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US ARMY MEDICAL CENTER OF EXCELLENCE
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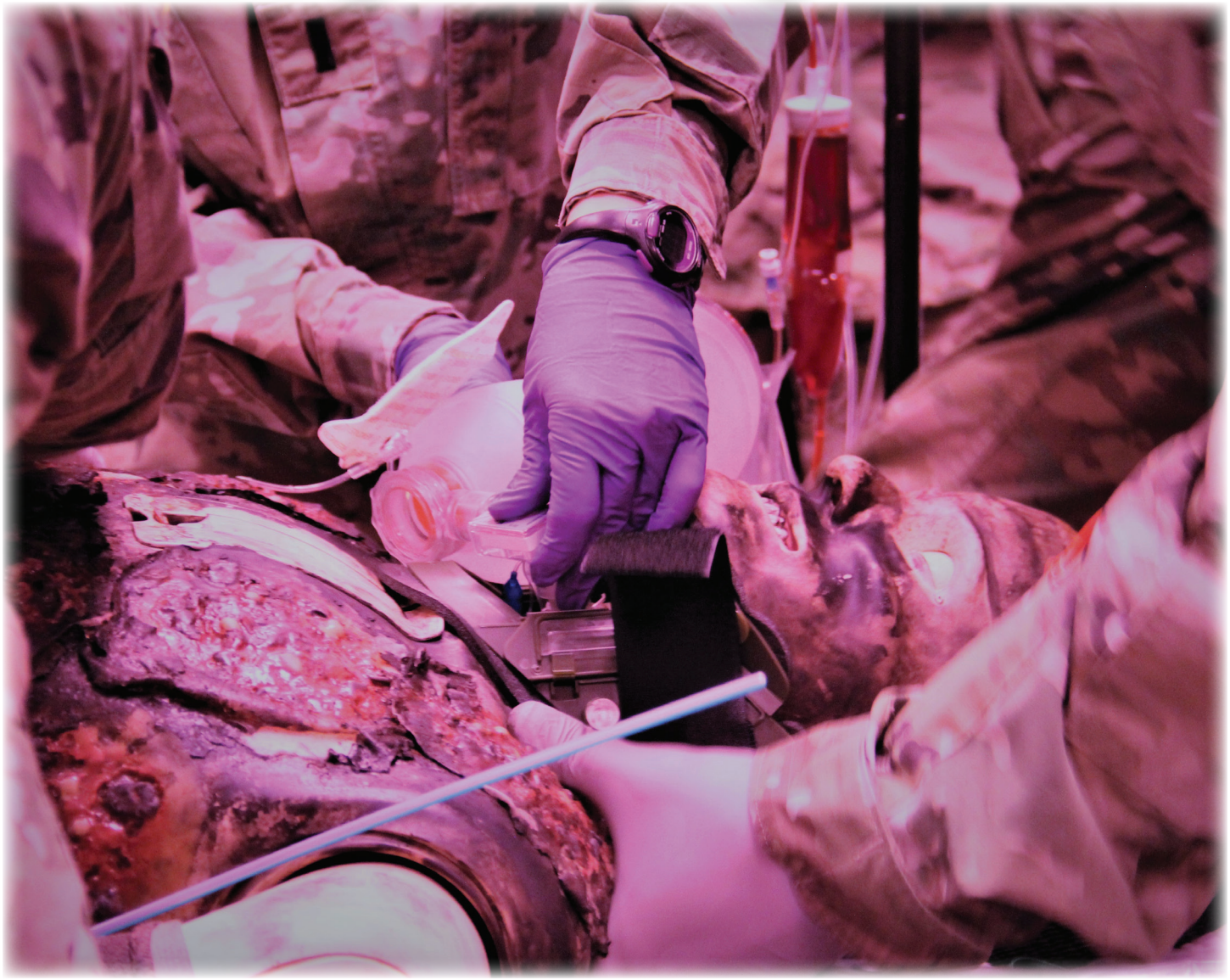
Moving Forward: Military Emergency Medicine



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Military emergency medicine encompasses more than the primary mission of battlefield life-saving experiences. Physicians who specialize in emergency medicine undergo extensive training and continuous learning. Some spend careers searching for ways to reduce morbidity, enhance techniques, and support the advancement of life saving technologies. Collaboratively others dedicate their careers to improving education and training delivery that is inclusive of residency programs. This multi-faceted field supports *The Medical Journal* dedicating two quarterly issues to the special focus topic of military emergency medicine. An over-whelming response from this area of specialty has been received and will be shared.

This issue for Summer 2021 is the first volume of the referenced two-part series. The second volume will be available for our Fall 2021 quarterly edition. Please ensure your command address is on our distribution list for surety to receive your copy. If you are remote, you can always find our issues online at https://medcoe.army.mil/the-medical-journal-archive.

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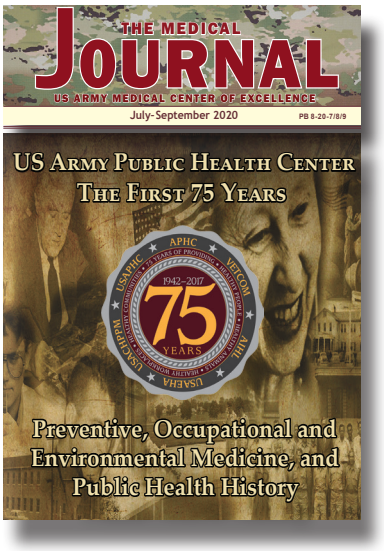

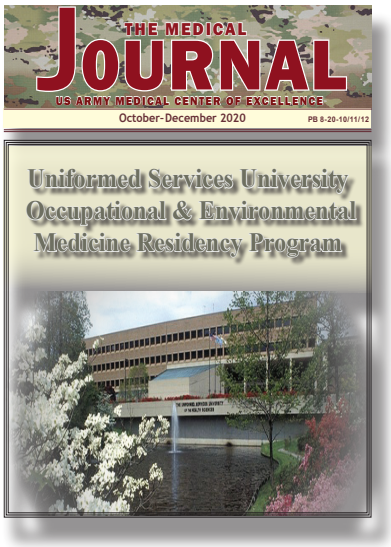

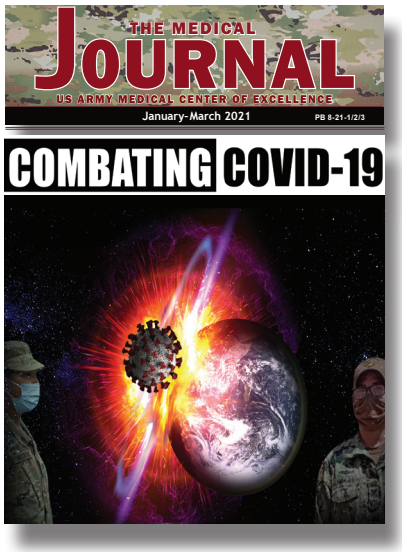

A Descriptive Analysis of Notional Casualties Sustained at the Joint Readiness Training Center: Implications for Health Service Support during Large-Scale Combat Operations

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Abstract

Introduction: The Joint Readiness Training Center (JRTC) offers a laboratory for study of combat casualty care delivery during brigade-sized collective training exercises. We describe the casualty outcomes during large-scale combat operations as part of a JRTC rotation.

Methods: During JRTC rotation 20-02, 2/4 Infantry Brigade Combat Team (IBCT) participated in force on force operations as part of a joint and multinational task force. Medical assets available included a Role II associated with the Brigade Support Medical Company and Role I facilities associated with six subordinate battalion elements. Observers, coaches, and trainers (OCTs) categorized all casualties as killed in action (KIA) or wounded in action (WIA). OCTs categorized WIA casualties as died of wounds (DOW) based upon time elapsed from time of injury to transportation to successive roles of care within time standards, dependent upon the severity of injuries. We portrayed our DOW rates using descriptive statistics.

Results: Force on force operations spanned 14 days. The task organization comprised 3,820 persons. Casualties included 642 KIA and 1061 WIA. Of the WIA, 502 (47.3%) dies from their wounds. The primary reason for DOW was evacuation delay from point of injury (POI) to military treatment facility (MTF) (443 casualties, 88.2%). An additional 40 casualties DOW at the Role 1 (8.0%) and 10 died at Role II (2.0%). Nine casualties (1.8%) DOW due to improper care rendered.

Discussion: Casualty DOW during simulated large-scale combat operations are overwhelmingly due to evacuation delays from POI. Medical readiness for near-peer force on force operations depends upon shared understanding across medical and non-medical personnel of casualty movement through echelons of care on the battlefield.

Introduction

The Joint Readiness Training Center (JRTC) at Fort Polk, LA, is an installation facilitating brigade-sized collective training exercises.[1] This training capability is increasingly important as the US Army transitions from counterinsurgency and expeditionary operations[2] and resumes focus on training for large-scale combat operations. Together with the National Training Center (NTC), JRTC offers a laboratory for conducting force on force operations against a near-peer threat with multi-domain capabilities. The training audience for NTC focuses on mobile mechanized units such as Stryker and Armor brigades, and the training audience for JRTC is primarily light infantry and Special Forces units. These training exercises enable brigade combat teams to build readiness in preparation for future deployments against near-peer adversaries.

The medical literature relevant to NTC[3-6] and JRTC[1] has historically focused on real world injuries and illnesses incurred during training events. However, equally important are the insights that analysis of notional casualties sustained during simulated operations

can provide. Indeed, all contemporary military medical data principally arises from the Department of Defense and Prehospital Trauma Registries with data collection starting during the recent wars in Iraq and Afghanistan.[7-9] Such data may have limited applicability to the unique medical challenges associated with large-scale combat operations. In the absence of a major conflict, JRTC and NTC offer the best lens into the population injury patterns likely to be experienced in these sorts of operations.

During 20 November–3 December 2019, the 2nd Infantry Brigade Combat Team (IBCT) assigned to 4th Infantry Division, Fort Carson, CO, participated in JRTC rotation 20-02. This rotation entailed a decisive action training environment designed to provide lessons related to large-scale combat operations. Our objective was to provide a descriptive analysis of the casualties sustained during this training exercise. Our intent was to derive insights for medical care delivery for US Army Forces Command units during force on force operations with a near-peer adversary.

Methods

Study Setting and Design: During JRTC rotation 20-02, 2/4 IBCT participated in force on force operations as part of a joint and multinational task force (TF). The study setting comprised the entirety of the JRTC training area of operations during these operations spanning 14 days. This was a strictly descriptive analysis of internal unit performance of notional casualties for the purposes of refining unit procedures. Hence, we completed this analysis as a performance improvement project not requiring oversight by an institutional review board.

Population: Task organization comprised organic units including two infantry battalions (TF Infantry 1 and 2), one cavalry squadron (TF Cavalry), a field artillery battalion (TF FA), a brigade engineer battalion (TF BEB), and a brigade support battalion (TF BSB). Additional units under operational control of 2/4 IBCT included a Stryker battalion (TF Stryker), and a British infantry regiment (attached to TF Infantry 1). Other support elements included a general support aviation battalion (GSAB), and a combat service support battalion (CSSB).

Medical Capabilities: Medical assets available included Role I facilities associated with each of the six subordinate maneuver battalion elements. A physician (specialty immaterial) and physician assistant staffed these facilities to provide basic initial tactical combat casualty care with negligible patient hold capacity. The BSB provided Role II capability. This facility offered additional staffing, beds (including 20 beds for patient hold up to 72 hours), and ancillary services including radiology, laboratory services, and behavioral health. A notional Role III facility existed for exercise purposes in the vicinity of the reception, staging, onward movement, and integration (RSOI) area.

Field litter ambulances (FLAs) provided the mainstay for medical evacuation (MEDEVAC) platform for most units. The infantry battalions had eight FLAs each, the cavalry squadron and field artillery battalion had three FLAs each, and the BEB had two FLAs. The Stryker battalion provided four Stryker medical evacuation vehicles (MEVs). Finally, the brigade support medical company (BSMC) assigned to the BSB had ten FLAs. The GSAB offered three additional HH-60 airborne MEDEVAC platforms.

Medical Evacuation: The scheme of maneuver for evacuation of casualties broadly followed US Army doctrine (Figure 1).[10] From point of injury (POI) following receipt of initial stabilizing medical care, casualties underwent ground transportation to company and battalion casualty collection points (CCPs). From there, casualties moved to battalion aid stations (BAS) for initial Role I care. Casualties requiring further treatment then moved to the Role II in vicinity of the brigade support area, with or without transit through an ambulance exchange point (AXP). Finally, casualties would then proceed to the Role III facility, if needed.

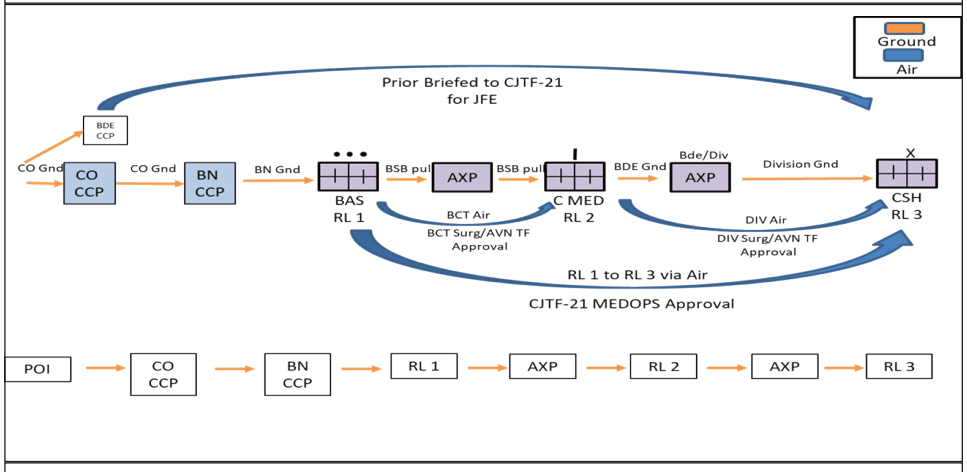
Ground transportation was the primary means of moving casualties. Units used a combination of CASEVAC for casualties with less severe notional injuries (use of non-standardized and non-dedicated vehicles that may not include the requisite equipment and personnel for en route care) versus MEDEVAC for casualties with more severe injuries (utilization of a standardized and dedicated platform with the provision of en route care).[11] Mission approval authority rested with the brigade surgeon section. Launch approval authority was the BSB commander for ground missions and the GSAB commander for air missions.[12]

Measurements: All participants in the exercise used multiple integrated laser engagement system (MILES) gear to determine whether soldiers sustained injuries. Cards issued to each participant prior to exercise start provided details regarding injury patterns for each casualty. When a participant's MILES gear indicated occurrence of an injury, observers, coaches, and trainers (OCTs) used these cards to define the specific injury sustained by the soldier. OCTs did have the ability to adjust the injuries as indicated on the cards based on the nature of the conflict (e.g., change injury from gunshot wound to explosive injury when a participant's MILES

gear triggers following an encounter with an improvised explosive device. Ultimately, OCTs categorized all casualties as killed in action (KIA) or wounded in action (WIA). OCTs categorized WIA casualties as died of wounds (DOW) based upon time elapsed from time to injury to movement to successive roles of care within time standards, dependent upon the severity of injuries (Table 1).

All casualties ultimately returned to the force for continued participation in the exercise. WIA casualties returned to duty at the discretion of the OCTs following notional treatment of injuries and a recovery period per the soldiers' injuries. KIA and DOW casualties underwent transportation to a mortuary affairs collection point and personnel and equipment holding area. At these locations, these individuals underwent regeneration to return to the force.

Figure 1. Casualty evacuation flow during Joint Readiness Training Center rotation 20-02.



Ground evacuation flow represented by orange arrows. Air evacuation flow represented by blue arrows. Abbreviations: AVN – aviation; AXP – ambulance exchange point; BAS – battalion aid station; BCT – brigade combat team; BDE – brigade; BN – battalion; BSB – brigade support battalion; CCP – casualty collection point; CJTF – combined joint task force; CO – company; CSH – combat support hospital; DIV – division; POI – point of injury; RL – role; TF – task force.

Data Analysis: We used descriptive statistics to portray the casualties sustained during this exercise. We reported numbers of WIA and KIA casualties for each subordinate battalion. Among WIA casualties, we reported DOW numbers and percentages. Finally, we reported the proximate cause for each DOW casualty: improper care versus evacuation delay. For evacuation delays, we stratified according to the evacuation step during which there was a delay.

Results

Force on force operations spanned 14 days. The task organization comprised 3,871 persons. Casualties included 642 KIA and 1,061 WIA (Table 2). Of the WIA, 502 (47.3%) died from wounds. The primary reason for DOW was evacuation delay from POI to medical treatment facility (443 casualties, 88.2%). An additional 40 casualties DOW at the Role 1 (8.0%) and 10 died at Role II (2.0%). Nine casualties (1.8%) died from wounds due to improper care rendered.

TF Infantry 1 served as the main effort during most phases of the operation and sustained the highest absolute numbers of casualties. They also sustained the highest DOW percentage (57.2%), driven primarily by delays in POI to Role I evacuation (Table 3). TF FA experienced the next highest DOW percentage (47.1%), also driven by evacuation delays. Those numbers largely stemmed from a single day of operations during which the unit's Role I augmented the medical capabilities of the brigade support area and casualties sustained from indirect fire did not receive expedient Role I care.

Discussion

This descriptive analysis portrays the notional casualties sustained during JRTC rotation 20-02 by an IBCT. The overall DOW percentage for the task force in its entirety was 44.8%. This DOW percentage overwhelmingly arose from evacuation delays. In particular, evacuation delays from POI to Role I were responsible for the vast majority of patients who DOW.

This rotation highlighted many important facets of large-scale combat operations. First, the numbers of casualties are extraordinarily high in comparison to counter-insurgency operations. Indeed, most days entailed a mass casualty event for one or more of the medical assets arrayed on the battlefield. Hence, it is imperative

Table 1. Joint Readiness Training Center casualty evacuation timelines.

Category	Injury to Medic/CLS	POI to Role 1	Role 1 to Role 2	Role 2 to Role 3
Routine	-	24 (NLT T+24)	24 (NLT T+48)	24 (NLT T+72)
Priority	2 (NLT T+2)	3 (NLT T+5)	3 (NLT T+8)	6 (NLT T+14)
Urgent	1 (NLT T+1)	2 (NLT T+3)	2 (NLT T+5)	4 (NLT T+9)

Abbreviations: CLS-combat lifesaver trained Soldier; NLT-no later than; POI-point of injury; T-time of injury.

that medical planners and providers alike anticipate, plan for, and rehearse their mass casualty plans, to include prehospital interventions and triage protocols, with regularity both before and during force on force operations.[13]

Second, the threat posed by enemy fires, in particular indirect fires, means that mobility is paramount. This complicated MEDEVAC insofar as the recurrent need to move the Role I and Role II facilities led to significant periods when medical coverage was incomplete. Many units attempted to minimize these periods of time through splitting their assets into forward and main aid stations. However, in this experience, the benefit of such maneuvers was limited by the fact that these split elements had such limited treatment capacity that they readily became overrun with casualties. Generally speaking, the best mitigation measures are to include training Role I and Role II movement and relocation, careful planning at brigade level to manage such movements to minimize the impact on the entire formation, and training and emphasis on prehospital treatment measures to optimize casualty outcomes prior to arrival to a military treatment facility.[8,14,15] The importance of prehospital healthcare delivery highlights the need for all soldiers, not just medics, to be facile with basic tactical combat casualty care principles such as hemorrhage control, including tourniquet placement and patient movement.[16-18]

Third, careful planning and rehearsals for casualty evacuation is critical. Emphasis upon rapid evacuation of casualties has long been the focus for the military healthcare system. In 2009, recognizing the importance of timely evacuation for casualty outcomes, former Secretary of Defense Robert Gates mandated availability of helicopter evacuation for casualties within 60 minutes.[19,20] However, large-scale combat operations pose significantly greater challenges for expedient evacuation for multiple reasons. First, the scope of the problem is much greater as these operations result in significantly greater numbers of casualties than experienced during counterinsurgency operations as occurred in Iraq and Afghanistan. Second, force on force operations with near peer adversaries generally imply greater challenges with evacuation due to contested airspace and compromised ground lines of communication.

