the current TCCC guidelines.[15,16] The management of the casualties from the Chinook crash is in contrast to our data, with only one patient being placed in a C-collar; there is no documented information whether there was an effort to evaluate the other 11 patients' cervical spines, or if there was any other immobilization completed. We also lack data on what equipment was available as the limited supplies may have been triaged. Most of the aircraft accidents demonstrated pelvic fractures, many of which were preliminarily treated with pelvic binders until operative management was available. Life-threatening hemorrhage in helicopter crashes appears to be uncommon among those that survive the initial impact and is usually due to shear forces on vasculature due to vertical acceleration (i.e. large deceleration forces causing pelvic fractures, leading to shearing of pelvic vasculature), not penetrating injuries. These injuries are usually non-survivable except in extreme cases where far-forward surgical capabilities lead to early operative hemorrhage control, as seen in the case of the helicopter mishap cared for on the USS Bataan. The robust point of care and en route interventions for these specific casualties is certainly not representative of care available to the majority of conventional service members and is usually only found in support of special operations missions.[9]

Perhaps the most surprising piece of data from this study is the lack of use of hypothermia prevention management kits (HPMK) or other similar warming devices in the treatment of these casualties. It is well established in both the civilian and military literature that hypothermia results in significantly increased morbidity and mortality.[17] The reason for a lack of hypothermia prevention (or at least documentation of such care) is unclear and is difficult to extrapolate from this data but highlights the need for increased emphasis on this intervention during training of medics and first responders. Previous studies have similarly shown low rates of hypothermia prevention interventions.[18]

Interestingly, of the ten patients also enrolled into the DoDTR, none received tube thoracostomies. Conversely, in two case reports of helicopter crashes during the same time frame, this procedure was required in four critical patients due to hemathoraces.[9,14] The reason for this seemingly conflicting data is unclear, although it is likely due, at least in some part, to incomplete documentation at the point-of-injury, a well-known occurrence.[11] This lack of documentation is more frequent in critically injured casualties, as documentation is rightly not prioritized over performing lifesaving interventions and may account for this discrepancy in results.

There are several limitations to the study. First, there are only 12 patients, all of whom are from the same calendar year in only one theater of operation, making it difficult to extrapolate our results for broad military application. There are many other aviation mishaps during both in the Iraq theater as well as Afghanistan, and this further illustrates the challenges in casualty data capture both prehospital and subsequently that were captured in operational records. We are only able to query the registry for information entered and cannot determine how many records are incomplete or how many data items are missing. Previous studies demonstrate poor prehospital documentation, which likely contributed to our limited data on prehospital interventions.[11,12] In addition, the retrospective observational nature of our investigation

means that we can only describe the incidence and not causation for why particular procedures were or were not performed. Also, encounter inclusion within the DoDTR requires subject arrival to a MTF with surgical capabilities alive or with on-going interventions. Because of this, we are unable to characterize subjects that died on the battlefield to which lifesaving interventions may have benefited from.

Conclusion

In this case series, hemorrhage control and extremity stabilization accounted for the majority of prehospital interventions. Larger datasets are needed to validate our findings and extrapolate this into mission planning. The DoD needs development and enforcement of better systems of capture and reporting to ensure casualty data without operationally sensitive information disclosure with clear command emphasis in order to ultimately make evidenced-based decisions on medical equipment, personnel, and training for the prehospital environment responding to aviation mishaps. Casualties from aviation mishaps during combat and training generally produce similar deceleration and blunt injury patterns. Hence, better communication and visibility of US Army Combat Readiness Center casualty data and the DoDTR would be very important.

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Assessing Challenges with Access to Care for Patients Presenting to the Emergency Department for Non-Emergent Complaints

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Abstract

Introduction: Emergency department (ED) utilization continues to climb nationwide resulting in overcrowding, increasing wait times, and a surge in patients with non-urgent conditions. Patients frequently choose the ED for apparent non-emergent medical issues or injuries that after-the-fact could be cared for in a primary care setting. We seek to better understand the reasons why patients choose the ED over their primary care managers.

Methods: We prospectively surveyed patients that signed into the ED at the Brooke Army Medical Center as an emergency severity index of 4 or 5 (non-emergent triage) regarding their visit. We then linked their survey data to their ED visit including interventions, diagnoses, diagnostics, and disposition by using their electronic medical record. We defined their visit to be non-urgent and more appropriate for primary care, or primary care eligible, if they were discharged home and received no computed tomography (CT) imaging, ultrasound, magnetic resonance imaging (MRI), intravenous (IV) medications, or intramuscular (IM) controlled substances.

Results: During the 2-month period, we collected data on 208 participants out of a total of 252 people offered a survey (82.5%). There were 92% (n=191) that were primary care eligible within our respondent pool. Most reported very good (38%) or excellent (21%) health at baseline. On survey assessing why they came, inability to get a timely appointment (n=73), and a self-reported emergency (n=58) were the most common reported reasons. Most would have utilized primary care if they had a next-morning appointment available (n=86), but many reported they would have utilized the ED regardless of primary care availability (n=77). The most common suggestion for improving access to care was more primary care appointment availability (n=96). X-rays were the most frequent study (37%) followed by laboratory studies (20%). Before coming to the ED, 38% (n=78) reported trying to contact their primary care for an appointment. Before coming to the ED, 22% (n=46) reported contacting the nurse advice line. Based on our predefined model, 92% (n=191) of our respondents were primary care eligible within our respondent pool.

Conclusions: Patient perceptions of difficulty obtaining appointments appear to be a major component of the ED use for non-emergent visits. Within our dataset, most patients surveyed stated they had difficulty obtaining a timely appointment or self-reported as an emergency. Data suggests most patients surveyed could be managed in the primary care setting.

Introduction

Background: Emergency department (ED) utilization has continued to climb nationwide resulting in overcrowding, increasing wait times, and a surge in patients with non-urgent conditions. The average number of visits has increased by 3.5% per year.[1] Demand growth for the ED has often resulted from use for non-urgent problems,[2] which in turn drives longer wait times. To meet patient needs, the Emergency Severity Index (ESI) triage system indexes patients into categories based on the urgency of their medical condition and the amount of resources they will need.[3,4] Focusing on civilian use of the ED, the ESI level can directly correlate with the

price of the visit, concluding that a trip to the ED is much more expensive than a trip to their primary care provider (PCP) for the same health issue.[4] EDs often serve as a "safety net" due to their legal obligation to treat all patients in need, without considering their ability to pay.[5] Thus, ED use does not always reflect urgent medical conditions. The potential for use of the ED for primary care issues is a particular risk for military beneficiaries as these patients do not bear any cost share or out-of-pocket expense for utilization of healthcare at military treatment facilities.[6]

Previous studies show that ED overuse has increased over all patient populations.[7] In 2017, the CDC reported that nearly 1 in 5 adults and children sought care in the ED at least once during the previous year.[8,9] Overcrowding in the ED can lead to longer wait times causing delays in care and negative patient outcomes.[10-13] Increased wait times are strongly associated with patients who leave without completing treatment, leading to negative patient perceptions and financial losses.[5,6,8-14] Patients choose the ED over other healthcare facilities due to various reasons including availability, the ability to get a complex workup done quickly, and fast tracking. A study done at the University of Sheffield, showed 44% of patients found their PCP inaccessible to their needs, limited appointments and lack of easy accessibility added to patients bypassing their PCP for the ED.[15] Previous studies have estimated 13-27% of ED visits are primary care-related visits that could have easily been managed in the primary care setting.[15-17]

In 2017, the CDC reported the combined ED visits for ESI level 4 and 5 was 27.9% of all ED visits.[18] Nursing staff places patients into these categories to help streamline the patient flow into the appropriate department, such as trauma or a fast track ED. Fast tracking originates from the fact that most of the overcrowding in the ED involves low acuity patients.[10,19-22] Low acuity patients are those with minor injuries or illnesses who will likely use fewer resources than a high acuity or urgent patient. Conversely, when patients come to the ED for a non-emergent visit, this likely results in a primary care appointment going unfilled. This creates a lost opportunity for the Military Health System (MHS). Little data exists which describe ED visits for non-emergent issues within the MHS.