Table 2. Casualty summary.

Task Force	KIA	WIA	DOW	DOW %
TF Infantry 1	409	717	410	57.2%
TF Infantry 2	42	34	0	0.0%
TF Stryker	40	165	25	15.2%
TF Cavalry	30	44	8	18.2%
TF FA	63	70	33	47.1%
TF BEB	81	34	11	32.4%
TF BSB	6	36	6	16.7%
Total	671	1100	493	44.8%

Abbreviations: BEB-brigade engineer battalion; BSB-brigade support battalion; DOW-died of wounds; FA-field artillery; KIA-killed in action; TF-task force; WIA-wounded in action.

Given this, it is unsurprising that while specific casualty numbers vary across rotations, our DOW experience is generally representative of that of other combat training center (CTC) rotations. A preponderance of DOW consistently occurs due to evacuation delays.[21] As the Army continues to shift focus from counterinsurgency operations to large-scale combat operations, this observation has prompted discussion within the military medical community about how best to address these challenges to optimize casualty outcomes. Solutions generally fall into actions for medical personnel and actions for leaders.

Regarding medical personnel, lessons learned from CTCs highlight the importance of close integration with all other staff members. Command surgeon sections must tie in with the sustainment warfighting function as a whole during every step of the planning and military decision-making process. This includes ensuring appropriate time and representation during sustainment rehearsals to fully examine the casualty treatment and evacuation plans for any gaps that will preclude effective execution. It also requires appropriate manning and resources to fully integrate with current operations to monitor and rapidly react to the casualty situation on the battlefield.

Because most evacuation delays occur at the POI, focused training and education for lower echelon leaders will have the greatest impact in reducing the numbers of casualties of DOW. Casualty response training for leaders is a program first developed in the Ranger regiment.[20] The program seeks to train leaders on the forward line of troops (e.g., platoon sergeants, first sergeants) how to manage casualty flow to minimize evacuation delays. This includes education regarding

Table 3. Died of wounds summary.

		Evacuation Delay		
Task Force	Improper Care	POI to Role 1	Role 1 to Role 2	Role 2 to Role 3
TF Infantry 1	0	408	2	0
TF Infantry 2	0	0	0	0
TF Stryker	1	12	13	0
TF Cavalry	3	1	3	4
TF FA	0	11	22	0
TF BEB	0	11	0	0
TF BSB	5	0	0	6
Total	9	443	40	10

Abbreviations: BEB-brigade engineer battalion; BSB-brigade support battalion; DOW-died of wounds; FA-field artillery; KIA-killed in action; TF-task force; WIA-wounded in action.

casualty collection point establishment and organization, loading casualties on both MEDEVAC and CASEVAC platforms, and management of evacuation platforms.

It merits acknowledging that the finding of negligible numbers of DOW casualties due to improper care delivered may simply reflect a dearth of subject matter experts to adjudicate said care. OCTs at CTCs are generally Medical Service Corps officers who specialize in operations and planning. These personnel are experts in assessing evacuation plans but not necessarily clinical care delivery. Manpower shortages among providers will always pose a challenge for making clinical OCTs available, but this would likely add significant training value to those medics and providers going through CTC training.

This study has important limitations. As a purely descriptive study, we can only demonstrate correlations and trends and not causality. Furthermore, we cannot offer any definitive evidence about the efficacy of strategies discussed to alleviate DOW burden on units engaged in large-scale combat operations. Also, as a study of notional casualties sustained during simulated operations, the extent to which these results reflect true casualty numbers and injury patterns likely occurring during large-scale combat operations is unclear.

Indeed, many of these casualty injuries and outcomes reflect subjective adjudication by OCTs. The time horizons defined by JRTC to guide evacuation time standards are largely arbitrary. The reality is within each evacuation category (routine, urgent, priority), there exists a broad range of potential injuries that may require distinct management timelines. These facts limit the real world applicability and generalizability of our findings. Nevertheless, in the absence of real world near-peer conflict, CTC training exercises are likely to provide the best possible representation available for the military medical community to project health service support requirements. Future CTC rotations and studies of these rotations might benefit from providing further fidelity into specific injury patterns experienced by notional casualties together with the evacuation timelines and simulated outcomes for those casualties.

Our JRTC experience offers a lens through which future command surgeon teams can approach planning medical concepts of support at CTC rotations. It highlights that the overwhelming source of loss of life for WIA soldiers is evacuation delays. It further demonstrates that these delays predominantly occur on the front end of the evacuation chain, at the POI. These findings suggest units should invest training time and resources into training leaders at echelon how to manage evacuation particularly from POI to Role I to stem the tide of morbidity on the battlefield.

References

1. Jerant AF, Epperly TD, Marionneaux RD. Medical support for operation cooperative nugget '95: Joint readiness training in the post-cold war era. *Mil Med*. 1997;162(11):720-725.
2. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of casualties evacuated from the Africa area of operations. *Afr J Emerg Med*. 2019;9(Suppl):S43-S46.
3. Darakjy S, Marin RE, Knapik JJ, Jones BH. Injuries and illnesses among armor brigade Soldiers during operational training. *Mil Med*. 2006;171(11):1051-1056.
4. Foulkes GD. Orthopedic casualties in an activated national guard mechanized infantry brigade during operation desert shield. *Mil Med*. 1995;160(3):128-131.
5. Giacoppe GN, Degler DA. Rapidly evolving adult respiratory distress syndrome with eosinophilia of unknown cause in previously healthy active duty Soldiers at an army training center: Report of two cases. *Mil Med*. 1999;164(12):911-916.
6. Zaloznik AJ, Stinson KR, Rennie DS. Impact of units on rotation at the National Training Center: The Fort Irwin MEDDAC experience. *Mil Med*. 1993;158(10):649-651.
7. April MD, Becker TE, Fisher AD, Naylor JF, Schauer SG. Vital sign thresholds predictive of death in the combat setting. *Am J Emerg Med*. 2020.
8. Schauer SG, April MD, Naylor JF, et al. Prehospital application of hemostatic agents in Iraq and Afghanistan. *Prehosp Emerg Care*. 2018;22(5):614-623.
9. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of data from the Department of Defense Joint Trauma System Prehospital Trauma Registry. *US Army Med Dep J*. 2017;(3-17)(3-17):92-97.
10. Department of the Army. Army Techniques Publication No. 4-02.3: Army Health System Support to Maneuver Forces. Washington, D.C.: Department of the Army; 2014.
11. Schauer SG, Naylor JF, Bellamy MA, Maddry JK, April MD. A descriptive analysis of causalities undergoing CASEVAC from the point-of-injury in the Department of Defense Trauma Registry. *Mil Med*. 2019;184(7-8):e225-e229.
12. Department of the Army. Army Techniques

Publication No. 4-02.2: Medical Evacuation. Washington, D. C.: Department of the Army; 2019.

13. Schauer SG, April MD, Simon E, Maddry JK, Carter R, Delorenzo RA. Prehospital interventions during mass-casualty events in Afghanistan: A case analysis. *Prehosp Disaster Med*. 2017;32(4):465-468.

14. Schauer SG, April MD, Naylor JF, et al. QuikClot(R) combat gauze(R) use by ground forces in Afghanistan the Prehospital Trauma Registry experience. *J Spec Oper Med Summer*. 2017;17(2):101-106.

15. Schauer SG, Naylor JF, Maddry JK, Hinojosa-Laborde C, April MD. Trends in prehospital analgesia administration by US forces from 2007 through 2016. *Prehosp Emerg Care*. 2019;23(2):271-276.

16. Schauer SG, April MD, Fisher AD, Cunningham CW, Gurney J. Junctional tourniquet use during combat operations in Afghanistan: The Prehospital Trauma Registry Experience. *J Spec Oper Med Summer*. 2018;18(2):71-74.

17. April MD, Lopes T, Schauer SG, et al. Advise and assist: A basic medical skills course for partner forces. *J Spec Oper Med Winter*. 2017;17(4):63-67.

18. Schauer SG, April MD, Naylor JF, et al. Prehospital application of hemostatic agents in Iraq and Afghanistan. *Prehosp Emerg Care*. 2018;22(5):614-623.

19. Howard JT, Kotwal RS, Santos-Lazada AR, Martin MJ, Stockinger ZT. Reexamination of a battlefield trauma golden hour policy. *J Trauma Acute Care Surg*. 2018;84(1):11-18.

20. Kotwal RS, Howard JT, Orman JA, et al. The effect of a golden hour policy on the morbidity and mortality of combat casualties. *JAMA Surg*. 2016;151(1):15-24.

21. S. J. Rairdon. Saving 30% More: Lowering Died of Wounds Rates in a Decisive Action Training Environment. Fort Leavenworth, KS: Center for Army Lessons Learned; 2018.

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Telemedicine at the Joint Readiness Training Center: Expanding Forward Medical Capability

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Abstract

Introduction: The US Army's transition from counterinsurgency operations to preparation for large-scale combat operations is likely to bring unique access to care challenges on the battlefield. Ruggedized computer systems exist that allow forward medical personnel to establish telehealth connections with rear-based specialists. We describe our use of one such device during simulated force on force operations at the Joint Readiness Training Center (JRTC).

Methods: Our infantry brigade combat team brought a telehealth device to JRTC 20-02. The device comprised a mobile laptop and peripheral medical devices. We used the Warfighter Information Network-Tactical Increment 2 Tactical Communications Node (TCN) to establish communication between the device and external entities. We sought to establish connectivity in the Fort Polk, LA, cantonment area as part of reception, staging, onward movement, and integration operations.

Results: We successfully executed video calls from the field utilizing the telehealth device at the JRTC rear aid station and the local military treatment facility on Fort Polk, LA. We also executed calls to our home station military treatment facility on Fort Carson, CO. Each of these calls lasted approximately five minutes with sustained high-quality video and audio feeds.

Conclusions: Our experience provides proof of concept that telehealth may enable rear-based medical personnel to expand the medical capabilities of medics based forward in the battlespace. Telehealth devices may prove feasible for use with strictly tactical communications architecture in the kinetic setting of large scale combat operations.

Introduction

The US Army's transition in recent years from counterinsurgency operations to preparation for large-scale combat operations requires careful assessment of associated limitations in current operational healthcare delivery capabilities. In a near-peer conflict, the Army is unlikely to enjoy the uncontested air space experienced in Iraq and Afghanistan. The implications for battlefield medicine are lengthening evacuation times. This possibility has led to increasing discussions in the literature regarding strategies to optimize casualty outcomes during prolonged field care.[1-3] Operations in an expanding global footprint, such as the continent of Africa, offer similar challenges.[4] Prolonged field care benefits from the ability to establish robust audio and visual communications between forward providers from higher echelons of care. Telehealth offers one potential solution to this battlefield medicine capability gap.

Telehealth is the provision of healthcare remotely through the use of technological solutions to provide audio and video feeds. The evidence base and use of this technology has increased markedly in the past decade.[5] Telehealth offers great opportunity to reduce costs and improve access to care through overcoming the barrier that geographic distance between patients and providers poses to healthcare delivery. Studied applications for telehealth include diabetes care,[6] cancer treatment,[7] palliative care,[8] and other specialty care delivery.[9-11] More

recently, the literature has explored the potential for telehealth to improve care delivery during the Coronavirus Infectious Disease 2019 pandemic.[12]

Telehealth devices offer a potential, equipment-based solution to facilitate health care delivery during large-scale combat operations.[13] By employing telecommunications technology, the tool is the tip of the spear for the Defense Health Agency and Medical Command's virtual health line of effort. These devices comprise mobile and ruggedized computer systems that facilitate video and audio feeds between forward locations and geographically separated, typically rear-based medical providers. They include subcomponents such as stethoscopes and electrocardiogram leads that transmit data across long distances. They allow tertiary care center specialists to provide point-of-care recommendations to the forward medics at the bedsides of sick and injured soldiers. These consultations have the potential to optimize casualty care, while potentially reducing requirements to physically transport personnel to higher levels of care, accelerating the rate soldiers return to duty.

Several units have used telehealth devices as part of National Training Center (NTC) rotations at Fort Irwin, CA. Specifically, the 3rd Armored Brigade Combat Team (ABCT), 4th Infantry Division, used them at NTC in October 2018. The 2nd ABCT, 1st Armored Division used them at NTC in March 2019. Using this equipment during these rotations helped solidify the potential utility of the devices during near-peer force-on-force conflicts. However, these rotations utilized wireless internet devices connected to commercial cellular networks to establish connectivity between these telehealth devices and rear locations. Such solutions may not always be available or may experience jamming. Commanders would benefit from the availability of alternative communications mechanisms for leveraging telehealth technology, namely through use of their tactical communications systems.

In November 2019, the 2nd Infantry Brigade Combat Team (IBCT), 4th Infantry Division executed its rotation at the Joint Readiness Training Center (JRTC) at Fort Polk, LA.[14] As part of this rotation, 2IBCT sought to employ telehealth devices strictly using its organic tactical satellite communications systems. We present the methods and outcomes of these efforts as a proof of concept study.

Methods

The setting for the efforts described in this manuscript include preparations at our home station at Fort Carson, CO. The execution of the telehealth connections took place in the Fort Polk cantonment area prior to starting force-on-force operations as part of the unit's JRTC rotation. This represented a proof of concept initiative as part of internal unit performance improvement without any patient involvement and did not involve an Institutional Review Board.

The brigade brought two distinct telehealth devices to its JRTC rotation. First was a Transportable Exam Station (TES). This military-grade tablet platform and impact-resistant casing can store myriad medical equipment, including a stethoscope, exam cameras, ultrasound devices, blood pressure cuffs, and electrocardiogram leads.[15] Second was a lighter and more mobile Telehealth in a Bag (THIAB). This comprised a mobile laptop and peripheral medical devices.[16] Ultimately, the unit only made use of the THIAB in establishing connectivity with higher echelons of care.

We utilized the Warfighter Information Network-Tactical (WIN-T) Increment 2 Tactical Communications Node (TCN) to establish communication between the THIAB and external entities. We first ensured the non-secure internal protocol router network (NIPRNet) enclave had a functioning Dynamic Host Configuration Protocol (DHCP) server setup in the router. Next, we consoled into the NIPRNet Tier 2 router and accessed the NIPRNet Tier 2 switch module either using a network virtual terminal protocol or secure shell commands. We used any spare port not in use and ensured its establishment as an access port for virtual local area networks 58 and 59 modeled after a typical user access port.

Next, we accessed the network and internet settings on the THIAB tablet, and then selected the option to Change Adapter. Generally, there are multiple adapters, including ethernet and wireless. The telehealth device pulled its own internet protocol (IP) address. In its normal configuration, the device defaults to utilization of the wireless adaptor and a mobile wireless network device. To prevent this, we disabled the wireless adapter and powered off the wireless network device. We then plugged an ethernet cable from the configured NIPRNet port on the TCN into the rear of the telehealth device. Taking note of which adapter was subsequently connected, we accessed properties for that adapter and selected Transmission Control Protocol/IP version 4. In the event of pre-existing configuration of a DHCP server, users select the option to pull an IP address automatically. If no pre-existing DHCP configuration existed, users gave the device a static IP based on the unit tactical template, ensuring use of a firewall as the default gateway.

Via these platforms, we planned several connections with the THIAB to higher echelons of care. First was to 2IBCT elements stationed at the JRTC Aid Station Rear (JASR) situated in North Fort Polk, LA. Second was to the military treatment facility servicing Fort Polk, LA, Baynes Jones Army Community Hospital (BJACH). Finally, we planned connection with our home station military treatment facility, Evans Army Community Hospital (EACH), Fort Carson, CO. We planned to establish these connections using a very small aperture terminal (VSAT) and the Combat Service Support Automated Information Systems Interface (CAISI) platforms. We planned a descriptive analysis based on our observations and recordings of these connections.

Results

Our unit successfully established connectivity between the telehealth THIAB device and computer systems based out of the JASR, BJACH, and EACH (Figure 1). Initial tests occurred during reception, staging, and onward movement and integration operations. These efforts successfully established wireless connectivity between the THIAB and the VSAT and CAISI platforms. These connections required no IP configuration or port protocols and made possible successful execution of multiple calls.

Specifically, we successfully executed ten video calls from the field at the JRTC to the JASR located at North Fort Polk. We further executed an additional ten video calls with BJACH on Fort Polk. Finally, we executed two calls back to our home station military treatment facility, EACH, Fort Carson, CO. Each of these calls lasted approximately five minutes with sustained high-quality video and audio feeds.

Discussion

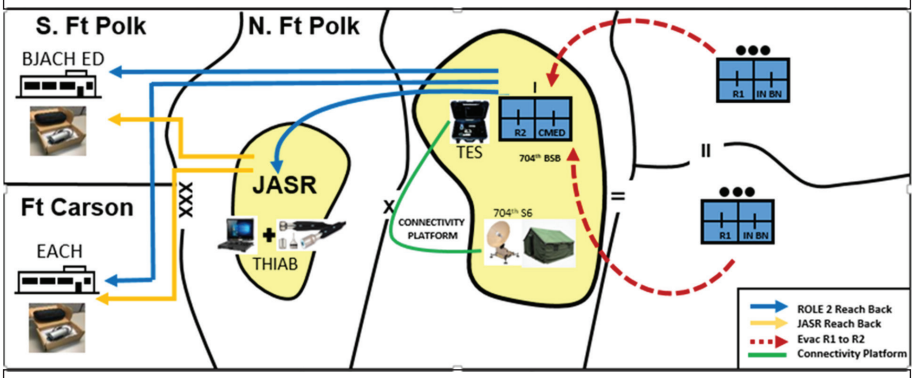
The contested environment of peer-to-peer conflict limits the ability to array forces on the battlefield. These mobility restrictions will limit the access of specialized low-density health care providers to casualties at the forward line of troops, threatening timely combat casualty care. Telehealth devices offer one potential solution to address this capability gap. Our experience provides proof of concept that telehealth devices may enable rear based medical personnel to guide casualty treatment by forward medics.

Our use of telehealth devices at the JRTC represents an important milestone in the development of battlefield telehealth technology. Previous units used this device at the NTC by leveraging commercial wirelesses devices to establish connectivity. Our rotation represents the first instance in which a BCT used this technology using their organic tactical communications modalities. Our experience highlights the potential feasibility of using this device in the kinetic setting of large-scale combat operations. It is likely to be a highly cost-effective solution[17] for bringing tertiary care expertise forward on the battlefield.