Goal of this Study: The purpose of our study was to determine why patients with non-emergency conditions seek care in the ED. We conducted a survey for patients visiting the ED categorized as ESI 4 or 5 and linked their survey data to associated interventions, workups, and dispositions.

Methods

Ethics: We submitted a research determination to the Regional Health Command – Central regulatory office. They reviewed our project and determined it met the primary definition of process improvement and did not require institutional review board oversight.

Subjects & Settings: Our study setting took place at the Brooke Army Medical Center (BAMC) at Joint Base San Antonio, TX. BAMC is the only level 1 trauma center in the Department of Defense (DoD). The ED had nearly 84,000 visits during the last calendar year. The facility also serves as a public, regional-receiving trauma center.

Our survey instrument addressed demographics, reasoning, and urgency for their visit to the ED, as well as their support system at home and reasoning for choosing the ED over their primary care manager. Investigators Steven G. Schauer, DO, MSCR and William Fernandez, MD drafted the surveys then the other investigators provided face validation of these instruments. Due to restrictions in place secondary to the pandemic, we were not able to perform a pilot phase with the surveys. We utilized quota sampling to determine the ideal number of surveys for the study. We provided abstractors training to include orientation to the standardized data abstraction forms and definitions of all variables. Study investigators also held weekly routine meetings to ensure proper case selections and exclusions.

Research staff offered surveys to patients triaged to ESI level 4 and 5, which represent non-emergent triage categories, as they checked into the ED.[2] Patients who were marked as "person under investigation" for COVID-19 were not eligible to participate. Patients were categorized by nursing staff before being added into the system, dependent on their presumed resource need. Trained research staff collected the surveys from various points in the ED, either the ED waiting room or the Rapid Treatment Assessment (RTA) waiting room. We offered surveys during varying shifts with their work hours generally equally distributed from 0600-0200 to capture nearly all times of day when we have a significant proportion of patients checking in. We asked patients assigned a score of 4 or 5 ESI if they would like to participate in research to improve the ED, before being placed into a room. A patient identification sticker was placed by the research staff on their survey to enable linking of survey data to their ED records for intervention and outcome data. All our ED evaluations including orders and disposition are captured within our electronic medical record (EMR). Team members Ashley D. Tapia, BS; Camaren M. Cuenca; Sarah A. Johnson; and Ryan S. Lauby extracted the data from the EMR system

Table 1. Demographics and disposition data (n=208).

Demographics	Age*	40 (29-57)
	Male	53% (110)
	Female	47% (98)
	Other	0% (0)
Preferred language	English	97% (201)
	Spanish	2% (5)
	Other	<1% (1)
Self-reported health quality	Excellent	21% (44)
	Very good	38% (80)
	Good	26% (54)
	Fair	11% (23)
	Poor	2% (5)
Sponsor branch	Army	44% (92)
	Air Force	39% (83)
	Navy	8% (18)
	Marines	2% (4)
	Other/no response	5% (11)
Sponsor	Active duty	44% (93)
	National Guard	2% (5)
	Reserve	4% (9)
	Retired	36% (76)
	Other/no response	12% (25)
Sponsor pay grade	Enlisted	61% (127)
	Officer	22% (47)
	Warrant Officer	2% (4)
	Other/no response	14% (30)
Patient	Self	84% (175)
	Spouse	8% (17)
	Child	6% (12)
	Other/no response	2% (4)
Marital status	Single (never married)	21% (44)
	Married/domestic partnership	67% (140)
	Widowed	1% (3)
	Divorced	9% (19)
	Separated/Other	1% (2)
Typical healthcare location	Doctors office	79% (166)
	Urgent care	2% (5)
	Emergency department	13% (29)
	Other	4% (8)
Select past medical history	Congestive heart failure	<1% (1)
	Coronary artery disease	2% (5)
	Heart attack	1% (3)
	Chronic kidney disease	1% (2)
	Diabetes	11% (24)
	Hypertension	22% (46)

**reported as median and interquartile range*

with verification to ensure accuracy.

An encounter was determined to be primary care eligible if they met all the following criteria: discharged home; no computed tomography (CT) imaging, ultrasound, or magnetic resonance imaging (MRI) performed; and no intravenous (IV) medications administered. If they received an oral medication, an intramuscular medication excluding controlled substances, received an x-ray, or had laboratory testing done they were still considered primary care eligible.[3-5]

Data Analysis: We performed all statistical analyses using commercially available database and statistical software. We presented continuous variables as means with confidence intervals (95%). We presented ordinal variables as medians with interquartile ranges (IQR). We presented nominal variables as percentages and numbers.

Table 2. Self-reported urgency and pain (n=208).

Self-reported urgency	Urgency*	6 (4-8)
	None#	3% (6)
	Mild (1-3)	17% (37)
	Moderate (4-6)	40% (83)
	Severe (7-10)	39% (82)
Self-reported pain	Pain*	6 (4-8)
	None#	8% (18)
	Mild (1-3)	17% (36)
	Moderate (4-6)	33% (68)
	Severe (7-10)	41% (86)

**reported as median and interquartile range*
#percent and N (mutually exclusive)

Table 3. Survey questions assessing why the patient came to the emergency department (n=208).

Why did you come to the ER instead of an alternate location (e.g. doctor's office or clinic)?	
This is an emergency	58
I couldn't reach my doctor	17
I couldn't get an appointment soon enough	73
ER was more convenient	46
My doctor/nurse told me to come to the ER	55
I have no other place I can go	16
I am unsatisfied with the care I receive by my regular doctor	7
I had no choice- the ambulance brought me	0
I needed answers to my health problems right away	36
The problem is too complex/ can't be handled during a routine doctor's office visit	16
I need a prescription filled or refilled	8
I was seen recently by my doctor for today's medical condition/problem	5
I can get everything done in one ER visit	25
I wanted a second opinion	1
I am going out of town – I need my condition to be addressed now	4
I couldn't wait for an appointment, my pain/condition has worsened	68
I prefer the emergency room	6
I do not have a Primary Care Provider assigned	11
I am unable/do not know how to schedule an appointment	7
Would you have gone to the clinic today if your primary care clinic (e.g. clinic or doctor's office) could…	
Provide a morning appointment	86
Provide an evening appointment	66
Provide a weekend appointment	34
It does not matter, I would still come to the ER.	77
How would you suggest improving your (or your dependent's) access to healthcare?	
A new clinic location	18
More routine appointment availability	96
More after-hours appointments during weeknights	47
More after-hours appointments during weekends	42

**patients could select more than one if applicable*

When reviewing the free text feedback, given the variable number and quality of responses we applied unstructured methods for assessing and extraction. The principal investigator Steven G. Schauer, DO, MSCR reviewed all comments for both relevancy and duplication of themes and presented to the remaining investigators for selection of the limited free-text comments provided within the manuscript.

Results

During the 2-month period survey data, we received surveys from 208 participants out of the total 252 people offered a survey (82.5%). Of the 208 respondents, the median age was 40 (IQR 29-57), most were male (53%), and most spoke English (97%). Most reported very good (38%) or excellent (21%) health at baseline. The largest proportion were Army affiliated (44%), enlisted (61%), and presenting for care themselves (84%) (Table 1). The median reported urgency was 6 (IQR 6-8) with a similar pain rating of 6 (IQR 4-8) (Table 2). On the survey assessing why they came, a self-reported emergency (n=58) and unable

Table 4. Frequency of studies and interventions (n=208)..

Studies	Laboratory study	20% (43)
	X-ray	37% (77)
	CT scan	2% (5)
	MRI	1% (2)
	Ultrasound	3% (6)
Interventions	Oral medication	11% (22)
	IV medication	2% (4)
	IM medication	27% (56)
	Topical medication	1% (3)

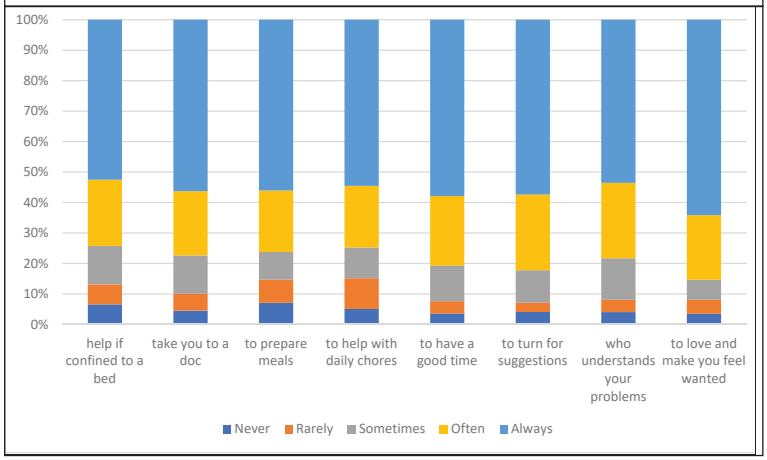
Table 5. Select comments lifted from the surveys.

more weekend services
should be able to refer to outside agency when PCM is unavailable
waiting times for an apt are getting longer and longer. I realize during COVID the availability is slimmer but that isn't helping me
I'm retired 100% VA but have no clue who to contact for [outlying] health care on base versus only going to the VA
a provider that answers the phone that is available
quick access to reoccurring prescriptions
Tele-behavioral health would be beneficial for patient with emergencies on the weekends; weekend appts.
no suggestions, I feel the ER @ BAMC is the most efficient, caring and logical option for me. The care here is wonderful, and I always feel leaving better than when i came in.
it takes too long to get an appointment-usually 3 weeks or more.... by then you might be DEAD
more doctors need to be hired so that more care can be given. my husband and i have 24 years each to this country, now have to wait 2/3 weeks for an appointment
I needed someone to talk to this morning. Instead I have to leave a message and home number for them to call me back
perhaps an urgent care section for these type of injuries separate from the main ER
I feel I'm being denied access to health care because of the [coronavirus] situation. My access has been the emergency room
I suggest more availability for appointments, for both active duty and their dependents. Most people have to go to the ER for events that a PCM should be able to handle
my primary care was moved from north central federal clinic to the top floor of Baptist emergency hospital; almost triple the distance away, and I can never book appts as they are always booked almost a month in advance. They always send me to the ER for even the slightest issues, just b/c they are always too far booked. Increase the amount of appts..?

to get a timely appointment (n=73) were cited the most. Most would have gone to primary care if they had a next-morning appointment available (n=86), but many reported they would have come to the ED regardless of primary care availability (n=77). The most reported suggestion for improving access to care was more routine appointment availability (n=96) (Table 3). X-rays were the most frequent study (37%) followed by laboratory studies (20%). Very few (2%) received an IV medication (Table 4). Before coming to the ED, 38% (n=78) reported trying to contact their primary care for an appointment. Before coming to the ED, 22% (n=46) reported contacting the nurse advice line. The majority of those surveyed reported a strong support system on overall questioning (Figure 1).

Respondents reported a median of 2 visits (IQR 1-4) to healthcare providers in the past year—of those, 6% (12) reported 10 or more visits within the past year with one patient estimating 60 visits. When questioned about the last year, 58% (n=121) reported a previous ED visit (median 1, IQR 0-2). We found that 11% (n=22) had 3 or more visits to the ED in the past year. The survey showed 8% (n=18) of respondents reported they had a hospital admission in the past year for all causes (e.g. emergency, scheduled surgery, etc.). The overwhelming majority (99%, n=207) were discharged from the ED. Of the IM medications (n=156) given, ketorolac was most frequent (n=35), followed by rabies prophylaxis (n=3), antibiotics (n=3), and a corticosteroid (n=3). The IV medications (n=4) consisted of antibiotics (n=2) and controlled substances (n=2). Based on our predefined model, 92% (n=191) were primary care eligible.

Figure 1. Responses to support system questions.



Of the free text comments reported, there appeared to be a theme of difficulty accessing appointments and/or limited appointments, and challenges with access during the COVID-19 pandemic (Table 5).

Discussion

In this study, we surveyed 208 patients ESI 4 and 5 patients visiting the ED. We determined most patients surveyed could likely be managed in a primary care setting, thus creating an opportunity to fill an unfilled primary care appointment with a non-emergent visit to the ED. This study adds data needed to better understand how to improve access of care to both emergent and non-emergent visits within the MHS. Our results suggest pain may be correlated with their self-reported urgency and likely a driving factor for the acute care visit. Most patients offered the survey reported not being able to make a timely appointment or a self-reported emergency as their reasoning for not going to primary

care. Unpublished data demonstrates, on recent average, more than 4,000 appointments go unfilled monthly within with San Antonio MHS which may represent a lack of easy access to obtaining an appointment rather than lack of access (personal communication, Business Operations Division, Brooke Army Medical Center). The most common studies performed were x-rays, and the most frequent IM medication was ketorolac, used for short term pain—both of which are easily obtainable in the primary care setting. Out of the patients surveyed, the majority were discharged, and based on our model, their visit was primary care eligible. Our findings suggest that many ED visits represent encounters that are manageable in the primary care setting.

The most common suggestion for improving access to care was more short-term primary care availability, with most patients reporting they would have gone to primary care if they could obtain a next morning appointment. Perhaps a more convenient method for accessing short-term appointments would alleviate some of the non-emergent visits. Based on our data, less than half of the surveyed patients reported contacting their primary care provider; further suggesting easier methods for appointments access would be beneficial. Most patients reported a strong support system, meaning getting to the appointments does not appear to be a factor. Merely having access to open appointments may be a contributor to non-emergent visits.[23] The majority of patients surveyed had reported a previous visit to the ED in the last year. A previous study indicated more frequent ED visits are associated with higher odds of having a non-urgent visit.[24] These results build on existing evidence showing that many visits to the ED that do not require urgent care with more specific application to the MHS.[1,25] Implementing a solution for real time appointment scheduling could help shift the non-emergent patients to primary care or other clinics. The New England Health Institute published a research article discussing possible solutions including open access scheduling, using case managers for frequent or vulnerable patients, and in-house urgent care clinics.[7] Educating patients on when it is appropriate to use the ED may also help lower unnecessary appointments.

In addition to educational interventions, instituting copayment to reduce non-urgent ED care-seeking behavior has been studied.[26-31] Although studies showed mixed results in reductions in ED use, two factors seemed to be important to the success of financial incentives to reduce non-urgent ED use: 1) assuring sufficient knowledge among beneficiaries that such cost-sharing policies exist, 2) establishing higher ED visit copayments to deter non-urgent use. Additionally, studies conducted within vertically-integrated health systems suggest care seeking behavior would shift from the ED to other settings (e.g., physician's office) as a result of ED copayments.[30] However, one ED-based study suggested that reluctance to pay cost-sharing could reduce ED care-seeking for potentially necessary visits (e.g., chest pain, shortness of breath, or abdominal pain complaints).[32] A solution could be a hybrid model in which copays are only implemented for non-emergency utilization (e.g. those discharged home that met our primary care model) and/or a rank-based system in which the copay is commensurate with the sponsors rank and income.