We learned several important lessons during testing. First, our signal personnel emphasized the importance of not overthinking the telehealth systems and devices. Medical personnel may lack experience using the tactical communications systems that are organic to the BCT. Similarly, signal personnel may hesitate at the prospect of managing communications using medical equipment. Nevertheless, in our experience most telehealth devices are in fact simple end user devices analogous to any other Non-Classified Internet Protocol Router Network (NIPRNet) computer added to the network. Medical and signal personnel alike will be able to achieve success replicating our efforts through following the methodology outlined in this paper.

That said, support from telehealth experts based at military treatment facilities is critical for ensuring success. Otherwise, personnel not familiar with the technology may struggle to effectively operate it. Our unit received its telehealth devices via sub-hand receipt from telehealth personnel assigned to our home station military treatment facility. These

Figure 1. Telehealth concept of operation for 2/4 Brigade Combat Team during Joint Readiness Training Center (JRTC) Rotation 20-02.



Abbreviations: BJACH-Baynes Jones Army Community Hospital (South Fort Polk Military Treatment Facility). BSB-brigade support battalion. CMED-Charlie Medical company (brigade support medical company). EACH-Evans Army Community Hospital (Fort Carson Military Treatment Facility). ED – Emergency Department. IN BN-Infantry Battalion. JASR-JRTC Aid Station Rear (the Military Treatment Facility utilized for real world medical care during JRTC rotations). R1-Role 1. R2-Role 2. TES-Transportable Exam Station. THIAB- Telehealth in a bag.

home station telehealth experts furthermore traveled on temporary duty to Fort Polk, LA, to assist with our efforts. Initial equipment receipt occurred throughout our reception, staging, onward movement and integration operations. This allowed the BCT signal staff to become familiar with the operation and troubleshooting of the device.

The familiarization of medics and providers is equally important. Again, lack of such familiarization may preclude effective operation of the device and, equally problematic, may prevent organizational buy-in for its use. In the case of the BCT, the medical and communications personnel used the device during multiple field exercises leading up to the JRTC 20-02. This prior experience was instrumental to successfully employing it at the JRTC. Indeed, our experience was that medics and providers were initially resistant to using this new technology. Achieving familiarity and buy-in is critical for the success of any operational telehealth enterprise.

BCT staffs also must carefully consider both the resources telehealth devices require and the opportunities it offers in determining how to incorporate use of these devices into the battle rhythm. Like any video teleconferencing platform, telehealth devices will have certain bandwidth requirements. In our experience, this bandwidth ranged 450 kilobytes per second to 1.3 megabytes per second. This bandwidth requirement may frequently be prohibitive given the impact on bandwidth requirements for other warfighting functions if used during active operations. There are also requirements related to maintaining this equipment that units must consider while employing these devices. The unpredictable and chaotic nature of large-scale combat operations in particular may further mean the ideal time windows for use of this device changes daily. It is imperative to limit use of this device to these time periods and ensures minimal impact on communications needed for combat operations while offering fewer disruptions to patient care activities.

Telehealth devices are unlikely to optimize initial injury treatment decisions given the imperative of rapid treatment of injury patterns likely to result in combat.[18-21] Instead, we believe the principal value arises from preservation of combat power through minimization of the transfer of soldiers with less severe illnesses and injuries to rear-based higher echelons of care. Some reports already exist highlighting the use of telehealth to guide disposition for casualties in Iraq and Syria.[22] Specific injury patterns may also be particularly amenable to care augmentation from telehealth use. For example, traumatic brain injuries potentially represent one such instance that may not be imminently life threatening but might benefit from a remote neurology consultation to guide whether and when rearward transportation is necessary.[23] Finally, the treatment of complex and unique patient populations with which military medical personnel may have limited experience treating, such as children, may benefit from the use of this technology.[24-27]

Our investigation has multiple limitations. First, as a strictly descriptive proof of concept study, we offer little in the way of objective data regarding either the technical performance of our telehealth connections let alone impact on patient care. Future efforts to use telehealth devices at CTC rotations would benefit from pre-defining outcomes for study such as exact times and durations of audio and visual connections, subjective reports of connection quality, and bandwidth usage during these connections. Future exercises also would benefit from formal surveys of signal staffs and medical teams to ascertain additional thoughts about best practices related to incorporation into tactical networks, ideal timing per unit battle rhythm, the optimal number of devices each echelon can effectively use, and the best use and contributions to patient care activities.

Our hope is that future units may build upon the experience outlined in this paper to further refine the methodologies for use of this device in both training and combat operations. They might also consider alternative telehealth devices, such as those designed for use with cellular phones.[28,29] Ultimately, we believe this technology shows promise for advancing the capabilities of military and emergency medicine in the setting of large scale combat operations.

References

1. Batchinsky AI, Wendorff D, Jones J, et al. Noninvasive SpO2/FiO2 ratio as surrogate for PaO2/FiO2 ratio during simulated prolonged field care and ground and high-altitude evacuation. *J Trauma Acute Care Surg*. 2020;89(2S Suppl 2):S126-S131.
2. Chipman AM, Wu F, Pati S, Burdette AJ, Glaser JJ, Kozar RA. Fresh frozen plasma attenuates lung injury in a novel model of prolonged hypotensive resuscitation. *J Trauma Acute Care Surg*. 2020;89(2S Suppl 2):S118-S125.
3. Smith M, Johnston K, Withnall R. Systematic approach to delivering prolonged field care in a prehospital care environment. *BMJ Mil Health*. 2020.
4. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of casualties evacuated from the africa area of operations. *Afr J Emerg Med*. 2019;9(Suppl):S43-S46.
5. Shigekawa E, Fix M, Corbett G, Roby DH, Coffman J. The current state of telehealth evidence: A rapid

review. *Health Aff (Millwood)*. 2018;37(12):1975-1982.

6. Appuswamy AV, Desimone ME. Managing diabetes in hard to reach populations: A review of telehealth interventions. *Curr Diab Rep*. 2020;20(7):28-020-01310-2.
7. Steingass SK, Maloney-Newton S. Telehealth triage and oncology nursing practice. *Semin Oncol Nurs*. 2020;36(3):151019.
8. Steindal SA, Nes AAG, Godskesen TE, et al. Patients' experiences of telehealth in palliative home care: Scoping review. *J Med Internet Res*. 2020;22(5):e16218.
9. McGinn MM, Roussev MS, Shearer EM, McCann RA, Rojas SM, Felker BL. Recommendations for using clinical video telehealth with patients at high risk for suicide. *Psychiatr Clin North Am*. 2019;42(4):587-595.
10. Haulman A, Geronimo A, Chahwala A, Simmons Z. The use of telehealth to enhance care in ALS and other neuromuscular disorders. *Muscle Nerve*. 2020;61(6):682-691.
11. Gaveikaite V, Grundstrom C, Winter S, Chouvarda I, Maglaveras N, Priori R. A systematic map and in-depth review of european telehealth interventions efficacy for chronic obstructive pulmonary disease. *Respir Med*. 2019;158:78-88.
12. Jordan V. Cochrane corner: Coronavirus (COVID-19): Remote care through telehealth. *J Prim Health Care*. 2020;12(2):184-185.
13. Sanchez E. Military hospital dials in virtual healthcare to combat COVID-19. Available at: https://www.refworks.com/refworks2/default.aspx?r=references|MainLayout::init. Accessed 30 August, 2020.
14. April MD, Brady DP. Mobile medic boosts combat casualty treatment. *Signal*. 2020;74(10):32.
15. GlobalMed. Transportable exam station. Available at: https://www.globalmed.com/transportable-exam-stations/. Accessed 30 August, 2020.
16. Patoka A. THIAB system expands virtual health capability. Available at: https://www.army.mil/article/202496/thiab_system_expands_virtual_health_capability. Accessed 30 August, 2020.
17. April MD, Murray BP. Cost-effectiveness analysis appraisal and application: An emergency medicine perspective. *Acad Emerg Med*. 2017;24(6):754-768.
18. Montgomery HR, Drew B. Tactical combat casualty care (TCCC) update. *J Spec Oper Med Summer*. 2020;20(2):152-153.
19. Schauer SG, April MD, Naylor JF, et al. QuikClot(R) combat gauze(R) use by ground forces in afghanistan the prehospital trauma registry experience. *J Spec Oper Med Summer*. 2017;17(2):101-106.
20. Schauer SG, April MD, Naylor JF, et al. Prehospital application of hemostatic agents in iraq and afghanistan. *Prehosp Emerg Care*. 2018;22(5):614-623.
21. Schauer SG, Naylor JF, Maddry JK, Hinojosa-Laborde C, April MD. Trends in prehospital analgesia administration by US forces from 2007 through 2016. *Prehosp Emerg Care*. 2019;23(2):271-276.
22. Nguyen C, Mbuthia J, Dobson CP. Reduction in medical evacuations from iraq and syria following introduction of an asynchronous telehealth system. *Mil Med*. 2020.
23. Yue JK, Upadhyayula PS, Avalos LN, Phelps RRL, Suen CG, Cage TA. Concussion and mild-traumatic brain injury in rural settings: Epidemiology and specific health care considerations. *J Neurosci Rural Pract*. 2020;11(1):23-33.
24. Schauer SG, Arana AA, Naylor JF, Hill GJ, April MD. Prehospital analgesia for pediatric trauma patients in iraq and afghanistan. *Prehosp Emerg Care*. 2018;22(5):608-613.
25. Naylor JF, April MD, Roper JL, Hill GJ, Clark P, Schauer SG. Emergency department imaging of pediatric trauma patients during combat operations in iraq and afghanistan. *Pediatr Radiol*. 2018;48(5):620-625.
26. Schauer SG, April MD, Hill GJ, Naylor JF, Borgman MA, De Lorenzo RA. Prehospital interventions performed on pediatric trauma patients in iraq and afghanistan. *Prehosp Emerg Care*. 2018;22(5):624-629.
27. Schauer SG, Hill GJ, Naylor JF, April MD, Borgman M, Bebarta VS. Emergency department resuscitation of pediatric trauma patients in iraq and afghanistan. *Am J Emerg Med*. 2018;36(9):1540-1544.
28. Gensheimer WG, Miller KE, Stowe J, Little J, Legault GL. Military teleophthalmology in afghanistan using mobile phone application. *JAMA Ophthalmol*. 2020.
29. Wong KH, Bayarsaikhan S, Levine BA, Mun SK. Prototype of a military medic smartphone medical graphical user interface for use by medics in deployed environments. *Mil Med*. 2020;185(Suppl 1):536-543.

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Innovative Solution for Airway Securement in Combat and Trauma Scenarios

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Introduction

Airway management is one of the most challenging problems in prehospital combat casualty care. Airway assessment and intervention are second only to hemorrhage control in priority in the initial treatment of trauma patients, and airway compromise continues to account for approximately 1 in 10 preventable battlefield deaths.[1] Combat medics often provide care in no- or low-light conditions, surrounded by the chaos of combat, and with the limited dexterity that accompanies bulky body armor, gloves, and heavy equipment.[2,3] Far-forward medical care is also limited by available resources, which are often only what a combat medic can fit in the aid bag.[4,5] Therefore, a procedure such as airway management that currently requires a high degree of skill becomes substantially more complex. Improved airway devices are listed 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.[6-11]

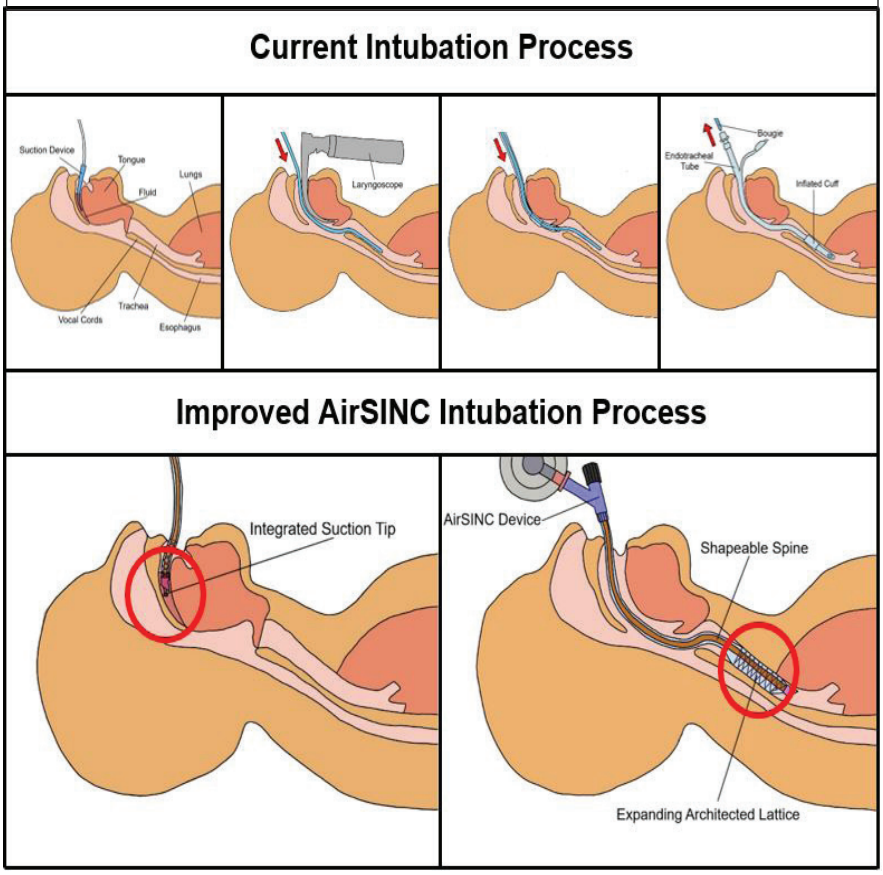
Current Airway Management Methods: Endotracheal intubation (ETI) is the preferred non-surgical prehospital airway management technique (Figure 1). In prehospital airway data from the far-forward Registry of Emergency Airways Arriving at Combat Hospitals (REACH), ETI comprised 86% of airways, while supraglottic airways and cricothyrotomy represented 8% and 6% of cases, respectively.[3] However, failure and complication rates are high for both ETI and cricothyrotomy in the prehospital environment. Success rates for ETI can decrease by 50% when providers do not maintain continuous practice and training,[12] a need often in excess of the exposure received in clinical settings. Combat medics already pose a 10-35% failure rate for ETI,[3,13] with complication rates remaining high as well. Considering the alternative surgical approach of cricothyrotomies in the combat environment, data does not support favorable outcomes for combat medic performance on the battlefield with failure rates ranging from 25% to 33%.[5,14,15]

The Critical Need for Improvement: Recent analyses demonstrate that airway management life-saving interventions are overlooked more than 50% of the time on the battlefield.[16] Subsequently, the Committee on Tactical Combat Casualty Care (CoTCCC) has explicitly listed airway management as a leading priority in the "Guidelines for Medical Personnel."[17] In the most recent conflict, 5-10% of the total combat casualty population required emergency airway management,[18] yet 46% of casualties still arrived at a combat support hospital (CSH) without a definitive airway despite needing one,[3] and 10% of combat deaths had airway compromise as the primary cause of death.[19]

From the civilian perspective, prehospital airway management is presently a challenging and perishable skill, one that is consistently shown to have unacceptable failure rates (frequently in the 20-40% range) in a variety of studies over the last decades.[20-23] The difficulty, complications and delay of other care and transport has led some authors to recommend simply embracing a "scoop and run" philosophy, forgoing airway management in certain pathologies such as out of hospital cardiac arrest.[23,24] However, this is not an option for more austere environments such as rural health systems.

Furthermore, airway identification is heavily dependent upon operator skill and his/her ability to visually identify the airway; however, visualization is often severely limited by trauma and the battlefield environment where there may be danger, low light, and confined spaces. Furthermore, the patient's condition (i.e., maxillofacial trauma, swollen facial features) or innate anatomical variation (i.e., short neck, prominent front teeth) may render standard anatomical landmarks unrecognizable. Even in the civilian clinical setting, the training required to attain proficiency in ETI poses a steep learning curve: the number of intubations performed prior to attaining a 90% probability of success in a study of physician anesthesiology trainees was as high as 47.[25] In the prehospital space, paramedic

Figure 1. Comparison of intubation process using current standard endotracheal tube with separate suction device vs simplified process with AirSINC.



intubation success has been directly correlated to the total number of patients that a paramedic has attempted to intubate, and is not correlated with time in service.[26] In the UK's landmark NAP4 airway management study, a lack of education or training was identified as a factor in airway complications occurring in the emergency department (ED) and intensive care unit (ICU) in 40% and 58% of cases, respectively.[27]

New Challenges to Consider: The Covid-19 crisis has exposed several shortcomings in the current standard of care for severely ill patients, particularly those requiring prolonged ventilation and tracheal intubation.[28]

1. Prolonged intubation can lead to tracheal stenosis at the cuff site, ulceration, dislocation, or scarring and stricture of the arytenoid cartilages. Such injuries are particularly prone to occur if an oversized endotracheal tube or over-pressurized cuff is used or is left in position for longer than a week.[29]

2. Traditional polyvinylchloride tracheal tubes with low pressure cuffs are prone to device failure by means of cuff failure, poor seating, and tube cracking, all of which may cause leaks with attendant loss of ventilation efficacy and, importantly, the risk of virally-contaminated air escaping into the local atmosphere.[30] Traditional tubes are also prone to dislodgement, with as many as 3% of prehospital intubations suffering this adverse event,[31] and 11%-13% becoming dislodged in the hospital setting.[32]

3. The process of intubation requires close patient contact, exposing healthcare providers (HCPs) to aerosolized secretions elevating the risk of virus transmission.[33-35] Exacerbating this situation are shortages of personal protective equipment, as well as overwhelmed emergency medical service (EMS) systems, EDs and ICUs that cannot provide for optimal environmental controls such as negative pressure rooms.[34,35] Since HCP risk is likely dose- and duration-dependent, a device that maximizes intubation success and minimizes procedure time will significantly mitigate virus transmission.[36]

4. Intubation is a complex manual skill requiring considerable hand-eye coordination.[37] Successful intubation requires the nearly simultaneous manipulation of as many as four implements: endotracheal tube, bougie/stylet, laryngoscope, and suction catheter, while also controlling patient head and neck position. These four implements must be skillfully and separately guided within the tight confines of the oropharynx and changed out as the procedure progresses or evolves. The minimum result is delayed intubation as multiple hand and eye movements are required as each implement is used and subsequently exchanged, while the worst outcome is psychomotor confusion and failed intubation. Integrating the key functions of bougie or stylet, and endotracheal tube into a single, smoothly operating, multi-functional unit will likely decrease the time to ventilation and increase first pass success rates, both key outcome indicators in airway management.

New developments in ETTs have the potential of producing a paradigm-shifting impact to the standard of care in airway management. Currently, a chief obstacle to airway management is the standard polyvinylchloride ventilation tube itself: a large, inflexible, fixed-diameter tube that must navigate a sinuous airway and traverse a relatively small glottic opening that varies by patient size, age, and condition. This tube is made from a relatively inexpensive, easily mass-produced material that can have substantial material property variation under the dynamic ambient conditions of the

battlefield. Further complications arise when maxillofacial injuries are present, as locating and navigating the airway can be difficult or even impossible with current equipment. The design has seen minimal improvements and research attention over decades and is a major contributor to the deficit in casualty airway management currently observed in the field.