We must acknowledge that our primary care eligible design relied on an after-the-fact review of their workup and interventions. In this design, it lends itself to challenges as we are unable to quantitively measure the emergency versus urgency mindset of patients, whether their issue truly requires an emergency (life, limb, eye sight, etc.) or represents an urgent need that is not met through the challenges we discovered with regard to the perceptions of access to care. The DoD adheres to the prudent layperson standard in determining whether a patient perceived an emergency, and thus a post-hoc review must take this into account.[34] Future studies, perhaps using a qualitative design, may lend to a better understanding of the immediacy of the medical need versus the convenience factor the military ED offers at no cost. Moreover, while not assessed in this particular study, a hybrid-based model in which components of the ED could be run like a primary care clinic, in which they are scheduled a time to be seen and the low triage levels are seen in the order in which they check in. Such a model is currently available in some civilian centers in which patients can pre-check in for their "emergency" and be seen at a semi-scheduled time. Additionally, we must also acknowledge that our population is unique, as the military healthcare represents a quasi-socialized medicine system in which our population has virtually unlimited access to care at little to no cost, and our emergency centers do not serve as a de facto safety net for the uninsured in the way our civilian counterparts often do.[35]

There are several limitations to this study. First, we only analyzed data until the patients were discharged, excluding any possible related return visits after the initial treatment. We based our study on a convenience sample with available staff which may limit generalizability. However, the staff coverage time was distributed through most of the 24 hours of operations from 0600-0200, which captures the overwhelming majority of our visit check in times. We only collected data for two months during the COVID-19 pandemic, which further

hindered access to care as in-person appointments were limited, and perhaps, patients feel as though they receive better quality care or the psychological benefits of an in-person assessment. Telemedicine could have played a factor as well by lowering the number of unnecessary ED visits. Given the MHS's forced expansion of telehealth services due to the COVID-19 pandemic, it remains unclear if this may serve as another viable option for reducing ED use for non-emergent reasons even after the healthcare system returns to normal function.[36] Our survey did not capture data relative to those additional challenges as our study was initially setup prior to the pandemic effects on the MHS. The use of the ESI 4 and 5 as inclusion criteria could have affected our data because this scoring system estimates nursing resources that will be required and not necessarily the acuity their illness or injury. As such, it is possible we missed other primary care eligible visits that received a higher ESI categorization. Furthermore, while patients stated they would have gone to primary care if an appointment were available, we do not yet have a method to assess whether that would actually happen.

Conclusion

Patient perceptions of difficulty obtaining appointments appears to be a major component of the ED use for non-emergent visits. Within our dataset, most patients surveyed stated they were unable to make a timely appointment or self-reported an emergency. Data suggests most patients could be managed in the primary care setting.

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New Versus Old, The i-View Video Laryngoscope Versus the GlideScope: A Prospective, Randomized, Crossover Trial

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Abstract

Background: A novel video laryngoscope device, the i-View, may extend intubation capability to the lowest echelons of deployed military medicine. The i-View is a one-time use, disposable laryngoscope. We compared time to completion of endotracheal intubation (ETI) between the i-View and GlideScope among military emergency medicine providers in a simulation setting.

Methods: We conducted a prospective, randomized, crossover trial. We randomized participants to i-View or GlideScope first before they performed 2 ETI—1 with each device. The primary outcome was time to completion of ETI. Secondary outcomes included first-pass success, optimal glottic view, and end-user appraisal. We used a Laerdal Airway Management Trainer for all intubations.

Results: Thirty-three emergency medicine providers participated. ETI time was less with GlideScope than i-View (22.2 +/- 9.0 seconds versus 30.2 +/- 24.0 seconds; p=0.048). Optimal glottic views, using the Cormack-Lehan scale, also favored the GlideScope (2 [1,2] versus 2 [2,2]; p=0.044). There was no difference in first-pass success rates (100% versus 100%). More participants preferred the GlideScope (24 versus 9; p=0.165); however, participants agreed that the i-View would be easier to use than the GlideScope in an austere environment (4 [4,5]).

Conclusions: We found the GlideScope outperformed the i-View with respect to procedural completion time. Participants preferred the GlideScope over i-View, but indicated the i-View would be easier to use than the GlideScope in an austere setting. Our findings suggest the i-View may be a suitable alternative to GlideScope for US military providers, especially for those in the prehospital setting.

Keywords: airway, video, laryngoscope, i-View, intubation, prehospital

Introduction

Background: Airway management is critical for the stabilization and resuscitation of both trauma and medical patients.[1,2] For US military medical personnel deployed to areas of armed conflict, endotracheal intubation (ETI) is essential as airway compromise is the second leading cause of preventable death on the battlefield, and ETI comprises the vast majority of airway interventions performed in both the prehospital and hospital settings.[3-7]

ETI performance on combat casualties may be complicated by maxillofacial injuries and other difficult airway scenarios. Published reports demonstrated difficulty intubating service members suffering traumatic maxillofacial injuries and several casualties requiring secondary airway intervention, such as cricothyroidotomy or tracheotomy.[8-11] In addition to maxillofacial injury, cervical spine injury, cervical immobilization, inhalation injury, and combat conditions outside of the controlled environment of a hospital may introduce additional factors that hinder successful performance of ETI.[12-17] Consequently, deploying military medical providers require availability of additional airway management devices to achieve optimal patient outcomes.[18] One such tool is a video laryngoscope (VL).

Figure 1.GlideScope Titanium (left) and i-View (right) handles and blades.

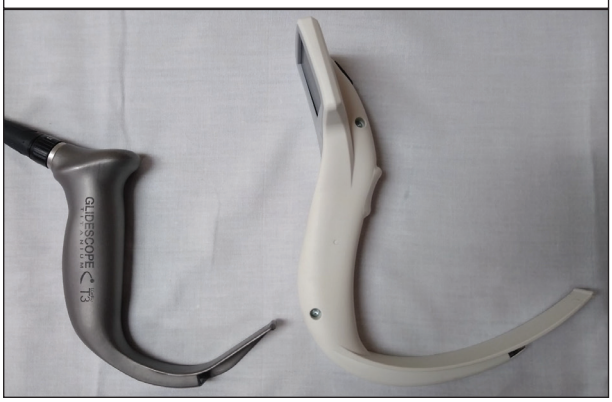
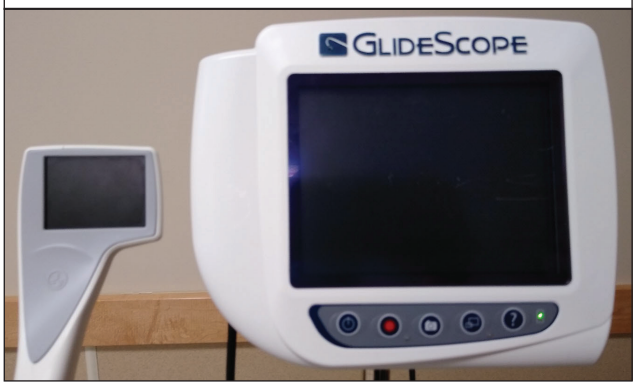


Figure 2. i-View viewfinder (left) and GlideScope Core video monitor (right).



VL offers advantages over traditional direct laryngoscopes and is uniformly recommended for use in the management of difficult airways.[15,19-21] The GlideScope Ranger (Verathon, Inc.) was the most commonly fielded VL device among US military units, but its distribution was limited to medical elements with surgical capabilities. Recently, the i-View (Intersurgical, Inc.) entered the market and offered an affordable alternative to the GlideScope that may enable distribution of a VL capability to the lowest levels of medical care in the deployed US military medical system.

The i-View differs from the GlideScope in many ways. Most notably, the i-View is a single-use item that costs <$200, while the GlideScope Ranger is a multi-use device that costs $12,292.67 (National Supply Number 6515-01-572-7262). The disposable, battery-powered i-View does not require maintenance, while the GlideScope and its power source require periodic performance checks and, if necessary, repair by a trained technician. The i-View's viewfinder is fixed to the end of the device handle along the intubator's visual axis, while the GlideScope's viewfinder is connected to the handle by cable and placed on or near the patient, but away from the intubator's visual axis. Finally, the i-View's blade mimics a MacIntosh blade, while the GlideScope has a hyperangulated blade that requires a manufacturer-specific stylet.

Numerous studies assessing ETI facilitated by the GlideScope reported favorable findings.[22-32] The GlideScope performed as well as or better in certain aspects of airway management than traditional direct laryngoscopy and other VL devices among simulation manikins and live patients in the prehospital, emergency department, intensive care unit, and operating room settings.[22-32] By contrast, there are no published data for the novel i-View VL device and no studies that compare it to the GlideScope.

Goals of the Investigation: We compared the performance of ETI between a novel VL device (i-View) and the GlideScope VL among military emergency medicine providers. Secondarily, we assessed end-user appraisal of ETI by device.

Methods

Ethics: The local institutional review board (IRB) determined this study was exempt from IRB oversight. All study participants consented to participation.

Participants & Materials: We enrolled emergency medicine physician and physician assistant (PA) staff and residents at one US Army emergency medicine residency training site located at Joint Base Lewis-McChord, WA. We selected emergency medicine providers for our study population as they must perform ETI as part of their clinical duties and are assigned to all echelons of the deployed military medical system. Our only exclusion criterion was physical injury preventing performance of ETI.

All participants performed ETI on an adult airway training manikin. The airway manikin replicated normal anatomy, and we did not institute any measures to create a difficult airway scenario. Participants performed VL facilitated ETI with both the i-View (Item #8008000; Intersurgical, Ltd; Berkshire, UK) and GlideScope Titanium (LoPro T3; Verathon, Inc; Bothwell, WA) (Figure 1). We were unable to utilize the GlideScope Ranger (the model commonly fielded in the US military) for this study due to lack of equipment availability. Although the Titanium and Ranger models both possess a hyperangulated blade, the Titanium is a reusable blade made of metal, while the Ranger is a video baton inserted into single-use plastic blades. Additionally, both the Titanium and Ranger have a detached viewfinder connected to the blade via cable; however, the viewfinder for the

Ranger is 8.9 cm in size, while the Titanium we used was connected to a GlideScope Core video monitor (Verathon, Inc; Bothwell, WA) 25.7 cm in size. By comparison, the viewfinder of the i-View is 6.0 cm in size (Figure 2). All participants utilized a cuffed 7.5 mm endotracheal tube with generic endotracheal tube stylet for i-View attempts and manufacturer-specific stylet for GlideScope attempts.

Table 1. Participant demographics.

Characteristic	Total (%) (n=33)
Age (years)	39.3 +/- 12.3
Gender	
Male (n, %)	26 (79%)
Female (n, %)	7 (21%)
Provider Type	
EM Physician, Staff	8 (24%)
EM Physician, Resident	16 (49%)
EM PA, Staff	7 (21%)
EM PA, Resident	2 (6%)
Previous VL ETI on Airway Manikins	
0 – 7	6 (18%)
8 – 14	5 (15%)
15 – 21	5 (15%)
22 – 28	5 (15%)
29 – 35	1 (3%)
>35	11 (33%)
Previous VL ETI on Living Patients	
0 – 7	17 (52%)
8 – 14	6 (18%)
15 – 21	3 (9%)
22 – 28	2 (6%)
29 – 35	0 (0%)
>35	5 (15%)

EM – Emergency medicine
PA – Physician assistant
VL – Video laryngoscopy
ETI – Endotracheal intubation

We conducted all study activities inside the department of emergency medicine in an environmentally controlled room. We secured airway manikins on a gurney that the participant was permitted to adjust to their preferred height. We placed all airway equipment in a standardized fashion to the side of the gurney on a Mayo stand. We powered off VL devices before each attempt. Participants wore hospital scrubs for study activities since we did not require them to wear or carry combat gear as we aimed to simulate conditions expected within deployed, fixed military treatment facilities, such as a Battalion Aid Station (Role 1), Brigade Aid Station (Role 2), Forward Surgical Element (Role 2e), and Field Hospital (Role 3).

Protocol: We conducted a prospective, randomized, crossover trial. A single investigator (DHT) provided a study brief and instructed all participants on operation of both VL devices. We instructed every participant to obtain what they considered a sufficient view of the glottis with each device one time before they performed tested iterations. Afterwards, we randomized participants utilizing a random number generator into 1 of 2 groups: i-View first or GlideScope first. Participants performed a total of 2 ETI, 1 with the i-View and 1 with the GlideScope. For each attempt, one investigator recorded time while another investigator assessed vocal cord visualization and ETI success. Our washout period comprised the time to reset between interventions to reduce participant loss to follow-up since there is no published data delineating the optimal washout period for ETI. After performing both ETI attempts, participants completed a survey to assess procedural confidence and VL device impressions.

Outcomes: The primary outcome of our study was time in seconds for ETI. Time started when the VL device blade passed the manikin's lips and time ended once the participant announced completion of the procedure. We based our measurement of time on methods utilized in previous studies comparing VL ETI.[25,28,33-36] Starting time when the device passed the manikin's lips negates time taken to power devices and setup equipment, thereby enabling a more accurate comparison of procedural performance by different devices.

Our secondary outcomes included ETI success, vocal cord visualization, participant confidence to perform ETI, and participant appraisal of VL devices. We defined success as the endotracheal tube properly placed within the trachea. Investigators assessed each attempt as a success or failure while blinding the participant to this result to prevent influencing self-confidence ratings. Investigator MAJ Eric M. Wagner, DSc PA-C directly observed the viewfinder of the VL devices during attempts to determine the optimal glottic view obtained and graded it utilizing the Cormack-Lehan scale.[37] We assessed participant confidence to perform ETI utilizing a 0-100 continuous Bandura scale.[38] We evaluated end-user assessments of ETI devices utilizing 5-point Likert items (Appendix 1).

Data Analysis: We performed all statistical analyses using standard statistical software packages. We report continuous variables as means with standard deviations, ordinal variables as medians with interquartile ranges, and nominal variables as numbers and percentages. We analyzed continuous data with the Paired t-Test, ordinal data with Two Sample t-Test,[39] and categorical data with the Chi-square test. We performed period and sequence analyses to assess for cross-over effects. Published data for time to complete VL ETI starting when the endotracheal tube passed the lips and complete once the endotracheal tube passed the vocal cords averaged 14.4 seconds for the Glidescope.[45-47] Pre-study power analysis for the primary outcome of time utilizing an expected mean of 14.4 seconds determined a sample size of 32 participants was required to detect a significant difference of 10 seconds between interventions. Statistical significance was set at $p < 0.05$ with a beta of 20%.

Results

From July to September of 2020, a total of 33 EM physicians, physician residents, PA, or PA residents consented to participate. We did not exclude any potential participants, and all completed study activities. Participants

Table 2. Endotracheal intubation (ETI) performance, by device.

Outcome	i-view (n=33)	GlideScope (n=33)	p-value
Time (seconds)	30.2 +/- 24.0	22.2 +/- 9.0	0.048#
Glottic View (1-4)*	2 [2,2]	2 [1,2]	0.044^
Success Rate (%)	100%	100%	N/A

**Cormack-Lehane grade:*
1 – Full view of glottis;
2 – Partial view of glottis or arytenoids;
3 – Only epiglottis visible;
4 – Neither glottis nor epiglottis visible
#reported as mean with standard deviation; calculated with Paired t-Test
^reported as median [IQR]; calculated with Two-sample t-Test

Table 3. End-user appraisal, by device.

Interrogatory	i-view (n=33)	GlideScope (n=33)	p-value
Preferred device: i-view or GlideScope?	9 (27%)	24 (73%)	0.165*
Easier to use: i-view or GlideScope?	4 [4,5]	4 [4,5]	0.100^
Easier to learn and remember: i-view or GlideScope?	4 [4,5]	4 [4,5]	1.000^

**reported as n (%); calculated with Chi-Square Goodness-of-fit test*
^reported as median [IQR]; calculated with Two-sample t-Test

averaged 39 years of age (range, 26–64) and most were male (79%) and physician residents (49%) (Table 1). Participants reported a high overall confidence level to perform VL (88.2, 95% CI 83.4, 93.0). Greater than 35 previous training VL ETI was reported by the largest proportion of participants (33%). Most participants (85%) reported limited experience with the i-View, while 30% indicated limited experience with the GlideScope.

We found a significant difference in time for ETI completion between the GlideScope and i-View in favor of the GlideScope (22.2 +/- 9.0 seconds versus 30.2 +/- 24.0 seconds; p=0.048) (Table 2). We also found a significant difference in optimal glottic view obtained between devices in favor of the GlideScope (2 [1,2] versus 2 [2,2]; p=0.044). There was no difference between devices with respect to procedural success (100% versus 100%). We performed crossover analyses by sequence and period and found no significant differences which indicates the effect observed with respect to time is valid.