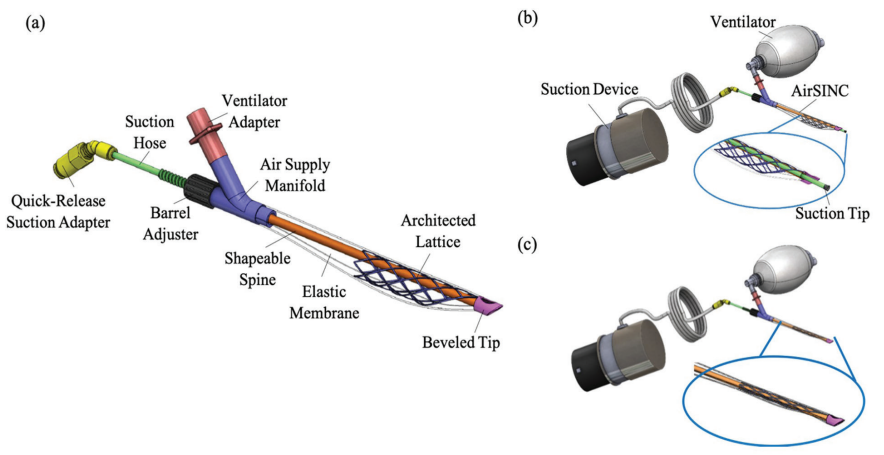
Discussion

An Innovative Solution: A concept for tackling these problems is the Airway Securement and Integrated Clearance System (AirSINC). Some of the advantages of our proposed device are as follows:

1. Radially expanding endotracheal tube that also functions as a narrow bougie for easier insertion, and contracts for removal.
2. Intubation tube with distributed securement area to avoid tube dislodgment, micro-aspiration, and tissue damage due to cuff pressure.
3. Limiting exposure of HCPs to patient pathogens through streamlining the intubation process and facilitating suction to maintain airway clearance and evacuate aerosols.
4. Robust and easy-to-use airway management device that minimally trained operators can use to clear and secure the airway.
5. Eliminating the need of multiple size intubation tubes; one tube fits all, and integrated bougie and oropharyngeal/tracheal catheter functions reduces necessary equipment to carry.

A schematic of our vision for AirSINC is shown in Figure 2 part (a). Figure 2 parts (b) and (c) show the system integrated with a respirator and suction device. A description for AirSINC is as follows (Figure 2 part (a)): at the proximal end of the figure, there is a universal adapter that allows any suction device to be attached to the suction hose. Prior to cannulation and securement of the trachea, the distal tip of the device can be used as an oropharyngeal suction catheter. The tip diameter can be manipulated as needed with the architected lattice if larger solid phase materials are present. The suction hose has a threaded section at the interface, termed the Barrel Adjuster (Figure 2 part (b)). This mechanism can be rotated to extend a small suction catheter from the distal end of the device for bronchial suction once the airway is secured. The air supply manifold serves as the interface for the suction and ventilation sources. The first inlet attaches to the Barrel Adjuster, and the second has a standardized 15 mm adapter that attaches to ventilation. The outlet is attached to an elastic membrane, which creates a sealed environment from the ventilation source to the patient. Near the distal end of the AirSINC, there is an expanding architected lattice. This lattice replaces the high-volume, low-pressure standard securement cuff in current intubation tubes. The lattice enables a larger and more even distribution of the contact forces, which can reduce injuries and tissue damage commonly associated with current endotracheal tubes. The lattice also permits the device to start at a smaller diameter than most adult tubes and expand to the largest adult sizes, essentially performing as a one-size-fits-all device. This feature will enable standardized placement and expansion procedures and reduce incidence of incorrectly sized tubes and associated complications. The open and closed configurations of the lattice are shown in Figure 2 part (b) and Figure 2 part (c) respectively.

Figure 2. Airway Securement and Integrated Clearance System (AirSINC). (a) Parts description. (b) AirSINC with architected lattice in expanded configuration and extended suction hose. (c) AirSINC with Architected lattice in contracted configuration and retracted suction hose. (b)-(c) also show AirSINC integrated to a suction device and ventilator.



Collaborative Effort: San Antonio, Texas is known as "Military City, USA" and is the home of military combat medicine. The effort supporting the AirSinc concept is built upon strong, established collaborations between University of Texas Health San Antonio (UTHSA), University of Texas at San Antonio (UTSA), US Army Institute of Surgical Research (USAISR), Brooke Army Medical Center (BAMC), and USAF 59th MDW, with extended relationships to

Naval Medical Research Unit San Antonio (NAMRU-SA), Medical Training and Education Center (METC), Joint Trauma System (JTS), and US Army Medical Center of Excellence (MEDCoE). The UT System schools (UTHSA and UTSA) have and will continue to lead the effort with significant contributions from US Army Institute of Surgical Research (USAISR).

The team has collaborated extensively over the past 4 to 5 years and accomplished substantial work in airway science and related areas.[38-46] A master cooperative research and development agreement (CRADA) is in place between USAISR and UT Health San Antonio, as well as between USAISR and UTSA, which will be leveraged for the project. A similar master agreement between UT Health San Antonio and UTSA has recently been finalized. Additionally, most members of the team have cross-appointments with the collaborating institutions. The team regularly interacts and supports a baseline effort on advanced airway technology development, and several graduate students have been and are supported in the effort. Funded projects to date include a Department of Defense (DoD)-funded Advanced Medical Technology Initiative grant entitled "Combat Airway Intubation Assistance Device with Haptic and Physiological Feedback," and a DoD contract entitled "Support the Task Area for Research and Development of Medical Equipment to Clear and Maintain a Combat Airway." A local technology advancement grant from the San Antonio Medical Foundation was awarded in 2018 and funds preliminary work in mechanical securement. Additional intramural and National Science Foundation (NSF) funding has been procured for related projects in airway clearance and suctioning technology.

Conclusion

The transformative design presented herein has the potential to improve care for compromised airways similar to what the automated external defibrillator did for cardiac arrest. The advantages in being less traumatic for and better tolerated by the patient will enable its employment for much longer timeframes than the current clinical standard, which is a critical need for both prehospital prolonged field care and long-term, hospital-based-ventilation (e.g., COVID-19) situations. The integrated bougie, environmental independency, and one-size-fits-all design make the AirSINC ideal for the prehospital caregiver needing an easy-to-use, reliable system that requires minimal pack space. Additionally, the proposed technology addresses gaps in care that are shared on and off the battlefield; while differences exist between the two sectors, they share many commonalities, and both will benefit from improved airway clearance and securement technology. A combined system will enable more rapid and effective care while also minimizing the weight and volume displacement in kits that must be manually transported by all first-responders. Beyond emergency care, intubation and airway management is integral to many fields of medicine ranging from anesthesia for surgical operations, critical care, and pulmonology, in addition to the current challenges of the COVID-19 pandemic. Across hundreds of thousands of annual intubations[47] in the US, even an incremental improvement in the technology could have a significant compounded effect on success, morbidity, and mortality. AirSINC may represent a marked leap forward.

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References

1. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 Suppl 5):S431-437.
2. Aberle SJ, Lohse CM, Sztajnkrycer MD. A Descriptive Analysis of US Prehospital Care Response to Law Enforcement Tactical Incidents. *J Spec Oper Med*. 2015;15(2):117-122.
3. Adams BD, Cuniowski PA, Muck A, De Lorenzo RA. Registry of emergency airways arriving at combat hospitals. *J Trauma*. 2008;64(6):1548-1554.
4. Mabry RL, Edens JW, Pearse L, Kelly JF, Harke H. Fatal airway injuries during Operation Enduring Freedom and Operation Iraqi Freedom. *Prehosp Emerg Care*. 2010;14(2):272-277.
5. Mabry RL, Frankfurt A. Advanced airway management in combat casualties by medics at the point of injury: a sub-group analysis of the reach study. *J Spec Oper Med*. 2011;11(2):16-19.
6. Klotz J, Leo M, Anderson B, et al. First Case Report of SAM? Junctional Tourniquet Use in Afghanistan to Control Inguinal Hemorrhage on the Battlefield. *Journal of special operations medicine: a peer reviewed journal for SOF medical professionals*. 2014;14:1-5.
7. Kotwal RS, Butler FK, Gross KR, et al. Management of Junctional Hemorrhage in Tactical Combat Casualty Care: TCCC Guidelines?Proposed

Change 13-03. *J Spec Oper Med*. 2013;13(4):85-93.

8. Kragh JF, Jr., Walters TJ, Baer DG, et al. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma*. 2008;64(2 Suppl):S38-49; discussion S49-50.
9. Kragh J, Walters T, Baer D, et al. Survival With Emergency Tourniquet Use to Stop Bleeding in Major Limb Trauma. *Annals of surgery*. 2009;249:1-7.
10. Richey SL. Tourniquets for the control of traumatic hemorrhage: a review of the literature. *WJES*. 2007;2:28-28.
11. Wedmore I, McManus J, Pusateri A, Holcomb J. A Special Report on the Chitosan-based Hemostatic Dressing: Experience in Current Combat Operations. *The Journal of trauma*. 2006;60:655-658.
12. Calkins MD, Robinson TD. Combat trauma airway management: endotracheal intubation versus laryngeal mask airway versus combitube use by Navy SEAL and Reconnaissance combat corpsmen. *J Trauma*. 1999;46(5):927-932.
13. Pugh HE, LeClerc S, McLennan J. A review of pre-admission advanced airway management in combat casualties, Helmand Province 2013. *J R Army Med Corps*. 2015;161(2):121-126.
14. Mabry RL. An analysis of battlefield cricothyrotomy in Iraq and Afghanistan. *J Spec Oper Med*. 2012;12(1):17-23.
15. Keller MW, Han PP, Galarneau MR, Brigger MT. Airway Management in Severe Combat Maxillofacial Trauma. *Otolaryngol Head Neck Surg*. 2015;153(4):532-537.
16. Lairet JR, Bebarta VS, Burns CJ, et al. Prehospital interventions performed in a combat zone: a prospective multicenter study of 1,003 combat wounded. *J Trauma Acute Care Surg*. 2012;73(2 Suppl 1):S38-42.
17. Montgomery HR, Butler FK, Kerr W, et al. TCCC Guidelines Comprehensive Review and Update: TCCC Guidelines Change 16-03. *Journal of special operations medicine*. 2017;17(2):21-38.
18. Hudson IL, Blackburn MB, Staudt AM, Ryan KL, Mann-Salinas EA. Analysis of Casualties That Underwent Airway Management Before Reaching Role 2 Facilities in the Afghanistan Conflict 2008-2014. *Mil Med*. 2020;185(Suppl 1):10-18.
19. Sebesta J. Special lessons learned from Iraq. *Surg Clin North Am*. 2006;86(3):711-726.
20. Fouche PF, Stein C, Simpson P, Carlson JN, Doi SA. Nonphysician Out-of-Hospital Rapid Sequence Intubation Success and Adverse Events: A Systematic Review and Meta-Analysis. *Ann Emerg Med*. 2017;70(4):449-459.e420.
21. Lossius HM, Røislien J, Lockey DJ. Patient safety in pre-hospital emergency tracheal intubation: a comprehensive meta-analysis of the intubation success rates of EMS providers. *Crit Care*. 2012;16(1):R24.
22. Spaite DW, Criss EA. Out-of-hospital rapid sequence intubation: are we helping or hurting our patients? *Ann Emerg Med*. 2003;42(6):729-730.
23. Stiell I, Nesbitt L, Pickett W, et al. The OPALS Major Trauma Study: Impact of advanced life-support on survival and morbidity. *CMAJ: Canadian Medical Association journal=journal de l'Association medicale canadienne*. 2008;178:1141-1152.
24. Smith RM, Conn AK. Prehospital care - scoop and run or stay and play? *Injury*. 2009;40 Suppl 4:S23-26.
25. Mulcaster JT, Mills J, Hung OR, et al. Laryngoscopic intubation: learning and performance. *Anesthesiology*. 2003;98(1):23-27.
26. Garza AG, Gratton MC, Coontz D, Noble E, Ma OJ. Effect of paramedic experience on orotracheal intubation success rates. *Journal of Emergency Medicine*. 2003;25(3):251-256.
27. Cook TM, Woodall N, Harper J, Benger J, Fourth National Audit P. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. *British journal of anaesthesia*. 2011;106(5):632-642.
28. Chavez S, Long B, Koyfman A, Liang SY. Coronavirus Disease (COVID-19): A primer for emergency physicians. *The American journal of emergency medicine*. 2020:S0735-6757(0720)30178-30179.
29. Cooper JD. Tracheal Injuries Complicating Prolonged Intubation and Tracheostomy. *Thorac Surg Clin*. 2018;28(2):139-144.
30. Paramaswamy R. A rare cause of complete airway obstruction caused by a defective pilot tube of a reinforced endotracheal tube. Ain-Shams *Journal of Anesthesiology*. 2019;11:1-4.
31. Wang HE, Cook LJ, Chang CC, Yealy DM, Lave JR. Outcomes after out-of-hospital endotracheal intubation errors. *Resuscitation*. 2009;80(1):50-55.
32. Carrión MI, Ayuso D, Marcos M, et al. Accidental removal of endotracheal and nasogastric tubes and intravascular catheters. *Crit Care Med*. 2000;28(1):63-66.
33. Meng L, Qiu H, Wan L, et al. Intubation and Ventilation amid the COVID-19 Outbreak: Wuhan's Experience. *Anesthesiology*. 2020;132(6):1317-1332.

34. Chen C, Zhao B. Makeshift hospitals for COVID-19 patients: where health-care workers and patients need sufficient ventilation for more protection. *The Journal of hospital infection*. 2020;105(1):98-99.

35. Vesoulis A TF, Edwards HS. I'm Mentally and Physically Exhausted. *TIME Magazine*. 2020;195(12/13):32-33.

36. Cook TM. Personal protective equipment during the coronavirus disease (COVID) 2019 pandemic - a narrative review. *Anaesthesia*. 2020;75(7):920-927.

37. Tarasi PG, Mangione MP, Singhal SS, Wang HE. Endotracheal intubation skill acquisition by medical students. *Medical education online*. 2011;16:10.3402/meo.v3416i3400.7309.

38. Berard D, Navarro J, Bascos G, et al. *Novel Ex-pandable Architected Breathing Tube for Improv-ing Airway Securement in Emergency Care*. 2020.

39. Blackburn MB, Nawn CD, Ryan KL. Testing of novel spectral device sensor in swine model of airway obstruction. *Physiological Reports*. 2019;7(19):e14246.

40. Corinne DN, Brian ES, Robert C, III, Caitlin K, Nicholas F, Jing Yong Y. Spectral characterization of tracheal and esophageal tissues using a hyperspectral camera and fiber optic sensors. Paper presented at: Proc.SPIE2016.

41. Nawn CD, Blackburn MB, De Lorenzo RA, Ryan KL. Using spectral reflectance to distinguish between tracheal and oesophageal tissue: applications for airway management. *Anaesthesia*. 2019;74(3):340-347.

42. Nawn CD, Souhan BE, Carter III R, Kneapler C, Fell N, Ye JY. Spectral characterization of tracheal and esophageal tissues using a hyperspectral camera and fiber optic sensors. Paper presented at: Optical Fibers and Sensors for Medical Diagnostics and Treatment Applications XVI2016.

43. Nawn CD, Souhan BE, Carter R, 3rd, Kneapler C, Fell N, Ye JY. Distinguishing tracheal and esophageal tissues with hyperspectral imaging and fiber-optic sensing. *J Biomed Opt*. 2016;21(11):117004.

44. Akhter F, Schoppe A, Navarro O, et al. Characterization of a novel emergency suction device for combat medics and civilian first responders. *Journal of Medical Devices*. 2019.

45. De Lorenzo RA, Hood RL, Jain P, Pescador R, Lasch M, Feng Y. Summary of Findings and Recommendations for Suction Devices for Management of Prehospital Combat Casualty Care Injuries. Texas Univ Medical School at San Antonio. 2017.

46. Jain P, Akhter F, Schoppe A, Hood RL, De Lorenzo RA. Airway Clearance Using Suction Devices in Prehospital Combat Casualty Care: A Systematic Review. *Prehospital and Disaster Medicine*. 2020:1-7.

47. Number of all-listed procedures for discharges from short-stay hospitals, by procedure category and age: United States, 2010. Center for Disease Control and Prevention;2015.

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Damage Control Resuscitation: A Narrative Review of Goals, Techniques, and Components

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Abstract

Damage control resuscitation (DCR) simultaneously tackles hemorrhage control and balanced resuscitation in complex multisystem trauma patients. This technique can improve patient outcomes. This review outlines the importance of DCR with hemorrhage control and administration of fresh whole blood or component therapy if not available and avoiding crystalloid administration. Additionally, administration of tranexamic acid and calcium prove beneficial in critically ill trauma patients. Avoidance of acidosis, hypothermia, and coagulopathy remains a key but challenging goal of DCR.

Keywords: trauma, hemorrhage, shock, resuscitation, damage control resuscitation, blood products

Introduction

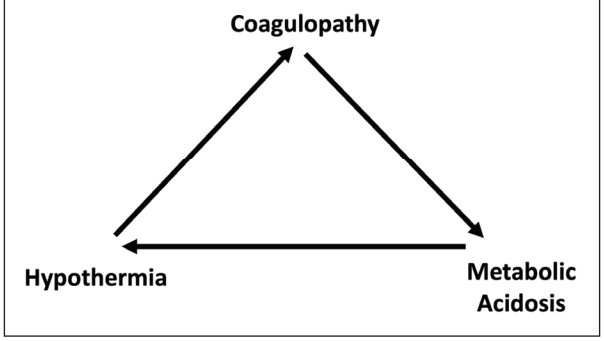
Hemorrhage remains the leading cause of preventable death on the battlefield, necessitating early administration of fresh whole blood or blood component products as well as rapid hemorrhage control.[1] Damage control resuscitation (DCR) includes the use of early hemorrhage control and transfusion of blood products targeting perfusion while reducing acidosis, coagulopathy, and hypothermia (Figure 1).[1-6] DCR possesses a critical role in resuscitation of critically ill trauma patients. Key components of DCR include recognition, hemorrhage control and hemostatic resuscitation, surgical control, and stabilization.[2-6] This manuscript will evaluate these components of DCR and provide an overview of the latest evidence.

Discussion

Initiation of DCR: Similar to other critical interventions in the initial phases of resuscitation, clinicians should initiate DCR in a systematic and timely fashion to extract maximum benefit. While this population overlaps with those requiring massive transfusion protocol (MTP), typically defined by greater than 10 units of packed red blood cells (PRBC) or whole blood (WB) in the first 24 hours, clinicians should make this determination using similar criteria, though far earlier in order to properly resuscitate these critically ill patients.[4-6] As identified in 10 years of battlefield casualties, hemorrhage comprised 90.9% of the potentially survivable battlefield injuries.[1] This stresses the importance of identifying the best candidates for DCR, promptly stopping hemorrhage, and replacing intravascular volume. Based on a cohort of patients with serious injuries, four factors predictive of MTP, and thus DCR, include systolic blood pressure (SBP)< 100 mm Hg, heart rate (HR)> 100 beats per minute, hematocrit (Hct)< 32%, and pH< 7.25.[7] Three of four factors present predicted a 70% likelihood of requiring MTP, while all four predicted an 85% likelihood.[7] Thus, these are useful predictive factors for initiating DCR. Elevated INR>1.5, base deficit >6 mEq/L, lactate >2.5 mmol/L, and >2 regions with free fluid on Focused Assessment with Sonography in Trauma (FAST) ultrasound examination also predict the need for aggressive resuscitation and thus should prompt consideration of DCR.[8-11] The Revised Assessment of Bleeding and Transfusion (RABT) score includes four points based on shock index (SI) > 1.0, pelvic fracture, penetrating trauma, and positive FAST. A score of two or greater demonstrates high sensitivity and specificity for predicting the need for massive transfusion.[12,13] One study of 380 trauma patients demonstrates that the RABT score, when

compared to the Assessment of Blood Consumption (ABC) score, has a higher sensitivity (84% v. 39%) and specificity (77% vs. 72%) for predicting need of MTP.[12] A second study including 1,018 patients found the RABT had a sensitivity and specificity of 78% and 91%, respectively, for predicting MTP, compared to 60% and 82%, respectively, for the ABC score.[13] Finally, injury pattern plays a key role in identifying those who may benefit from DCR. These patterns include multi-amputation trauma, clinically obvious penetrating wounds, pelvic trauma, above knee amputation, and uncontrolled junctional or truncal bleeding.[3,14] In conjunction with the physical pattern, evidence of physiologic derangement should trigger DCR with evidence of coagulopathy, severe hypothermia, or mangled extremities, which further exacerbates the metabolic disturbance present in trauma.[14]

Figure 1. Trauma Triad.



Hemorrhage Control: Direct pressure on wounds, tourniquet use and/or junctional tourniquet, and hemostatic dressings can provide bleeding control.[15,16] If able, direct pressure can effectively stop bleeding. This may not be possible in situations where the source of bleeding is difficult to determine. If an extremity is the suspected source, the provider should apply a tourniquet application proximal to the suspected site of bleeding. Junctional tourniquets can provide control at sites such as the axilla, neck, and groin. Providers can control bleeding from superficial wounds with hemostatic dressings and pressure.

More advanced techniques, such as Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) and resuscitative thoracotomy or exploratory laparotomy with aortic control, have been shown to improve survival in very limited scenarios. These procedures maintain cerebral and coronary perfusion until the source of bleeding can be surgically controlled.[17-22] Most trauma surgical societies recommend their use only for penetrating or blunt thoracoabdominal trauma with profound shock (SBP < 60mm Hg), signs of life (pupillary reactivity, spontaneous breathing, palpable carotid pulse, measurable blood pressure, motor movement, or organized electrical activity), or for patients with < 10-15 minutes of pre-hospital arrest.[23,24] Outcomes, while overall poor, are better for penetrating trauma than blunt trauma. Immediate access to surgery is required to address the source of bleeding and to limit complications of ischemia and ischemic-reperfusion injury.

Perfusion Goals: The tenets of DCR place obtaining hemostasis over obtaining normal perfusion. Clinicians should avoid restoration of normal blood pressure, as it is not associated with improved outcomes and is associated with greater amounts of fluid administration.[25,26] This in turn may result in increased bleeding from hemorrhage sites, and administering crystalloid fluid is associated with dilutional coagulopathy, anemia, tissue edema, and endothelial damage. This concept is termed permissive hypotension.[25,27-30] The evidence behind permissive hypotension primarily comes from studies before the utilization of balanced produce resuscitation; no studies with uncontrolled bleeding demonstrate that high volume resuscitation to obtain normal pressures is associated with improved patient outcomes.[25,26,28,31-33] One of the first studies published in 1994 evaluated this strategy in 598 patients with hypotension and penetrating torso injuries. Patients in the immediate resuscitation group received rapid infusion of isotonic crystalloids, while those in the delayed resuscitation group underwent access placement followed by flushing of the line.[25] Patients receiving immediate resuscitation demonstrated an 8% higher risk of mortality and lower hemoglobin compared with those not receiving a fluid bolus.[25] A later meta-analysis of liberal versus restricted fluid resuscitation for traumatic shock including blunt and penetrating trauma found no difference in overall mortality.[34] However, when one study with a large number of protocol violations was excluded, patients with liberal fluid resuscitation had greater risk of mortality. A randomized controlled trial published after the meta-analysis found patients randomized to the 110 mm Hg group had higher rates of mortality compared to the 70 mm Hg group, though patients were provided crystalloid to achieve these targets.[35] Ultimately, determining an optimal number for resuscitation in daily practice is unlikely and not practical. Rather than targeting a specific number, clinicians should focus on hemostatic control and peripheral perfusion with distal pulses and pulse oximetry waveform, mental status (if possible), shock index (HR divided by SBP), base deficit, and/or lactate.

Fresh Whole Blood: Beginning in World War I and popular in the Vietnam War with utilization of more

than 1 million units of cold-stored whole blood (WB), fresh whole blood (FWB) transfusion ensures that hemorrhagic shock is corrected in the ratio in which blood is lost.[36] In comparison to FWB, a 1:1:1 ratio of Platelets:Plasma:Red Blood Cells (RBC) transfuses a hematocrit of 29%, platelet count of 90,00/uL, and coagulation factors diluted to 62%.[37] Resuscitation of US combat casualties in hemorrhagic shock with warmed FWB was associated with increased survival as compared to resuscitation with component therapy.[38] As protocols have emerged throughout the 75th Ranger Regiment as well as Norwegian and Swedish Military, FWB has been standardized for rapid collection and transfusion throughout conventional military practice.[39] With higher oxygen carrying capacity, hemostatic function, and coagulopathy mitigation, FWB represents the ideal fluid for DCR.[38,40]

A limitation for FWB is that it must be used immediately and cannot be stored; donors should be prescreened for transmissible diseases like human immunodeficiency virus (HIV), Hepatitis B and C, and malaria; and it is type-specific, requiring an ABO match. Cold-stored Whole Blood (CWB), also known as Low-Titer O-Whole Blood (LTOWB), improves the availability of whole blood while maintaining an acceptable safety profile. Low anti-A and anti-B titer group O whole blood can be used as a universal donor for resuscitation of exsanguinating hemorrhage and can be stored for 21 days in CPD or 35 days in CPDA-1.[39,41] This storage profile also allows donors to be formally screened for transmissible diseases.[42] This practice has been adopted in the civilian sector; the South Texas Regional Advisory Council for Trauma (STRAC) has implemented prehospital low titer cold stored O RhD-positive blood with excellent results.[43,44]

Red Blood Cells: If WB is not a resuscitative fluid option, clinicians should utilize component therapy in a 1:1:1 fashion in those requiring MTP. Multiple studies have evaluated this ratio with permutations to optimize mortality, with 1:1:1 minimizing deaths from exsanguination as well as physiologic hemostasis, providing support for this recommendation transfusion ratios in critically ill patients undergoing DCR.[45-47] Packed RBCs are the key oxygen carrying capacity to this transfusion ratio, containing more than 80% of the red blood cells as compared to the initial unit of blood.[46] However, pRBCs have a shelf life of two weeks with lower concentration of proteins causing non-hemolytic transfusion reaction. Additionally cryopreserved red blood cells are superior to liquid red blood cells based on their biochemical profile.[47] Notably, thawed pRBCs cannot be transfused without glycerol removal as glycerol is lethal.[46]

Platelets: Crucial for thrombosis formation to terminate hemorrhage, platelets play a crucial role in a balanced resuscitation in DCR. In evaluation of both military and civilian trauma patients undergoing MTP, medium to high ratio of platelets was associated with survival at 24 hours and 30 days, highlighting the crucial role early platelet administration plays in DCR.[48,49] While the current evidence supports a 1:1:1 transfusion strategy, this optimal treatment group within the Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) trial received platelets first, which may underscore the keystone and underappreciated role platelets occupy within DCR.[50] However, clinicians should carefully consider patients on antiplatelet agents, where thromboelastogram (TEG) (inclusive of both thromboelastography and rotational thromboelastometry) may assist in guiding resuscitation. In individuals on antiplatelet agents with non-traumatic supratentorial intracerebral hemorrhage, clinicians should avoid empiric administration of platelets, which is associated with increased odds of death and disability at three months.[51,52] Clinicians should incorporate joint decision making with neurointerventionalists and consider use of TEG to drive care.

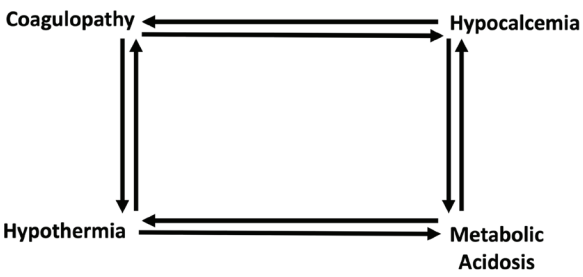
Other Components: Trauma with major hemorrhage is associated with fibrinogen depletion, which standard 1:1:1 transfusion therapy does not replenish.[53-56] Fibrin is a vital component of hemostasis, and maintaining fibrinogen levels can assist in managing coagulopathy. The goal fibrinogen level should be greater than 2 g/L during DCR.[57] Observational studies demonstrate reduced mortality in patients receiving higher fibrinogen content with transfusion therapy.[58-61] Clinicians can rapidly administer fibrinogen to bleeding trauma patients via cryoprecipitate or fibrinogen concentrate, though the latter is expensive with little evidence support to date. Clinicians can administer cryoprecipitate with standard MTP ratios in a 1:1:1:1 ratio. For every 6 units of RBC and FFP, clinicians should administer one to two 5-unit bags of cryoprecipitate.

Prothrombin Complex Concentrate (PCC) includes factors II, VII, IX, and X. While clinicians should not use PCC routinely for trauma, specific recommendations include anticoagulated patients or evidence of delayed initiation of clot formation refractory to other therapies (i.e., cryoprecipitate, tranexamic acid (TXA), or fibrinogen).[16]

Factor VII is a principal trigger for thrombus formation and assists in clot stabilization. Recombinant Factor VIIa has been evaluated as an agent for managing intractable hemorrhage, but there is currently a paucity of evidence demonstrating effectiveness. It is currently

licensed for use in patients and alloantibodies to Factor VIII or Factor IX.[62] However, current guidelines suggest clinicians should avoid routine use, as it is associated with risk of venous thromboembolism and may worsen outcomes.[16,63]

Figure 2. Trauma Tetrad.



Clinicians should avoid crystalloids (ie, normal saline and lactated Ringer's) and colloid solutions (ie, albumin) in patients with severe trauma and hemorrhage, as these solutions dilute clotting factors, contribute to hyperchloremic metabolic acidosis (for normal saline specifically), and possess no oxygen carrying capacity.[64] These agents do not improve mortality and may be associated with multiorgan injury.[64]

Tranexamic Acid: TXA has become integral to DCR since the Clinical Randomisation of an Antifibrinolytic in Significant Haemorrhage 2 (CRASH-2) and Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) studies, where its use in hemorrhagic trauma demonstrated improved mortality; this benefit is greatest in patients receiving massive transfusion, where 30 day mortality benefit is as high as 13.6%.[58,65] TXA mitigates traumatic coagulopathy by preventing hyperfibrinolysis catalyzed by endogenous release of tissue plasminogen activator (tPA) and urokinase plasminogen activator (uPA).[65] At higher doses, it also has a direct inhibitory effect on plasmin, encouraging clot formation, a crucial aspect of hemorrhage control.[66] However, clinicians must balance a potential risk of venous thromboembolism with TXA use with improved hemostasis.[67-70]

Current dosing regiments in an average adults generate serum concentrations on the lower end of doses recommended for both plasminogen competitive inhibition as well as post-operative bleeding. [71-73] TXA binds to plasminogen competitively reaching full effect and saturation against tPA at serum concentrations around 17.5-20 mcg/ml, but reaches full effect against uPA and direct plasmin inhibition closer to 150mcg/ml.[71,72,74] This suggests higher doses (2g intravenous (IV) or 26.6 mg/kg) may prevent fibrinolysis to a greater degree.[71] The US Army Rangers (Unpublished Ranger Medic Handbook 2019) and other research groups (NCT 01990768) are currently evaluating loading doses of 2g without a continuous infusion dose for efficacy and safety. Further research is needed to determine if higher dosing imparts additional survival benefit.

Current best practice guidelines recommend administration of 1g of TXA over 10 minutes followed by 1g over the next 8 hours for patients in hemorrhagic shock undergoing DCR.[16] The survival benefit of TXA is time dependent, with a survival benefit only if given within 3 hours and a 10% decrease in benefit with every 15 minute delay in administration.[75] TXA has been studied for use in traumatic brain injury (TBI), though current data are conflicting.[76,77] Intraosseous and intramuscular administration have similar bioavailability compared to intravenous TXA, and clinicians should consider these routes in patients with limited IV access.[78-80]

Calcium: Recently, the lethal triad of trauma has expanded to include hypocalcemia, playing a significant role in DCR (Figure 2).[81] Both the pathophysiology of trauma and blood transfusion in DCR patients result in hypocalcemia.[82-84] As blood is the preferred fluid of DCR, the incidence of hypocalcemia in trauma patients increases with the administration of blood products. In the setting of MTP, 37% of patients suffer severe hypocalcemia.[83,85,86] In these trauma patients undergoing MTP, patients with severe hypocalcemia (ionized calcium less than 0.90 mmol/L) demonstrated more pronounced thrombocytopenia and acidosis as well as increased mortality (49% versus 24%), suggesting an association of hypocalcemia with the lethal dyad.[87] Several studies including trauma patients undergoing acute resuscitation have demonstrated that hypocalcemia below 1.0 mmol/L is associated with increased mortality.[82,88,89] Similarly in the pre-hospital setting, commensurate calcium administered to those patients receiving prehospital blood products for resuscitation mitigated hypocalcemia.[84] This recent but key development in DCR highlights a fundamental advance to improve resuscitation in both the pre-hospital and initial hospital resuscitation of trauma patients.

Vasopressors: In the setting of polytrauma requiring DCR, resuscitation relies primarily on hemorrhage control and balanced blood component administration, though patients may benefit from vasopressor use. Utilization of norepinephrine early in critically ill patients with hemorrhagic shock secondary to blunt trauma may result in increased mortality.[90,91] While the Department of Defense Clinical Practice Guideline states that vasopressors should not be used to treat

hemorrhagic shock, more recent data have suggested utility in the early administration of vasopressin.[16] Unlike catecholaminergic vasopressors, the posterior pituitary secretes vasopressin to increase osmolality in response to hypotension by binding to the vasopressin 1 (V1) and vasopressin 2 (V2) receptors. In the initial phase of hemorrhagic shock, the posterior pituitary secretes up to 20% of its endogenous vasopressin stores in response to hypotension.[92,93] With shock progression, endogenous vasopressin stores rapidly deplete, decreasing catecholamine sensitivity and arterial and venous vascular tone.[94,95] Low dose exogenous vasopressin may mitigate decreased vascular tone in shock states, improving cerebral perfusion pressures and cerebrovascular compliance; additionally, the venoconstriction activity of vasopressin increases preload.[96,97] A recent randomized control trial evaluated early low dose use of vasopressin at 4U bolus in trauma patients receiving greater than 6 units of blood products in 12 hours and found vasopressin use was associated with fewer blood products transfused at 48 hours.[94] Analysis of secondary outcomes found no difference in mortality, amount of crystalloids infused, or total complications. While this study was not powered to detect mortality difference, vasopressin's decrease in transfusion requirements actively complements the ongoing goals of DCR.

Prevention of Acidosis: In critically ill trauma patients, metabolic acidosis is an independent predictor of coagulopathy and mortality.[98-103] Understanding the mechanism and correction of acidosis in trauma may reverse coagulopathy and improve survival. While multifactorial, acidosis in shock results from local tissue and systemic hypoperfusion, decreasing serum pH.[4] This in turn produces coagulopathy through both reduced activation of clotting factors and degradation of active fibrinogen and platelets. The enzyme kinetics of the coagulation cascade have a reduced activity in reduced pH and optimally operate at a pH between 8.0 and 8.5.[104] In vitro coagulation assays demonstrate reduced efficacy of both intrinsic and extrinsic pathways as the pH is decreases from 7.4 to 7.0.[105] Similarly, in an acidemic state, available fibrinogen and platelets are reduced by 35% and 50%, respectively, with commensurate increases in standard clotting assays.[106-108] TEG studies reveal impairment in the propagation phase of thrombin generation but a relatively preserved thrombin initiation phase.[106,107,109,110]

Current best practice of correcting and preventing further acidosis includes judicious hemostatic resuscitation, which restores tissue perfusion.[3] Rapid pH driven corrections with various buffer solutions (e.g., bicarbonate, Tris- hydroxymethyl aminomethane) do not improve fibrinogen levels or coagulation kinetics.[106,107,111,112] Conversely, one study demonstrated a prolonged coagulopathy in the setting of rapid correction with sodium bicarbonate.[107] Aggressive resuscitation with hyperchloremic saline solutions has been found to worsen base deficit through hyperchloremic acidosis, further disrupting the balanced resuscitation.[4] Similarly, the storage process for blood products with glycerol often creates an acidic medium and can contribute to acidosis.[113]

Various in vitro and in vivo models have evaluated targeted replacement of fibrinogen or clotting factors to reverse the coagulopathy of acidosis.[110,114-117] PCC and cryoprecipitate have been found to improve measured coagulation deficits observed in traumatic coagulopathy. While some debate exists, current literature suggests correction of acidosis is not necessary prior to their administration to effectively reverse coagulopathy.[106,110,114] However, while targeted factor replacement improves coagulation parameters in acidosis, further research is necessary to determine if this translates to benefit in survival.[115,116,118] The treatment end goal should be restoration of hemostasis and end organ perfusion with gradual correction of acidosis and base deficit.

Buffer Solution: There is currently no clear evidence to support correction of acidosis with sodium bicarbonate or other buffer solutions even in the setting of severe acidosis (i.e., pH < 7.1).[4,5,119] Multiple in vivo trials fail to demonstrate improved coagulation kinetics or TEG parameters with pH correction.[107,111,112] Presumably, degradation of fibrinogen during acidosis is not recovered with correction of pH.[119] Rapid alkalinization may also cause intracellular shifts in calcium by as much as 10%, paradoxically worsening coagulopathy and decreasing vascular tone.[6] Sodium bicarbonate additionally creates an increased carbon dioxide (CO_2¬) burden which may increase mortality in severely ill trauma patients.[120] Tris-hydroxymethyl aminomethane (THAM) buffer solution is an attractive alternative to sodium bicarbonate but is less well studied in trauma.[112] Early retrospective studies in military trauma patients suggest no survival benefit to the use of THAM in adult or pediatric patients but note that more data are needed before conclusions can be drawn.[121,122]

Prevention of Hypothermia: As one of the vertices of the trauma triad (Figures 1 and 2), hypothermia, defined by a body temperature less than 35 degrees Celsius, is associated with worse outcomes, hastening coagulopathy and acidosis.[123] Additionally, decreases in core temperature shift the hemoglobin-oxygen dissociation curve to the left, reducing oxygen delivery to

tissues with resultant decreased myocardial contractility, exacerbating the underlying oxygen deprived state.[81] Hypothermia alone is an independent risk factor for critically trauma patients at 24 hours and 28 days and plays a crucial role in trauma induced coagulopathy, which in one database carried a 45.5% mortality in the first 24 hours.[124,125] A multicenter retrospective study found hypothermia increases transfusion, length of stay, and mortality.[126] Hypothermia also reduces thrombin generation and increases fibrinolysis.[127] Even with swift correction of hypothermia, the resulting coagulopathy corrects in a delayed fashion, highlighting the importance of concurrent balanced resuscitation to prevent further spiraling.[128] Thus preventing and treating hypothermia serves to mitigate the acidotic and coagulopathic effects of heat loss in those undergoing DCR. Aggressive rewarming and early use of warm blankets may reduce morbidity and mortality.