More participants preferred the GlideScope over the i-View; however, this was not significantly different than expected (24 versus 9; p=0.165) (Table 3). Participants assessed the i-View as easy to use as the GlideScope (4 [4,5] versus 4 [4,5]; p=0.100) and as easy to learn, remember, and perform (4 [4,5] versus 4 [4,5]; p=1.000). Participants agreed the i-View would be easier to use than the GlideScope in an austere environment (4 [4,5]).

Discussion

We compared performance of ETI between the i-View and GlideScope Titanium in the hands of military emergency medicine providers. We found the GlideScope outperformed the i-View with respect to procedural completion time and optimal glottic view; however, there was no difference in ETI success rate between devices. Participants preferred the GlideScope over the i-View, but indicated the i-View would be easier to use than the GlideScope in an austere setting. Our findings suggest the i-View may be a suitable alternative to the GlideScope for US military providers, especially for those in the prehospital setting.

Previous trials that measured time for ETI performance with a GlideScope on airway manikins reported times of 14.9–17.2 seconds.[25,33,40,41] Although start and end times for these studies varied slightly, they all used a manikin similar to ours and did not replicate difficult airways. Participants for these studies ranged from emergency medicine physicians to anesthesiologists to Air Force Critical Care Air Transport Team (CCATT) members. In our study, the time for GlideScope facilitated ETI was 22.2 seconds, which is not consistent with the results of these studies. This finding, however, is likely due to methodological differences between these studies and ours, with the most notable difference being that participants in previous studies performed multiple iterations of VL ETI (as many as 6 times per device, with as many as 5 devices, for a total of 45 ETIs), while in our study participants only performed 2 total ETI, 1 per 2 devices.[33,40,41] We found that i-View ETI was 8 seconds slower than the Glidescope. Although statistically significant, this difference may not be clinically significant, and the average time for i-View ETI of 30 seconds suggests it may enable airway intervention prior to the onset of significant hypoxemia.[42] Our findings suggest the i-View may be a suitable alternative to the GlideScope for military providers. Consequently, distribution of the i-view, especially to the lowest echelons of the deployed military medical system, should be considered, given the logistical advantages of the i-View over the GlideScope. The GlideScope currently has a very limited distribution around the battlefield.

Emergency department GlideScope ETI success rates range from 75-91% on live patients[23,24,26-30,43] and 100% on cadavers and airway manikins.[22,25] We found that the success rate for both GlideScope and i-View ETI was 100%. The success rate for GlideScope observed in our study is consistent with previous results and reinforces our finding that i-View ETI performance with respect to success is comparable to GlideScope enabled ETI. However, while the results of our and previous studies utilizing airway manikins demonstrated 100% success rates, none of the numerous clinical trials involving live patients in an emergency department setting reported 100% success rate.[23,24,26-30,43] Furthermore, these success rates reflect overall procedural success, not necessarily

first-pass success. Consequently, our findings should not be considered to translate directly to performance of battlefield VL enabled ETI on combat casualties. Future studies of combat casualty airway management in the deployed setting that incorporates VL enabled ETI are warranted to provide accurate and comprehensive assessments of this life-saving intervention.

Reports of optimal glottic views obtained with the GlideScope are limited to studies of ETI performed by anesthetists in the operating room setting.[34-36,44] We found GlideScope achieved a grade 1 or 2 view in all attempts, and it outperformed the i-View with respect to glottic views obtained. Although the i-View attained a grade 2 view in most attempts, it infrequently obtained a grade 1 view (9%, 3 of 33). The difference between optimal glottic views obtained with the GlideScope and i-View is explained by the difference in blade angulation between devices. The GlideScope has a hyperangulated blade which facilitates glottic visualization with minimal airway manipulation, while the i-View's blade mimics a MacIntosh laryngoscope. Although the i-View's blade shape may not enable maximal glottic views, we found it does achieve sufficient visualization to enable successful ETI—with the added benefits that it may be converted into a DL device if necessary and does not require use of a manufacturer-specific stylet.

Previous studies reporting end-user appraisals of different VL devices found the GlideScope to be the most favored VL device among participants.[33,41] Wallace et al asked 40 CCATT members to appraise 5 different VL devices.[41] Participants, both novice and expert, rated the GlideScope as the easiest to use, although statistical significance of this result was not reported.[41] El-Tahan et al queried 21 anesthesiologists on their experience performing ETI with 4 different devices.[33] They reported 100% of participants identified the GlideScope as their preferred device for real-life difficult ETI; however, they too did not report the statistical significance of this result.[33] We also found that participants preferred the GlideScope over the i-View. This finding may be attributed to differences between device view finders, with the significantly larger GlideScope view monitor offering superior visual quality. Additionally, several participants noted the fixed view finder of the i-View was more difficult to see because as the device was advanced in the airway the angle of the viewfinder changed slightly, and the intubator had to adjust their head position to maintain a clear picture. This was not experienced with the GlideScope monitor as it was detached from the device handle and remained stationary throughout procedural execution. However, participants indicated that they considered the i-View easier to use in the austere setting than the GlideScope. While the majority of the population tested have not deployed, they have completed training exercises, and all residents completed Advanced Wilderness Life Support training. This training familiarizes them with the challenges of austere medicine. Additionally, 100% (8 of 8) of the staff emergency medicine providers who participated in the study considered the i-View easier to use in the austere than the GlideScope. This finding further supports distribution of the i-View to the lowest levels of the deployed military medical system to provide a VL capability to military prehospital providers.

Our study has several important limitations. First, we utilized airway training manikins for all ETI attempts. Simulation manikins do not fully replicate living human tissue and physiology. Furthermore, our manikins possessed normal airway anatomy, and we did not institute any measures to replicate difficult intubation conditions, such as secretions, blood, and debris in the oropharynx, simulated cervical spine immobilization, etc. Consequently, we were not able to assess differences between VL devices in difficult airway situations. Second, we used the GlideScope Titanium instead of the GlideScope Ranger, the latter being the model commonly fielded by the US military. Despite both devices sharing specific design (i.e. hyperangulated blade) and operation features (i.e. detached view finder), differences between devices (i.e. different sized viewfinders) preclude strict correlation between the i-View and the Ranger. Future studies between the i-View and GlideScope Ranger may be beneficial. However, we consider the similarities between GlideScope devices sufficient to enable a generalized comparison with the i-View. We did not institute a significant washout period between crossover arms. As there is no published data outlining optimal washout periods for ETI, we elected a minimal washout period to optimize participant participation. Therefore, outcomes of the second intervention may have been improved by virtue of the performance of the first intervention attempted. However, we attempted to control for this by randomizing the initial intervention performed. Furthermore, we performed statistical evaluations of period and sequence groupings which validated the treatment effects observed. Lastly, our study population is limited to emergency medicine providers at one US Army installation. Consequently, our findings may not be generalizable to all military providers, with or without emergency medicine residency training.

Conclusion

We found the GlideScope outperformed the i-View with respect to procedural completion time and optimal

glottic view; however, there was no difference in ETI success rate between devices. Participants preferred the GlideScope over the i-View, but indicated the i-View would be easier to use than the GlideScope in an austere setting. Our findings suggest the i-View may be a suitable alternative to the GlideScope for US military providers, especially those in the prehospital setting.

Appendix

Appendix 1. Study survey.

#_____ ---_____

Survey

Thank you for your participation. Please complete the survey below.

Please **CIRCLE** your preference

Which device do you prefer? Glidescope video laryngoscope iView video laryngoscope

In the right-hand column below labeled "Confidence," rate how confident you are in performing the task, at this point in time, by recording a number from 0-100 using the scale below.

0 10 20 30 40 50 60 70 80 90 100

Completely not confident Supremely confident

Endotracheal Intubation Task	Confidence
1. Visualize the vocal cords with video laryngoscopy ETI?	_____
2. Intubate successfully on first attempt with video laryngoscopy ETI?	_____
3. Overall confidence to perform video laryngoscopy ETI?	_____

The following questions assess your experience with both types of laryngoscopes. Please **CIRCLE** your answers for the following questions using the scales provided.