Conclusion

DCR plays a crucial role in early resuscitation in critically ill trauma patients. Timely initiation of hemorrhage control and balanced resuscitation can improve patient outcomes. This multifaceted approach hinges on resuscitation with ideally FWB (balanced components if FWB is not available); administration of TXA and calcium; careful consideration of vasopressors; and mitigation of hypothermia, acidosis, and coagulopathy. Informed from both civilian and military experience, employing early DCR guidance serves to improve patient outcomes.

References

1. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011): Implications for the future of combat casualty care. *J Trauma Acute Care Surg.* 2012;73(6 SUPPL. 5). doi:10.1097/TA.0b013e3182755dcc.
2. Dutton RP. *Fall 2005 International TraumaCare (ITACCS) Damage Control Anesthesia*. www.itaccs.com. Accessed July 29, 2020.
3. Duchesne JC, Kimonis K, Marr AB, et al. Damage control resuscitation in combination with damage control laparotomy: A survival advantage. *J Trauma - Inj Infect Crit Care*. 2010;69(1):46-52. doi:10.1097/TA.0b013e3181df91fa.
4. Kaafarani HMA, Velmahos GC. Damage Control Resuscitation In Trauma. *Scand J Surg.* 2014;103(2):81-88. doi:10.1177/1457496914524388.
5. Giannoudi M, Harwood P. Damage control resuscitation: lessons learned. *Eur J Trauma Emerg Surg.* 2016;42(3):273-282. doi:10.1007/s00068-015-0628-3.
6. Jansen JO, Thomas R, Loudon MA, Brooks A. Damage control resuscitation for patients with major trauma. *BMJ.* 2009;338(7708):1436-1440. doi:10.1136/bmj.b1778.
7. Schreiber MA, Perkins J, Kiraly L, Underwood S, Wade C, Holcomb JB. Early Predictors of Massive Transfusion in Combat Casualties. *J Am Coll Surg.* 2007;205(4):541-545. doi:10.1016/j.jamcollsurg.2007.05.007.
8. Ogura T, Nakamura Y, Nakano M, et al. Predicting the need for massive transfusion in trauma patients: The Traumatic Bleeding Severity Score. In: *J of Trauma and Acute Care Surg.* Vol 76. Lippincott Williams and Wilkins; 2014:1243-1250. doi:10.1097/TA.0000000000000200.
9. Moore FA, Nelson T, McKinley BA, et al. Massive transfusion in trauma patients: Tissue hemoglobin oxygen saturation predicts poor outcome. *J Trauma - Inj Infect Crit Care*. 2008;64(4):1010-1023. doi:10.1097/TA.0b013e31816a2417.
10. Brown JB, Lerner EB, Sperry JL, Billiar TR, Peitzman AB, Guyette FX. Prehospital lactate improves accuracy of prehospital criteria for designating trauma activation level. *J Trauma Acute Care Surg.* 2016;81(3):445-452. doi:10.1097/TA.0000000000001085.
11. Brohi K, Cohen MJ, Ganter MT, et al. Acute coagulopathy of trauma: Hypoperfusion induces systemic anticoagulation and hyperfibrinolysis. *J Trauma - Inj Infect Crit Care*. 2008;64(5):1211-1217. doi:10.1097/TA.0b013e318169cd3c.
12. Joseph B, Khan M, Truitt M, et al. Massive Transfusion: The Revised Assessment of Bleeding and Transfusion (RABT) Score. *World J Surg.* 2018;42(11):3560-3567. doi:10.1007/s00268-018-4674-y.
13. Hanna K, Harris C, Trust MD, et al. Multicenter Validation of the Revised Assessment of Bleeding and Transfusion (RABT) Score for Predicting Massive Transfusion. *World J Surg.* 2020;44(6):1807-1816. doi:10.1007/s00268-020-05394-5.
14. Joint Trauma System Clinical Practice Guideline (JTS CPG) Damage Control Resuscitation (CPG ID:18).
15. Guerado E, Bertrand ML, Valdes L, Cruz E, Cano JR. Resuscitation of Polytrauma Patients: The Management of Massive Skeletal Bleeding. *Open Orthop J.* 2015;9(1):283-295. doi:10.2174/1874325001509010283.
16. Cap AP, Pidcake HF, Spinella P, et al. Damage Control Resuscitation: Joint Trauma System Clinical

Practice Guidelines.; 2018. https://prolongedfieldcare.files.wordpress.com/2017/06/damage-control-resuscitation-isr-cpg-03feb2017.pdf. Accessed January 9, 2019.

17. Du Bose JJ, Scalea TM, Brenner M, et al. The AAST prospective Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) registry: Data on contemporary utilization and outcomes of aortic occlusion and resuscitative balloon occlusion of the aorta (REBOA). *J Trauma Acute Care Surg*. 2016;81(3):409-419. doi:10.1097/TA.0000000000001079.

18. Brenner M, Inaba K, Aiolfi A, et al. Resuscitative Endovascular Balloon Occlusion of the Aorta and Resuscitative Thoracotomy in Select Patients with Hemorrhagic Shock: Early Results from the American Association for the Surgery of Trauma's Aortic Occlusion in Resuscitation for Trauma and Acute Care Surgery Registry. *J Am Coll Surg*. 2018;226(5):730-740. doi:10.1016/j.jamcollsurg.2018.01.044.

19. Rhee PM, Acosta J, Bridgeman A, Wang D, Jordan M, Rich N. Survival after emergency department thoracotomy: Review of published data from the past 25 years. *J Am Coll Surg*. 2000;190(3):288-298. doi:10.1016/S1072-7515(99)00233-1.

20. Asensio JA. Practice management guidelines for emergency department thoracotomy. *J Am Coll Surg*. 2001;193(3):303-309. doi:10.1016/S1072-7515(01)00999-1,

21. Seamon MJ, Fisher CA, Gaughan JP, Kulp H, Dempsey DT, Goldberg AJ. Emergency department thoracotomy: Survival of the least expected. *World J Surg*. 2008;32(4):604-612. doi:10.1007/s00268-007-9392-9.

22. Moore EE, Knudson MM, Burlew CC, et al. Defining the limits of resuscitative emergency department thoracotomy: A contemporary western trauma association perspective. *J Trauma-Inj Infect Crit Care*. 2011;70(2):334-339. doi:10.1097/TA.0b013e3182077c35.

23. Burlew CC, Moore EE, Moore FA, et al. Western trauma association critical decisions in trauma: Resuscitative thoracotomy. *J Trauma Acute Care Surg*. 2012;73(6):1359-1363. doi:10.1097/TA.0b013e318270d2df.

24. Seamon MJ, Haut ER, Van Arendonk K, et al. An evidence-based approach to patient selection for emergency department thoracotomy: A practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2015;79(1):159-173. doi:10.1097/TA.0000000000000648.

25. Bickell WH, Wall MJ, Pepe PE, et al. Immediate versus Delayed Fluid Resuscitation for Hypotensive Patients with Penetrating Torso Injuries. *N Engl J Med*. 1994;331(17):1105-1109. doi:10.1056/NEJM199410273311701.

26. Hussman B, Heuer M, Lefering R, et al. Prehospital Volume Therapy as an Independent Risk Factor after Trauma. Biomed Res Int. April 2015. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4407400/. Accessed July 29, 2020.

27. McSwain NE, Champion HR, Fabian TC, et al. State of the art of fluid resuscitation 2010: Prehospital and immediate transition to the Hospital. *J Trauma*. 2011;70(5SUPPL.):2-10. doi:10.1097/TA.0b013e31821b201d.

28. Yaghoubian A, Lewis RJ, Putnam B, De Virgilio C. Reanalysis of prehospital intravenous fluid administration in patients with penetrating truncal injury and field hypotension. *Am Surg*. 2007;73(10):1027-1030. doi:10.1177/000313480707301023.

29. Geeraedts LMG, Pothof LAH, Caldwell E, De Lange-De Klerk ESM, D'Amours SK. Prehospital fluid resuscitation in hypotensive trauma patients: Do we need a tailored approach? *Injury*. 2015;46(1):4-9. doi:10.1016/j.injury.2014.08.001.

30. Cotton BA, Guy JS, Morris JA, Abumrad NN. The cellular, metabolic, and systemic consequences of aggressive fluid resuscitation strategies. *Shock*. 2006;26(2):115-121. doi:10.1097/01.shk.0000209564.84822.f2.

31. Haut ER, Kalish BT, Cotton BA, et al. Prehospital intravenous fluid administration is associated with higher mortality in trauma patients: A national trauma data bank analysis. *Ann Surg*. 2011;253(2):371-378. doi:10.1097/SLA.0b013e318207c24f.

32. Hampton DA, Fabricant LJ, Differding J, et al. Prehospital intravenous fluid is associated with increased survival in trauma patients. *J Trauma Acute Care Surg*. 2013;75(1 SUPPL1). doi:10.1097/TA.0b013e318290cd52.

33. Holcomb JB, Del Junco DJ, Fox EE, et al. The prospective, observational, multicenter, major trauma transfusion (PROMMTT) study: Comparative effectiveness of a time-varying treatment with competing risks. *JAMA Surg*. 2013;148(2):127-136. doi:10.1001/2013.jamasurg.387.

34. Edelman DA, White MT, Tyburski JG, Wilson RF. Post-traumatic hypotension: Should systolic blood pressure of 90-109 mmHg be included? *Shock*. 2007;27(2):134-138. doi:10.1097/01.shk.0000239772.18151.18.

35. Schreiber MA, Meier EN, Tisherman SA, et al. A controlled resuscitation strategy is feasible and safe in hypotensive trauma patients: Results of a prospective randomized pilot trial. *J Trauma*

Acute Care Surg. 2015;78(4):687-697. doi:10.1097/TA.0000000000000600.

36. Neel S. *Medical Support of the US Army in Vietnam, 1965-1970*. Washington, D.C.: Department of the Army; 1973. https://books.google.com/books?hl=en&lr=&id=BpxHAQAAIAAJ&oi=fnd&pg=PP17&ots=YsYvEG4 PcC&sig=fWNQAZOvZvJp7pJUlNmgMq7yvXk#v=onepage&q&f=false. Accessed July 20, 2020.

37. Hess JR. Resuscitation of trauma-induced coagulopathy. *Hematology Am Soc Hematol Educ Program*. 2013;2013:664-667. doi:10.1182/asheducation-2013.1.664.

38. Spinella PC, Perkins JG, Grathwohl KW, Beekley AC, Holcomb JB. Warm fresh whole blood is independently associated with improved survival for patients with combat-related traumatic injuries. *J Trauma - Inj Infect Crit Care*. 2009;66(SUPPL. 4). doi:10.1097/TA.0b013e31819d85fb.

39. Fisher AD, Miles EA, Cap AP, Strandenes G, Kane SF. Tactical Damage Control Resuscitation. *Mil Med*. 2015;180(8):869-875. doi:10.7205/MILMED-D-14-00721.

40. Armand R, Hess JR. Treating coagulopathy in trauma patients. *Transfus Med Rev*. 2003;17(3):223-231. doi:10.1016/S0887-7963(03)00022-1.

41. Taylor A, Eastridge BJ, Fisher AD, Cap AP. Advances in the Use of Whole Blood in Combat Trauma. In: *Resuscitation*. ; 2016:15A-16A.

42. Strandenes G, Berséus O, Cap AP, et al. Low titer group o whole blood in emergency situations. *Shock*. 2014;41(SUPPL. 1):70-75. doi:10.1097/SHK.0000000000000150.

43. McGinity AC, Zhu CS, Greebon L, et al. Prehospital low-titer cold-stored whole blood: Philosophy for ubiquitous utilization of O-positive product for emergency use in hemorrhage due to injury. *J Trauma Acute Care Surg*. 2018;84(6S Suppl 1):S115-S119. doi:10.1097/TA.0000000000001905.

44. Newberry R, Winckler CJ, Luellwitz R, et al. Prehospital Transfusion of Low-Titer O + Whole Blood for Severe Maternal Hemorrhage: A Case Report. *Prehospital Emerg Care*. 2019. doi:10.1080/10903127.2019.1671562.

45. Borgman MA, Spinella PC, Perkins JG, et al. The ratio of blood products transfused affects mortality in patients receiving massive transfusions at a combat support hospital. *J Trauma - Inj Infect Crit Care*. 2007;63(4):805-813. doi:10.1097/TA.0b013e3181271ba3.

46. Cap A, Badloe J, Wooley T, et al. *Frozen and Deglycerolized Red Blood Cells*.; 2016.

47. Hampton DA, Wiles C, Fabricant LJ, et al. Cryopreserved red blood cells are superior to standard liquid red blood cells. *J Trauma Acute Care Surg*. 2014;77(1):20-27. doi:10.1097/TA.0000000000000268.

48. Perkins JG, Andrew CP, Spinella PC, et al. An evaluation of the impact of apheresis platelets used in the setting of massively transfused trauma patients. *J Trauma - Inj Infect Crit Care*. 2009;66(SUPPL. 4). doi:10.1097/TA.0b013e31819d8936.

49. Cap AP, Spinella PC, Borgman MA, Blackbourne LH, Perkins JG, Houston S. Timing and location of blood product transfusion and outcomes in massively transfused combat casualties. 2012. doi:10.1097/TA.0b013e318260625a.

50. Holcomb JB, Tilley BC, Baraniuk S, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: The PROPPR randomized clinical trial. *JAMA - J Am Med Assoc*. 2015;313(5):471-482. doi:10.1001/jama.2015.12.

51. Baharoglu MI, Cordonnier C, Salman RAS, et al. Platelet transfusion versus standard care after acute stroke due to spontaneous cerebral haemorrhage associated with antiplatelet therapy (PATCH): a randomised, open-label, phase 3 trial. *Lancet*. 2016;387(10038):2605-2613. doi:10.1016/S0140-6736(16)30392-0.

52. Pohlman TH, Fecher AM, Arreola-Garcia C. Optimizing transfusion strategies in damage control resuscitation: Current insights. *J Blood Med*. 2018;9:117-133. doi:10.2147/JBM.S165394.

53. Vladutiu CJ, Stringer EM, Kandasamy V, Ruppenkamp J, Menard MK. Emergency Care Utilization Among Pregnant Medicaid Recipients in North Carolina: An Analysis Using Linked Claims and Birth Records. *Matern Child Health J*. 2019;23(2):265-276. doi:10.1007/s10995-018-2651-6.

54. Collins P, Solomon C, Sutor K, et al. Theoretical modelling of fibrinogen supplementation with therapeutic plasma, cryoprecipitate, or fibrinogen concentrate. *Br J Anaesth*. 2014;113(4):585-595. https://bjanaesthesia.org/article/S0007-0912(17)30749-3/fulltext. Accessed July 25, 2020.

55. Schlimp CJ, Schöchl H. The role of fibrinogen in trauma-induced coagulopathy. *Hamostaseologie*. 2014;34(1):29-39. doi:10.5482/HAMO-13-07-0038.

56. Schöchl H, Schlimp CJ, Maegele M. Tranexamic acid, fibrinogen concentrate, and prothrombin complex concentrate: Data to support prehospital use? *Shock*. 2014;41(SUPPL. 1):44-46. doi:10.1097/SHK.0000000000000093.

57. Rossaint R, Bouillon B, Cerny V, et al. The

European guideline on management of major bleeding and coagulopathy following trauma: Fourth edition. *Crit Care*. 2016;20(1):1-55. doi:10.1186/s13054-016-1265-x.

58. Morrison JJ, Dubose JJ, Rasmussen TE, Midwinter MJ. Military application of tranexamic acid in trauma emergency resuscitation (MATTERs) study. *Arch Surg*. 2012;147(2):113-119. doi:10.1001/archsurg.2011.287.

59. Dente CJ, Shaz BH, Nicholas JM, et al. Improvements in early mortality and coagulopathy are sustained better in patients with blunt trauma after institution of a massive transfusion protocol in a civilian level I trauma center. J *Trauma - Inj Infect Crit Care*. 2009;66(6):1616-1624. doi:10.1097/TA.0b013e3181a59ad5.

60. Stinger HK, Spinella PC, Perkins JG, et al. The ratio of fibrinogen to red cells transfused affects survival in casualties receiving massive transfusions at an army combat support hospital. *J Trauma*. 2008;64(2 Suppl). doi:10.1097/ta.0b013e318160a57b.

61. Shaz BH, Dente CJ, Nicholas J, et al. Increased number of coagulation products in relationship to red blood cell products transfused improves mortality in trauma patients. *Transfusion*. 2010;50(2):493-500. doi:10.1111/j.1537-2995.2009.02414.x.

62. Franchini M, Crestani S, Frattini F, Sissa C, Bonfanti C. Recombinant activated factor VII in clinical practice: a 2014 update. *J Thromb Thrombolysis*. 2015;39(2):235-240. doi:10.1007/s11239-014-1114-1.

63. Dutton RP, Mackenzie CF, Scalea TM. Hypotensive resuscitation during active hemorrhage; impact on in-hospital mortality. *J Trauma*. 2002;52(6):1141-1146. doi:10.1097/00005373-200206000-00020.

64. Wise R, Faurie M, Malbrain MLNG, Hodgson E. Strategies for Intravenous Fluid Resuscitation in Trauma Patients. *World J Surg*. 2017;41(5):1170-1183. doi:10.1007/s00268-016-3865-7.

65. Roberts I, Shakur H, Coats T, et al. The CRASH-2 trial: a randomised controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events and transfusion requirement in bleeding trauma patients. *Heal Technol Assess*. 2013;17(10):1-79. doi:10.3310/hta17100.

66. Pabinger I, Fries D, Schöchl H, Streif W, Toller W. Tranexamic acid for treatment and prophylaxis of bleeding and hyperfibrinolysis. *Wien Klin Wochenschr*. 2017;129(9-10):303-316. doi:10.1007/s00508-017-1194-y.

67. Ageron FX, Gayet-Ageron A, Ker K, et al. Effect of tranexamic acid by baseline risk of death in acute bleeding patients: a meta-analysis of individual patient-level data from 28 333 patients. *Br J Anaesth*. 2020;124(6):676-683. doi:10.1016/j.bja.2020.01.020.

68. Johnston LR, Rodriguez CJ, Elster EA, Bradley MJ. Evaluation of military use of tranexamic acid and associated thromboembolic events. *JAMA Surg*. 2018;153(2):169-175. doi:10.1001/jamasurg.2017.3821.

69. Myers SP, Kutcher ME, Rosengart MR, et al. Tranexamic acid administration is associated with an increased risk of posttraumatic venous thromboembolism. *J Trauma Acute Care Surg*. 2019;86(1):20-27. doi:10.1097/TA.0000000000002061.

70. El-Menyar A, Sathian B, Asim M, Latifi R, Al-Thani H. Efficacy of prehospital administration of tranexamic acid in trauma patients: A meta-analysis of the randomized controlled trials. *Am J Emerg Med*. 2018;36(6):1079-1087. doi:10.1016/j.ajem.2018.03.033.

71. Grassin-Delyle S, Theusinger OM, Albrecht R, et al. Optimisation of the dosage of tranexamic acid in trauma patients with population pharmacokinetic analysis. *Anaesthesia*. 2018;73(6):719-729. doi:10.1111/anae.14184.

72. Koster A, Faraoni D, Levy JH. Antifibrinolytic Therapy for Cardiac Surgery: An Update. *Anesthesiology*. 2015;123(1):214-221. doi:10.1097/ALN.0000000000000688.

73. Wąsowicz M, Jerath A, Bojko B, Sharma V, Pawliszyn J, McCluskey S. Use of a novel technique, solid phase microextraction, to measure tranexamic acid in patients undergoing cardiac surgery. *Can J Anesth*. 2012;59(1):14-20. doi:10.1007/s12630-011-9614-3.

74. Yee BE, Wissler RN, Zanghi CN, Feng C, Eaton MP. The effective concentration of tranexamic acid for inhibition of fibrinolysis in neonatal plasma in vitro. *Anesth Analg*. 2013;117(4):767-772. doi:10.1213/ANE.0b013e3182a22258.

75. Gayet-Ageron A, Prieto-Merino D, Ker K, et al. Effect of treatment delay on the effectiveness and safety of antifibrinolytics in acute severe haemorrhage: a meta-analysis of individual patient-level data from 40 138 bleeding patients. *Lancet*.2018;391(10116):125-132. doi:10.1016/S0140-6736(17)32455-8.

76. Collaborators C-3. Effects of tranexamic acid on death, disability, vascular occlusive events and other morbidities in patients with acute traumatic brain injury (CRASH-3): a randomised, placebo-controlled trial. *Lancet*. 2019;394(10210):1713-1723. doi:10.1016/S0140-6736(19)32233-0.

77. Rowell SE, Meier EN, McKnight B, et al. Effect of Out-of-Hospital Tranexamic Acid vs Placebo on 6-Month Functional Neurologic Outcomes in Patients with Moderate or Severe Traumatic Brain Injury. *JAMA - J Am Med Assoc*. 2020;324(10):961-974. doi:10.1001/jama.2020.8958.

78. Boysen SR, Pang JM, Mikler JR, Knight CG, Semple HA, Caulkett NA. Comparison of tranexamic acid plasma concentrations when administered via intraosseous and intravenous routes. *Am J Emerg Med*. 2017;35(2):227-233. doi:10.1016/j.ajem.2016.10.054.

79. DeSoucy E, Davidson A, Hoareau G, et al. Pharmacokinetics of Tranexamic Acid via Intravenous, Intraosseous, and Intramuscular Routes in a Porcine (Sus scrofa) Hemorrhagic Shock Model - PubMed. *J Spec Oper Med*. 2019;19(4):80-84. https://pubmed.ncbi.nlm.nih.gov/31910476/. Accessed August 5, 2020.

80. Spruce MW, Beyer CA, Caples CM, et al. Pharmacokinetics of Tranexamic Acid Given as an Intramuscular Injection Compared to Intravenous Infusion in a Swine Model of Ongoing Hemorrhage. *Shock*. 2020;53(6):754-760. doi:10.1097/SHK.0000000000001427.

81. Ditzel RM, Anderson JL, Eisenhart WJ, et al. A review of transfusion- And trauma-induced hypocalcemia: Is it time to change the lethal triad to the lethal diamond? *J Trauma Acute Care Surg*. 2020;88(3):434-439. doi:10.1097/TA.0000000000002570.

82. Magnotti LJ, Bradburn EH, Webb DL, et al. Admission Ionized Calcium Levels Predict the Need for Multiple Transfusions: A Prospective Study of 591 Critically Ill Trauma Patients. *J Trauma Inj Infect Crit Care*. 2011;70(2):391-397. doi:10.1097/TA.0b013e31820b5d98.

83. Webster S, Todd S, Redhead J, Wright C. Ionised calcium levels in major trauma patients who received blood in the Emergency Department. *Emerg Med J*. 2016;33(8):569-572. doi:10.1136/emermed-2015-205096.

84. Kyle T, Greaves I, Beynon A, Whittaker V, Brewer M, Smith J. Ionised calcium levels in major trauma patients who received blood en route to a military medical treatment facility. *Emerg Med J*. 2018;35(3):176-179. doi:10.1136/emermed-2017-206717.

85. MacKay EJ, Stubna MD, Holena DN, et al. Abnormal Calcium Levels During Trauma Resuscitation Are Associated With Increased Mortality, Increased Blood Product Use, and Greater Hospital Resource Consumption: A Pilot Investigation. *Anesth Analg*. 2017;125(3):895-901. doi:10.1213/ANE.0000000000002312.

86. Ho KM, Leonard AD. Concentration-dependent effect of hypocalcaemia on mortality of patients with critical bleeding requiring massive transfusion: a cohort study. *Anaesth Intensive Care*. 2011;39(1):46-54. http://www.ncbi.nlm.nih.gov/pubmed/21375089. Accessed January 9, 2019.

87. Giancarelli A, Birrer KL, Alban RF, Hobbs BP, Liu-DeRyke X. Hypocalcemia in trauma patients receiving massive transfusion. *J Surg Res*. 2016;202(1):182-187. doi:10.1016/J.JSS.2015.12.036.

88. Hästbacka J, Pettilä V. Prevalence and predictive value of ionized hypocalcemia among critically ill patients. *Acta Anaesthesiol Scand*. 2003;47(10):1264-1269. http://www.ncbi.nlm.nih.gov/pubmed/14616325. Accessed January 4, 2019.

89. Cherry RA, Bradburn E, Carney DE, Shaffer ML, Gabbay RA, Cooney RN. Do early ionized calcium levels really matter in trauma patients? *J Trauma*. 2006;61(4):774-779. doi:10.1097/01.ta.0000239516.49799.63.

90. Uchida K, Nishimura T, Hagawa N, et al. The impact of early administration of vasopressor agents for the resuscitation of severe hemorrhagic shock following blunt trauma. *BMC Emerg Med*. 2020;20(1). doi:10.1186/s12873-020-00322-1.

91. Sperry JL, Minei JP, Frankel HL, et al. Early use of vasopressors after injury: Caution before constriction. *J Trauma - Inj Infect Crit Care*. 2008;64(1):9-14. doi:10.1097/TA.0b013e31815dd029.

92. Landry DW, Levin HR, Gallant EM, et al. Vasopressin deficiency contributes to the vasodilation of septic shock. *Circulation*. 1997;95(5):1122-1125. doi:10.1161/01.CIR.95.5.1122.

93. Cohn SM, Derosa M, McCarthy J, et al. Characterizing vasopressin and other vasoactive mediators released during resuscitation of trauma patients. *J Trauma Acute Care Surg*. 2013;75(4):620-628. doi:10.1097/TA.0b013e31829eff31.

94. Sims CA, Holena D, Kim P, et al. Effect of Low-Dose Supplementation of Arginine Vasopressin on Need for Blood Product Transfusions in Patients with Trauma and Hemorrhagic Shock: A Randomized Clinical Trial. *JAMA Surg*. 2019;154(11):994-1003. doi:10.1001/jamasurg.2019.2884.

95. Morales D, Madigan J, Cullinane S, et al. Reversal by vasopressin of intractable hypotension in the late phase of hemorrhagic shock. *Circulation*. 1999;100(3):226-229. doi:10.1161/01.CIR.100.3.226.

96. Williams TDM, da Costa D, Mathias CJ, Bannister R, Lightman SL. Pressor effect of arginine vasopressin in progressive autonomic failure. *Clin Sci*. 1986;71(2):173-178. doi:10.1042/cs0710173.

97. Sanui M, King DR, Feinstein AJ, Varon AJ, Conn SM, Proctor KG. Effects of arginine vasopressin during resuscitation from hemorrhagic hypotension after traumatic brain injury. *Crit Care Med*. 2006;34(2):433-438. doi:10.1097/01.CCM.0000196206.83534.39.

98. Cheddie S, Muckart DJJ, Hardcastle TC. Base

deficit as an early marker of coagulopathy in trauma. *South African J Surg*. 2013;51(3):88-90. doi:10.7196/SAJS.1665.

99. Ferrara A, MacArthur JD, Wright HK, Modlin IM, McMillen MA. Hypothermia and acidosis worsen coagulopathy in the patient requiring massive transfusion. *Am J Surg*. 1990;160(5):515-518. doi:10.1016/S0002-9610(05)81018-9.

100. Cohen MJ, Kutcher M, Redick B, et al. Clinical and mechanistic drivers of acute traumatic coagulopathy. In: Journal of Trauma and Acute Care Surgery. Vol 75. *J Trauma Acute Care Surg*; 2013. doi:10.1097/TA.0b013e31828fa43d.

101. Hodgman EI, Morse BC, Dente CJ, et al. Base deficit as a marker of survival after traumatic injury: Consistent across changing patient populations and resuscitation paradigms. *J Trauma Acute Care Surg*. 2012;72(4):844-851. doi:10.1097/TA.0b013e31824ef9d2.

102. Siegel JH, Rivkind AI, Dalal S, Goodarzi S. Early Physiologic Predictors of Injury Severity and Death in Blunt Multiple Trauma. *Arch Surg*. 1990;125(4):498-508. doi:10.1001/archsurg.1990.01410160084019.

103. Rutherford EJ, Morris JA, Reed GW, Hall KS. Base Deficit Stratifies Mortality and Determines Therapy. *J Trauma Inj Infect Crit Care*. 1992;33(3):417-423. doi:10.1097/00005373-199209000-00014.

104. Hoffman M. The Cellular Basis of Traumatic Bleeding. *Mil Med*. 2004;169(12S):5-7. doi:10.7205/milmed.169.12s.5.

105. Meng ZH, Wolberg AS, Monroe DM, Hoffman M. The effect of temperature and ph on the activity of factor viia: Implications for the efficacy of high-dose factor viia in hypothermic and acidotic patients. *J Trauma*. 2003;55(5):886-891. doi:10.1097/01.TA.0000066184.20808.A5.

106. Darlington DN, Kheirabadi BS, Scherer MR, Martini WZ, Dubick MA. Acidosis and correction of acidosis does not affect rFVIIa function in swine. *Int J Burns Trauma*. 2012;2(3):145-157. http://www.ncbi.nlm.nih.gov/pubmed/23272296. Accessed July 25, 2020.

107. Martini WZ, Dubick MA, Pusateri AE, Park MS, Ryan KL, Holcomb JB. Does bicarbonate correct coagulation function impaired by acidosis in swine? *J Trauma - Inj Infect Crit Care*. 2006;61(1):99-106. doi:10.1097/01.ta.0000215574.99093.22.

108. Martini WZ, Pusateri AE, Uscilowicz JM, Delgado A V, Holcomb JB. Independent Contributions of Hypothermia and Acidosis to Coagulopathy in Swine Background: Clinical coagulopathy. 2005. doi:10.1097/01.TA.0000156246.53383.9F.

109. Engström M, Schött U, Romner B, Reinstrup P. Acidosis Impairs the Coagulation: A Thromboelastographic Study. *J Trauma Inj Infect Crit Care*. 2006;61(3):624-628. doi:10.1097/01.ta.0000226739.30655.75.

110. Viuff D, Lauritzen B, Pusateri AE, Andersen S, Rojkjaer R, Johansson PI. Effect of haemodilution, acidosis, and hypothermia on the activity of recombinant factor VIIa (NovoSeven). *Br J Anaesth*. 2008;101(3):324-331. doi:10.1093/bja/aen175.

111. Darlington DN, Kheirabadi BS, Delgado A V, Scherer MR, Martini WZ, Dubick MA. Coagulation Changes to Systemic Acidosis and Bicarbonate Correction in Swine. 2011. doi:10.1097/TA.0b013e318214f522.

112. Martini WZ, Dubick MA, Wade CE, Holcomb JB. Evaluation of tris-hydroxymethylaminomethane on reversing coagulation abnormalities caused by acidosis in pigs. *Crit Care Med*. 2007;35(6):1568-1574. doi:10.1097/01.CCM.0000266682.74602.6A.

113. Zander R, Sümpelmann R. Säure-Basen-Status gelagerter und gewaschener Erythrozyten. *Anasthesiol Intensivmed Notfallmedizin Schmerztherapie, Suppl*. 2001;36(1). doi:10.1055/s-2001-11834.

114. Lesperance RN, Lehmann RK, Harold DM, Beekley AC, Sebesta JA, Martin MJ. Recombinant factor VIIa is effective at reversing coagulopathy in a lactic acidosis model. *J Trauma Acute Care Surg*. 2012;72(1):123-129. doi:10.1097/TA.0b013e318224e24a.

115. Curry N, Foley C, Wong H, et al. Early fibrinogen concentrate therapy for major haemorrhage in trauma (E-FIT 1): Results from a UK multi-centre, randomised, double blind, placebo-controlled pilot trial. *Crit Care*.2018;22(1). doi:10.1186/s13054-018-2086-x.

116. Curry N, Rourke C, Davenport R, et al. Early cryoprecipitate for major haemorrhage in trauma: a randomised controlled feasibility trial. *Br J Anaesth*. 2015;115(1):76-83. https://bjanaesthesia.org/article/S0007-0912(17)31243-6/fulltext. Accessed July 25, 2020.

117. Moe DM, Lallemand MS, McClellan JM, et al. Three- versus four-factor prothrombin complex concentrates for "factor-based" resuscitation in a porcine hemorrhagic shock model. *J Trauma Acute Care Surg*. 2017;83(6):1114-1123. doi:10.1097/TA.0000000000001646.

118. Egea-Guerrero JJ, Freire-Aragón MD, Serrano-Lázaro A, Quintana-Díaz M. Resuscitative goals and new strategies in severe trauma patient resuscitation. *Med Intensiva*. 2014;38(8):502-512. doi:10.1016/j.medin.2014.06.003.

119. De Robertis E, Kozek-Langenecker S, Tufano R, Romango G, Piazza O, Zito Marinosci G.

Coagulopathy induced by acidosis, hypothermia and hypocalcaemia in severe bleeding. *Minerva Anestesiol*. 2015;18(1):65-75. https://pubmed.ncbi.nlm.nih.gov/24608516/. Accessed August 5, 2020.

120. Wilson RF, Spencer AR, Tyburski JG, Dolman H, Zimmerman LH. Bicarbonate therapy in severely acidotic trauma patients increases mortality. *J Trauma Acute Care Surg*. 2013;74(1):45-50. doi:10.1097/TA.0b013e3182788fc4.

121. de Taboada G, Umar MA, Casmaer ML, Blackbourne LH, Schauer SG. The US military experience with THAM. *Am J Emerg Med*. December 2019. doi:10.1016/j.ajem.2019.11.026.

122. Naylor JF, April MD, Hill GJ, Kempski KM, Arana AA, Schauer SG. THAM Administration to Pediatric Trauma Patients in a Combat Zone. *South Med J*. 2018;111(8):453-456. doi:10.14423/SMJ.0000000000000843.

123. Leibner E, Andreae M, Galvagno SM, Scalea T. Damage control resuscitation. *Clin Exp Emerg Med*. 2020;7(1):5-13. doi:10.15441/ceem.19.089.

124. Balvers K, Van Der Horst M, Graumans M, et al. Hypothermia as a predictor for mortality in trauma patients at admittance to the intensive care unit. J Emergencies, *Trauma Shock*. 2016;9(3):97-102. doi:10.4103/0974-2700.185276.

125. Maegele M. Coagulation factor concentrate-based therapy for remote damage control resuscitation (RDCR): a reasonable alternative? *Transfusion*. 2016;56:S157-S165. doi:10.1111/trf.13526.

126. Klauke N, Gräff I, Fleischer A, et al. Effects of prehospital hypothermia on transfusion requirements and outcomes: A retrospective observatory trial. *BMJ Open*. 2016;6(3). doi:10.1136/bmjopen-2015-009913.

127. Martini WZ. Coagulopathy by hypothermia and acidosis: Mechanisms of thrombin generation and fibrinogen availability. *J Trauma - Inj Infect Crit Care*. 2009;67(1):202-208. doi:10.1097/TA.0b013e3181a602a7.

128. Gonzalez EA, Moore FA, Holcomb JB, et al. Fresh frozen plasma should be given earlier to patients requiring massive transfusion. *J Trauma - Inj Infect Crit Care*. 2007;62(1):112-119. doi:10.1097/01.ta.0000250497.08101.8b.

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An Analysis of Prehospital Trauma Registry: After-Action Reviews on Airway Interventions in Afghanistan

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Abstract

Background: Failed airway management is the second leading cause of preventable death on the battlefield. The prehospital trauma registry (PHTR) after action-review (AAR) allows for unique perspectives and an enhanced analysis of interventions performed. We analyzed AAR comments related to airway interventions performed in deployed settings to examine and identify trends in challenges related to airway management in combat.

Design and Methods: We analyzed all AAR comments included for airway interventions reported in the Joint Trauma System PHTR. We applied unstructured qualitative methods to analyze themes within these reports and generated descriptive statistics to summarize findings related to airway management.

Results: Out of 705 total casualty encounters in the PHTR system between January 2013 and September 2014, 117 (16.6%) had a documented airway intervention. From this sample, 17 (14.5%) had accompanying AAR comments for review. Most patients were identified as host nation casualties (94%, n =16), male (88%, n = 15), and prioritized as urgent evacuation (100%, n = 17). Twenty-five airway interventions were described in the AAR comments, the most being endotracheal intubation (52%, n = 13), followed by ventilation management (28%, n = 7), and cricothyroidotomy (12%, n = 3). Comments indicated difficulties with surgical procedures and suboptimal anatomy identification.

Conclusions: AAR comments focused primarily on cricothyroidotomy, endotracheal intubation, and ventilation management, citing needs for improvement in technique and anatomy identification. Future efforts should focus on training methods for these interventions and increased emphasis on AAR completion.

Keywords: trauma, prehospital, military, after-action review, performance

Introduction

Preventable combat deaths in the prehospital environment continue to be an analytical focus for areas of medical improvement.[1-4] Previous literature demonstrates that failure of airway management is the second leading cause of preventable death.[5] Lifesaving interventions in these situations can be as simple as the insertion of a nasopharyngeal airway (NPA), or as complex as the placement of a surgical airway. Airway procedures can be performed by different levels of medical personnel at all stages of prehospital care, from a combat medic at the point of injury (POI) to a physician at the Role 2 military treatment facility (MTF). However, airway interventions and management can be high-stress, time sensitive, and often anxiety provoking for inexperienced personnel, including physicians, physician assistants, medics, and corpsman who may be generally unfamiliar with airway management or lack significant exposure prior to performing airway interventions on the battlefield.[6]

As previously described, injuries sustained during

combat operations in Iraq and Afghanistan, and the subsequent medical care provided, contribute to ongoing analysis and refinement of best practice guidelines for prehospital care.[7,8] Improvements in documentation from POI to hospital environments enable performance improvement (PI). Such improvements include the constant evolution of the Committee on Tactical Combat Casualty Care (CoTCCC) and Joint Trauma System (JTS) guidelines, who utilize combat casualty data to improve clinical practice guidelines (CPG) for future use.