1. Ease of use of the Glidescope video laryngoscope?

Not easy at all	Not easy	Neutral	Easy	Very Easy
1	2	3	4	5

2. Ease of use of the iView video laryngoscope?

Not easy at all	Not easy	Neutral	Easy	Very Easy
1	2	3	4	5

3. The Glidescope is easily learned, remembered and performed by medical providers?

Not easy at all	Not easy	Neutral	Easy	Very Easy
1	2	3	4	5

4. The iView is easily learned, remembered and performed by medical providers?

Not easy at all	Not easy	Neutral	Easy	Very Easy
1	2	3	4	5

5. For medical providers with limited endotracheal intubation experience, the iView would be easier to use than the Glidescope?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

6. In an austere environment, the iView would be easier to use than the Glidescope?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

7. I would choose the iView over the Glidescope as my primary video laryngoscope tool?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

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An Assessment of Combat Medic Supraglottic Airway Device Design Needs Using a Qualitative Methods Approach: A Preliminary Analysis

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Abstract

Introduction: Airway obstruction is the second leading cause of potentially preventable death on the battlefield during the recent conflicts. Previous studies have noted challenges with enrolling medics using quantitative methods, with specific challenges related to limited prior experience with the devices presented. This limited the ability to truly assess the efficacy of a particular device. We sought to implement a qualitative methods design for supraglottic airway (SGA) device testing.

Methods: We performed prospective, qualitative-designed studies in serial to discover emerging themes on interview. We obtained consent and demographic information from all participants. Medics were presented 2-3 airway devices in the same session with formal training by a physician with airway expertise to include practice application and troubleshooting. Semi-structured interviews were used after the training to obtain end-user feedback with a focus on emerging themes.

Results: Of the 77 medics surveyed and interviewed, the median age was 24, and 86% were male. During the interview sessions, we noted five emerging themes: (1) insertion, which pertains to the ease or complexity of using the devise; (2) material, which pertains to the tactile features of the device; (3) versatility, which pertains to the conditions in which the device can be used as well as with which other devices it can be used; (4) portability, which refers to how and where the device is stored and carried; and (5) training, which refers to the ease and frequency of initial and ongoing training to sustain medics' technical capability when using the device.

Conclusions: In our preliminary analysis after enrolling 77 medics, we noted 5 emerging themes focused on insertion material, versatility, portability, and training methodology. Our results will inform the future enrollment sessions with a goal of narrowing the market options from themes to ideal device or devices or modifications needed for the operational environment.

Keywords: airway, prehospital, combat, medic, qualitative

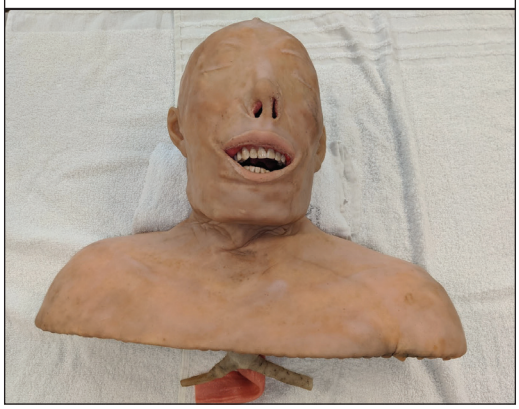
Introduction

Background: Airway obstruction is the second leading cause of potentially preventable deaths on the battlefield during the recent conflicts.[1] Recent data demonstrates high mortality associated with the need for airway interventions in the prehospital, combat setting.[2,3] Optimized airway management is among the top five battlefield research and development priorities identified by the Committee on Tactical Combat Casualty Care (CoTCCC), yet the challenge of airway management has evolved little during the recent conflicts.[4] Schauer, et al. noted that medics lacked access to various devices recommended in TCCC guidelines including the Control-Cric which limits the ability to interpret, and more importantly apply the results of, quantitative studies.[5]

A previously published study demonstrated that outcomes are similar with cricothyrotomy versus supraglottic airway (SGA) device placement in the combat setting,

suggesting that SGAs may supplant the need for cricothyrotomy training and/or application.[6] Moreover, a previous study found that we are likely to not detect any differences between devices due to (1) limitations in training prior to enrollment (e.g. we are finding challenges due to inadequate training) and, (2) we are unlikely to identify the ideal device using an randomized, cross-over design, as all devices will likely perform in a similar fashion in the hands of untrained or limited trained medics.[7] As such, the development of such a device or selection of the optimal device for medics to carry lends itself well to the use of qualitatively designed studies. Moreover, such a design may capture additional data that would otherwise be challenging to capture using quantitative metrics.

Figure 1. Airway simulation mannequin; adult airway trainer by Syndaver, Beyond Human, Tampa, FL.



Goal of this Investigation: We seek to determine, using qualitative methods, what the best SGA device(s) is/are for use by medics in the prehospital, combat setting.

Methods

Ethics: We submitted project the proposal to the US Army Institute of Surgical Research (USAISR) regulatory office. Our study was determined to meet exemption criteria. We requested and received a waiver of consent documentation.

Surveys: We provided structured surveys that asked basic demographic information as well as prior airway management experience, prior to the airway training and interview sessions which captured information about the participants. Such information included demographics, rank, time since training, training level, and overall airway experience in the training and the real-world setting.

Training: In previous studies by Schauer, et al., we found that lack of training prior to evaluating devices greatly hindered the ability to get relevant data. Training was provided as part of this study to ensure competency and comfort with the devices prior to the de-briefing rather than receiving feedback based on their lack of skills required to operate the device.[5,7] We stratified medics into groups of no more than four per station with one Syndaver airway trainer (Figure 1) and one physician. Based on serial testing and feedback, we down-selected from the available list of devices (Table 1) and presented 2-3 devices at a time.[8] We limited the number of devices at each time to ensure we received relevant feedback for each device without dilution related to presenting too many devices or participant fatigue with training diluting the feedback received with each device. In other words, we wanted to ensure we had quality feedback with each device rather than overall feedback about the training session. The devices presented were based on repetitive feedback provided with the devices receiving the most positive feedback used more frequently. The training included indications for airway device placement. We then provided the medics with a demonstration of the device including how to troubleshoot the placement if proper seating did not occur. Once the medics completed the training, we provided them unlimited opportunities to practice placing the device with a physician present to coach them on device placement and any troubleshooting as required until they stated they were comfortable with the device. Once the medics completed training for one device, they began training for the next device. The sessions lasted until the medics stated they were satisfied with the training and comfortable with the device to the point they would be ready to place it in a real patient.

Qualitative Methods: The general theoretical commitments of the capability approach assume that individuals have unique capability sets, which allow them to choose between potential alternatives when selecting between compatible options when attempting to achieve a satisfactory outcome. These capability sets can be observed and described in relationship to choosing a specific option for implementation by the research team.[9] The goal of this method is to begin with a range of choices rather than one optimal choice to understand participant preference. In this method, preference is

Table 1. List of airway devices included in the study.

Air-Q intubating laryngeal airway
AuraGain LM
AuraStraight LM
King LT
LM Solus
LMA Fastrach
LMA Supreme
i-gel
Baska Mask
WellLead Wei Nasal Jet Tube
SuperNO2VA Nasal Pap Ventilation System

LM = Laryngeal Mask
LMA = Laryngeal Mask Airway

understood as the maximization of utility. As such, the capability approach methodology nicely aligns with the phenomenon in question and provides a general framework for how to organize, begin, and develop our research. In other words, we wanted to present our overall study population with the full range of choices rather than selecting the devices we felt may be optimal. We wanted to allow the study population to draw from the full market of devices to advise us from which devices to narrow the options down.

Table 2. Interview guide questions.

What surprised you about using this device?
What hindered your ability to use this device?
What assisted your ability to use this device?
What did you like about this device?
What did you not like about this device?
When did it function?
When did it not function?
Where did it function?
Where did it not function?
Did it simplify your work?
Did it make your work harder?
What would do to make this device more valuable?
What would you change about this device if you could?
What would you not change about this device?
How would you recommend we train on this device?
How often to you think training is necessary?

Capability approach is grounded in an emergent research design, which involves an ongoing, iterative process that is constantly open to change during data collection, analysis, and integration into a broader understanding of study aims and questions. While such a design is flexible it is not unstructured. It appreciates that at the earliest stages of empirical research there are multiple directions, strategies, and options that can and will emerge as researchers make purposeful decisions prior to, during, and after data collection. Emergent design allows researchers to adjust and assimilate unexpected information throughout the research process. These adjustments, in turn, allow for refinement of the research process as data is reduced into meaningful themes.[9]

A study investigator led the interviews for the debriefing session to obtain the qualitative data. We used a series of questions that were provided by the qualitative expert Erika A. Jeschke, PhD, as a general guide to structure the interview process; however, the participants were welcome to deviate from the interview structure should they have other relevant information to share (Table 2). The sessions were recorded by research coordinators, which allowed for post-enrollment transcription as were the actual training sessions to ensure that we captured other spontaneously provided information by the medics. Another investigator, typically the PI, not performing the debriefing also took notes in real-time to ensure maximal data capture. After the first two sessions, the interviewers were led solely by the civilian investigators on the research team rather the military officers to maximize the feedback received. Additionally, the participants were advised all feedback was anonymous, non-punitive, not shared with their chain of command, and that we had no financial interests in any device. We sought to maximize the open discussion with minimal interference as a result of the often unspoken power-differential between officers and enlisted and/or physicians and medics.

At this point in the analytic process, the team members held teleconference meetings to compare their interpretations of themes. The third and final phase involved constructing a taxonomy of common themes contained within the entire data set. This manuscript contains a preliminary analysis of our findings and lays the foundation for the use of qualitative methods for medic-centric studies. While multiple investigators supported these stages, the overall principal investigator (PI) Steven G. Schauer, DO, MSCR was involved in all aspects and enrollment events to ensure continuity during all events and thematic analyses. Additionally, the PI took notes during each session and all aspects were recorded and later transcribed for our qualitative methods expert to review. We entered the study with a naïve goal for number of themes or specific themes for which we were seeking feedback.

Quantitative Data Analysis: We collected a limited amount of quantitative data. We aggregated and analyzed the data using commercially available software programs. We present limited descriptive statistics.

Results

We performed three enrollment sessions with 77 medics, with 5 from the US Army Medical Center of Excellence training cadre (JBSA Fort Sam Houston, TX), 62 combat medics from the 4th Infantry Division (Fort Carson, CO), and 10 special operations combat medics from the 160th Special Operations Aviation Regiment (Hunter Army Airfield, GA) and supporting elements. The median age was 24, and 86% were male. The median time since they completed their most recent training (advanced individual training, designator training, etc.) was 3 years (interquartile range 1-5). Most were assigned to the 2-4 Stryker Brigade Combat Team (at the time of enrollment, it was 2-4 Infantry Brigade Combat Team). All were 68W military occupational specialty. In the past year, the median number of reported supraglottic airway placements (SGA) for training was 1, endotracheal intubation 0, and cricothyrotomy 1. In the real-world setting, in total the median number of reported supraglottic airway placements was 0, endotracheal intubation 0, and cricothyrotomy 0 (Table 3). Regarding

procedure performance on living patients, 25% (20) reported SGA placement, 18% (14) reported endotracheal intubation, and 11% (9) reported cricothyrotomy placement.

Table 3. Description of participants.

Demographics	Age*	24 (21-28)
	Male	86% (66)
Unit	Medical Center of Excellence	6% (5)
	2-4 Stryker Brigade Combat Team	81% (62)
	160th Special Operations Aviation Regiment	10% (8)
	116th Military Intelligence Brigade	2% (2)
Rank	Private 2	6% (5)
	Private First Class	16% (12)
	Specialist/corporal	40% (31)
	Sergeant	21% (16)
	Staff Sergeant	13% (10)
	Sergeant First Class	4% (3)
Training experience*	Supraglottic airways	1 (0-3)
	Endotracheal intubations	0 (0-1)
	Cricothyrotomy	1 (0-8)
Real-world experience*	Supraglottic airways	0 (0-1)
	Endotracheal intubations	0 (0-0)
	Cricothyrotomy	0 (0-0)

**reported as median and interquartile range*

The investigators completed naïve thematic analysis on all initial data collected. From this analysis, we noted five general themes and challenges regarding using the devices presented.

1. Insertion, which pertains to the ease or complexity of using the devise.
2. Material, which pertains to the tactile features of the device.
3. Versatility, which pertains to the conditions in which the device can be used as well as with which other devices it can be used.
4. Portability, which refers to how and where the device is stored and carried.
5. Training, which refers to the ease and frequency of initial and ongoing training to sustain medics' technical capability when using the device.

Discussion

Currently, we have completed the initial phase of analysis on a sub-set of collected data. We have taken this data to serve as our pilot information as we pivot from previous research into a complete qualitative project that will lead to a complete set of results. Therefore, we will discuss preliminary pilot results in terms of the changes we have made to our process and a set of initial naïve themes with which to better understand how medics describe the utility of various airway devices. One of the most salient insights gained from the first round of pilot focus-groups was to use medical officers for the training, but not for the focus-group interview sessions. We suspected this was due to a combination of elements that set the tone in the interview session. First, there might be a disequilibrium in terms of the power-balance between researcher—major and captain ranks—and participants —junior to mid-grade enlisted. The military hierarchy places officers above enlisted and the medical hierarchy places physicians above medics. This could construct a reticence in participants who are not adjusted to be in the position of subject matter experts providing input for the needs of the intended end-users. Second, physicians have more familiarity with the device. As such, it is easier for questioning to cease when their own personal preferences are upheld or reinforced. One of the challenges was that physician interviews tended to ask closed-ended questions that proffered yes or no answers without eliciting contextual detail (e.g. which airway device did you like the best?). Therefore, before the second round of data collection a new interview guide was constructed by the qualitative expert from the original data collected. This guide was meant to assist novice interviewers in asking open-ended questions. Physicians still performed observational training. However, research associates, Nguvan Uhaa, LPN and Jessica Mendez, BS, without familiarity with the airway devices performed the focus-group interviews. As the data is reduced across the whole data set, we strive to articulate a set of solid themes that can then be used to identify which airway device provides the most overarching functionality for medics.

We came to the emerging themes through an analysis of the notes collected and the transcripts provided to our qualitative methods expert for interpretation. While we have narrowed our scope to these emerging themes, we primarily intend for this preliminary analysis to serve as a lessons-learned through the implementation of such a method which is uncommon in general and even more uncommon in DOD-based research. Through the repetitive feedback, we arrived at these themes based on the reoccurring positive and negative feedback received with each device in which we categorized their feedback into broader categories. However, we must note that while the use of this method is uncommon in the scientific community, it is quite commonly used in the military in the form of after-action reviews.[10]

We have several limitations we must consider with our study. First, we are using a qualitative method which our study team has limited experience with, with most airway based studies focused on quantitative metrics.[5, 11-13] Of note, the US military uses a semi-qualitative methods approach with the use of after-action reviews; however, that is not frequently in the research setting.[10] Second, this is a preliminary analysis after enrolling 77 medics into our study. We have not reached saturation of our data, so we plan to conduct additional enrollment

sessions. However, we intended this to be a proof-of-concept, pilot analysis. Our demographics, including our experience was based on self-reporting, so it is possible experience was hyper-inflated by the medics. To this end, most of our medics reported little to no experience, which also limits the ability to provide data grounded in substantial real-world experience. Lastly, our study group consisted of only 68W-trained medics, and therefore it remains unclear how our results will extrapolate to other types of medics within the military.

Conclusion

In our preliminary analysis after enrolling 77 medics, we noted five emerging themes focused on insertion material, versatility, portability, and training methodology. Our results will inform the future enrollment sessions with a goal of narrowing the market options from themes to ideal device or devices or modifications needed for the operational environment.

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