Table 1. After-action review airway intervention comment analysis.

	Overall (117)	Conventional Military (27)	Special Operations (11)	Afghan (56)	Other** (25)
AAR Airway Intervention Comments					
Yes	15% (17)	4% (1)	0% (0)	29% (16)	0% (0)
No	85% (100)	96% (26)	100% (11)	71% (40)	100% (23)

*All data are presented as percentage (total number) for their respective column.
** 'Other' includes AAR cases without unit identifiers and without any patient demographics given in AAR comments

The origins and development of the Prehospital Trauma Registry (PHTR) have been previously described, as has the historically poor documentation rates within it.[1,7,8] Previous studies have attempted to quantitatively identify challenges.[4,9] We seek to build on previously published analyses and perform a focused thematic analysis of AAR data on airway management in the PHTR to highlight challenges and opportunities for improvement.

Methods

The US Army Institute of Surgical Research regulatory office reviewed protocol H-16-013 and determined it was exempt from institutional review board oversight. We obtained only de-identified data.

The JTS PHTR is a data collection and analytic tool designed to provide near-real-time feedback to commanders. As previously described,[10] the primary purpose of this tool is to improve command visibility of their casualties, augment command decision-making processes, validate and refine prehospital casualty response systems, 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 [PPE]), and tertiary prevention (casualty response system and tactical combat casualty care [TCCC]).[11] The US Central Command JTS Prehospital Directorate collected TCCC cards and TCCC AARs and transferred information from these documentation tools into the initial PHTR. Previous authors have described efforts to establish the PHTR.[1,12]

The PHTR system designated data descriptors to include a mechanism of injury (MOI), evacuation status, military service component, and patient nationality. Investigators included all PHTR cases involving airway interventions, then correlated these charts to AAR comments via unique case numbers. The research team analyzed descriptions of specific improvements noted from a free text comment section within the AAR, and intervention categories were based on an internally generated data dictionary. Given the diverse nature of the sources, the nonstandard format for users to report information, and the variable degree of detail in each report, we applied unstructured qualitative methods to analyze themes. We reported data in a descriptive format and supplemented by selected quotes lifted from the sources to illustrate key themes. We performed all analyses and presented limited quantitative data metrics using descriptive statistics.

Results

There were 705 casualty encounters in the PHTR system between January 2013 and September 2014 available for analysis. Within that 705, 117 (16.6%) encounters had a documented airway intervention. Afghan civilians represented the highest fraction of airway interventions at nearly half (48%, n=56; Table 1). There were 17 AARs available for review. Most (94%, n=16) involved host national casualties.

Table 2. After-action review demographic analysis.

	Overall (17)	Conventional Military (1)	Afghan (16)
Demographics			
Male	88% (15)	100% (1)	88% (14)
Evacuation Status			
Urgent	100% (17)	100% (1)	100% (16)
Mechanism of Injury			
Explosion	53% (9)	0% (0)	56% (9)
GSW	47% (8)	100% (1)	44% (7)
Status			
Alive	0% (0)	0% (0)	0% (0)
Dead	0% (0)	0% (0)	0% (0)
NOS	100% (17)	100% (2)	100% (16)

*All data are presented as percentage (total number) for their respective column.
GSW = gunshot wound
NOS = Not otherwise specified

The patients were mostly male (88%, n = 15), and all listed as urgent for patient evacuation (100%, n = 17, Table 2). Overall, most patients were injured by explosion (53%, n = 9), although these were all Afghan patients, with the remainder of injuries sustained from gunshot wound (GSW, 47%, n = 8).

A total of 25 airway interventions were described in AARs across the 17 cases reviewed. The most common airway

intervention was placement of an endotracheal tube (ETT), described in 52% of patient encounters (n = 13), followed by ventilation management (28%, n = 7), and cricothyroidotomy (12%, n = 3, Table 3). Host nation patients had the highest proportion of ETT use (56%). The only interventions performed on a US military patient were unsuccessful use of bag valve mask (BVM) followed by a cricothyroidotomy. AAR comments on endotracheal intubation and ventilation management were the pair most frequently described together (n = 6, 35% of all cases), followed by NPA and cricothyroidotomy (n = 1, 6%). Examples of category-specific AAR improvement comments are quoted in Table 4. Comments broadly indicated technical difficulties related to surgical airway procedures and suboptimal anatomy identification. These comments included numerous references on a lack of or need for greater "exposure" to airway management, the need to "review" procedural steps, and stress a need to ensure proper "teaching" on airway interventions.

Table 3. After-action review airway intervention analysis.

	Overall (25)	Conventional Military (2)	Afghan (23)
Intervention			
NPA	8% (2)	0% (0)	9% (2)
OPA	0% (0)	0% (0)	0% (0)
SGA	0% (0)	0% (0)	0% (0)
ETT	52% (13)	0% (0)	56% (13)
Cricothyroidotomy	12% (3)	50% (1)	9% (2)
Ventilator	28% (7)	50% (1)	26% (6)

*All data are presented as percentage (total number) for their respective column.
NPA = nasopharyngeal airway
OPA = oropharyngeal airway
SGA = supraglottic airway
ETT = endotracheal tube

Discussion

We reviewed a total of 17 AARs stemming from 117 cases of airway intervention found in the PHTR system encompassing 18 months of combat operations in Afghanistan from 2013 to 2014. These findings reveal a lack of documented reviews on airway management techniques in general, with less than 1 in 8 cases that involved airway management having AAR documentation. Despite the goal of the PHTR and its accompanying AAR system to establish a database of feedback for analysis and trends, low numbers of completed AAR on airway interventions reflect continued trends of suboptimal prehospital documentation.[1,12] Of the reviewed comments, most referred to a lack of training or equipment surrounding airway interventions.

Cricothyroidotomy is an airway management skill within the scope of practice for both combat medics and corpsmen, is taught during initial training, and is well-supported as an initial airway intervention in previous literature and TCCC guidelines.[13-17] Out of three AAR comments reporting the performance of a cricothyroidotomy, two stated that the intervention was unsuccessful. One attributed the failure to improper landmark identification; neither reported a successful procedure. These results suggest a need for increased anatomical training. Previous literature reports that the highest rate of successful cricothyroid membrane identification by combat medics is 78% after focused training.[18] Inadequate anatomic familiarity may help explain issues identified in this AAR commentary and historical rates of 65-67% for successful medic-performed cricothyroidotomy.[19-21] In general, the frequency of critical interventions performed by physicians in military treatment facilities is low, decreasing opportunities for medics to gain experience through observation or performance of these procedures.[22,23] Specifically, recent literature found only two cricothyroidotomies performed across eight MTFs over two years.[22] Given the relatively low rate of success and the limited opportunities for enlisted medics to gain experience, continued emphasis on cricothyroidotomy as a first-line intervention for airway management necessitates improved training methods. Cricothyroidotomy is a rapid, life-saving procedure requiring minimal to no specialized equipment. Familiarity and technical mastery can be invaluable tools for military medical providers at all levels of training. Future research into performance improvement could include technique variations, such as using a gum elastic introducer (bougie) to aid placement,[24] and training enhancements such as high fidelity simulator models, virtual or augmented reality simulators, or live tissue training.

Endotracheal intubation (ETI) is recognized as the gold standard of airway management in the hospital setting; however, its use in the military prehospital environment is generally restricted to special operations medics and otherwise overshadowed by an emphasis on cricothyroidotomy for initial airway management.[15,17,25] Some of the AAR comments identified successful ETT placement in the Role 1 setting, but the majority illustrated technical errors specifically attributed to enlisted personnel, including two cases of accidental esophageal intubation. Overall, like faults identified in cases of cricothyroidotomy, AAR comments for failed ETT placement generally described poor anatomical orientation and insufficient procedural familiarity. Although our AAR dataset did not contain provider backgrounds or experience levels, inadequate understanding of the interventions performed was obvious in some comments. This includes one comment stating that "this was [the corpsman]'s first attempt at intubation… considering that he has never had any exposure to intubation (especially

a mannequin)." Literature evaluating methods to improve medic proficiency in ETI is scant, the most recent showing improved confidence after education with anesthesia personnel, and further research is needed.[25] Additionally, two cases described an emergent need for a cricothyroidotomy due to a lack of or malfunctioning airway equipment, and one directly stated that the surgical intervention was "needlessly" performed due to issues with improper intubation instruments. In addition to improved training for providers, increased awareness of equipment, including checks for functionality, could eliminate some issues regarding intubation reviewed here. Conversely, it may be possible the equipment they were issued is not sufficiently durable for the operational environment.

The application of a BVM device had multiple AAR comments, primarily regarding technique and proper rate of breathing. The proper performance of the E-C clamp technique (making a "C" with the thumb and second digit around the facemask and an "E" with the three remaining digits to support the mandible, thus creating a quality seal) is a basic skill for all combat medics, yet AAR comments appear to note significant performance shortcomings indicating greater emphasis on training.[18] This may be due to a lack of simulated or live patient experience, but unlike cricothyroidotomy or ETI, can be readily practiced between medics to improve technique and proficiency. The exact issue with the E-C technique in these encounters is unclear, but continuous instruction and assessment should be done, especially for those deployed.

Table 4. After-action review comments by section.

Cricothyroidotomy
• "airway proved difficult as patient was a large adult, thus difficult to intubate with a Mac[intosh] 4. Vellecula appreciated but immobile as base could not be reached, gum elastic bougie was attempted and failed… [get] a 5-Mac blade for laryngoscope…patient needlessly getting a [cricothyroidotomy] due to insufficient equipment" (64)
• "[Rapid sequence intubation with endotracheal tube] attempted, could not progress due to swelling. Cric[othyroidotomy] due to doubts using rescue device… Corspmen who attempted [cricothyroidotomy] cut too low to gain successful intubation…" (103)
• "could hear a lot of fluid in the throat/chest… placed into recovery position in attempt to drain the blood with no success… then attempted a cric[othyroidotomy] but wasn't successful." (546)
Intubation
• "Correct airway assistance by corpsmen with c-spine stabilization and cricoid pressure made for easy intubation." (44)
• "Team leader should have determined need to intubate, whether he was planning on doing so or not." (81)
• "[Glasgow Coma Score] on presentation was 9 and then 8… decision to intubate was made… 8-0cm ET tube placed." (246)
• "[The Corpsman] initially attempted to intubate but placed it into the esophagus." (356)
• "Provide teaching to Corpsmen on how to troubleshoot issues with intubation." (392)
• "the laryngoscope light [was] not properly working… the initial [ETT] we used, a 7.5cm, was too large… attempted to intubate the patient and likely passed it through the vocal cords without an adequate light source as I provided cricoid pressure and could feel the tip of the [ETT]. At this point, I attempted to intubate as he was not having any success… after finally being able to get the light working… I visualized the cords and attempted to pass the tube through – it was then I realized it was too large. I downgraded to a 7cm tube and then was able to successfully pass it through with adequate breath sounds, sustained pulse oximetry at 100%." (415)
• "He attempted to intubate the patient and I believe that he was able to visualize the vocal cords. However, due to difficulty with the [ETT] and the stylet being too rigid, he had difficulty with passing it through the cords." (438)
• "due to limitations with teaching my Corpsmen how to intubate (i.e. lack of a mannequin)… unsuccessful intubation" (440)
• "due to the patient becoming combative and difficult to care for, the decision was made to intubate. [The Corpsman] initially attempted to intubate the patient. However, he was unsuccessful.. This was [the Corpsman]'s first attempt at intubation… considering that he has never had any exposure to intubation (especially a mannequin), it was a good effort. He needed to advance the laryngoscope blade a bit more and remember to lift towards the opposite corner of the room. Cric pressure was provided to him, but due to his lack of lifting, he was unable to visualize the vocal cords." (441)
• "Pt arrived to [Battalion Aid Station] after sustaining a single GSW to the back of the head… The patient initially arrived with a [Glasgow Coma Score] of 3 but was breathing on his own… reportedly was verbal prior to arrival… [Rapid Sequence Intubation] meds were provided. Intubation was successful with the first attempt." (446)
• "[The Corpsman] attempted to intubate the patient. He reports that he was able to visualize the vocal cords but lost sight of the [ETT] actually passing through them. He proceeded to place the [ETT] and almost hubbed it to the casualty's mouth. After withdrawing to 23cm, it was identified that the placement was incorrect and had passed into the esophagus." (470)
• "[Afghan National Army] attempted intubation although did not use paralytic (when we got there Pt with broken incisor likely from intubation attempt)… We attempted intubation with 8-0 however tube was too large so we switched to 7-0. After unable on second attempt, a bougie used to introduce tube and 7-0 successfully placed… Intubation tray was missing a syringe to inflate the cuff; in addition the laryngoscope blade and handle did not have a functioning light; in the future we need to check and double check equipment between all casualties." (503)
• "tube holder placed with opening cephalad instead of caudad… Tube not displaced as a result." (624)
Ventilation
• "Ensure BVM is hooked up to oxygen tank. Learn to troubleshoot ventilating [patient] with BVM (using E-C technique)." (246)
• "Review procedure on properly applying BVM to patient to ventilate patient" (356)
• "Needs to work on his ability to successfully ventilate a patient using a BVM – specifically with this E-C clamp technique…" (415)
• "remember to hyperventilate between 30-40 breaths/min [in suspected head injury with increased intracranial pressure]." (446)
• "[The Corpsman] could stand to improve his ability to successfully ventilate a patient using a BVM (i.e. E-C technique)." (470)
• "monitor [breaths per minute] with BVM better" (503)
• "[Medic} tried to apply manual ventilations by a BVM but had no success." (546)

The use of AARs and other post-event debriefing methods demonstrates benefits to pre-hospital providers and overall patient care.[26,27] Critical assessments of medical incidents demonstrate improvement in provider quality of life, to include decreased drug use for stress management.[26] Paramedic documentation of airway interventions, such as ETI, significantly improves following increased emphasis on review processes and implementation of more structured systems.[28] This increased documentation facilitates improved learning opportunities and training to further develop prehospital skills and improved out-of-hospital resuscitation.[28,29] Increased emphasis on the AAR process in prehospital medicine could therefore increase multiple aspects of provider skills and patient care.

Limitations

The main limitation of our analysis is incomplete data entry from the free text nature of the PHTR AAR system. This is also complicated by a lack of data regarding time intervals between patient encounters and AAR completion, or about what relationship the AAR commenter had in the respective patient encounter. These variables can introduce significant perception and recall biases, as well as decreased rates of return altogether. Additionally, none of the five cases in which the patient's ultimate disposition was

listed as 'dead' are included in this analysis because those cases lacked an AAR comments on airway management. These cases likely represent the casualties where the most detailed AARs would be beneficial. In light of this, future movement away from a free text-based system along with mandated documentation completion would be beneficial to make substantial improvements in compliance and depth of feedback. This could include a well-organized AAR reporting model utilizing a check box system to easily delineate intervention type (cricothyroidotomy, ETI, BVM, etc.), whether overall the intervention technique should be sustained or improved, and subset areas for improvement (such as anatomical identification, user technique, and procedural familiarity), while retaining a free text section for further elaboration.

Conclusion

Our study illustrated, for the first time, a thematic review of airway intervention AAR commentary in the PHTR. Most commentary focused on cricothyroidotomy, ETI, and BVM application, generally finding a need for improvement in anatomy identification and technique. Future research efforts should focus on evaluating current training methods, primarily with enlisted medical personnel, and possible instructive alternatives to improve understanding and increase chances of intervention success. Efforts should focus on increasing AAR completion to improve education opportunities and skill development.

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References

1. Schauer SG, et al. A descriptive analysis of data from the Department of Defense Joint Trauma System Prehospital Trauma Registry. *US Army Med Dep J*. 2017. Oct-Dec(3-17): p. 92-97.
2. Schauer SG, et al. Outcomes of Casualties Without Airway Trauma Undergoing Prehospital Airway Interventions: A Department of Defense Trauma Registry Study. *Mil Med*. 2020. 185(3-4): p. e352-e357.
3. Schauer SG, et al. Survival of Casualties Undergoing Prehospital Supraglottic Airway Placement Versus Cricothyrotomy. *J Spec Oper Med*. 2019. 19(2): p. 91-94.
4. Blackburn MB, et al. Prehospital airway procedures performed in trauma patients by ground forces in Afghanistan. *J Trauma Acute Care Surg*. 2018. 85(1S Suppl 2): p. S154-S160.
5. Eastridge BJ, et al. Death on the battlefield (2001-2011): Implications for the future of combat casualty care. *J Trauma*. 2012. 73(6, Supplement 5): p. S431-S437.
6. Hudson IL, et al. Analysis of Casualties That Underwent Airway Management Before Reaching Role 2 Facilities in the Afghanistan Conflict 2008-2014. *Mil Med*. 2020. 185(Suppl 1): p. 10-18.
7. Kotwal RS, Montgomery HR, Mechler KK. A Prehospital Trauma Registry for Tactical Combat Casualty Care. *US Army Med Dep J*. 2011: p. 15-17.
8. Kotwal RS, et al. Eliminating preventable death on the battlefield. *Arch Surg*. 2011. 146(12): p. 1350-8.
9. Schauer SG, et al. Prehospital Airway Management in Iraq and Afghanistan: A Descriptive Analysis. *South Med J*. 2018. 111(12): p. 707-713.
10. Nohrenberg JL, Tarpey BW, Kotwal RS. Data Informs Operational Decisions: The Tactical Evacuation Project. United States Army Aviation Digest 2014; Oct-Dec:17-9. Accessed August 4, 2017, http://www.rucker.army.mil/aviationdigest/images/AVN_DIG_2014_10-12.pdf.).
11. Kotwal RS, et al. Saving Lives on the Battlefield: A Joint Trauma System Review of Pre-Hospital Trauma Care in Combined Joint Operating Area ? Afghanistan (CJOA-A) Executive Summary. *J Spec Oper Med*. 2013. 13(1): p. 77-85.
12. Robinson JB, et al. Battlefield Documentation of Tactical Combat Casualty Care in Afghanistan. *US Army Med Dep J*. 2016(2-16): p. 87-94.
13. Mabry RL, Frankfurt A. Advanced airway management in combat casualties by medics at the point of injury: a sub-group analysis of the reach study. *J Spec Oper Med*. 2011. 11(2): p. 16-9.
14. Mabry R, McManus JG. Prehospital advances in the management of severe penetrating trauma. *Crit Care Med*. 2008. 36(7 Suppl): p. S258-66.
15. Montgomery HR, et al. TCCC Guidelines

Comprehensive Review and Update: TCCC Guidelines Change 16-03. *J Spec Oper Med*. 2017. 17(2): p. 21-38.

16. Dye C, et al. *Airway Management in Prolonged Field Care* (CPG ID:80). JTS, Editor. 2020: Fort Sam Houston, TX.
17. Soldier's Manual and Training Guide. Department of the Army. 2013: Washington, DC.
18. Moore A, et al. A Comparison of the Laryngeal Handshake Method Versus the Traditional Index Finger Palpation Method in Identifying the Cricothyroid Membrane, When Performed by Combat Medic Trainees. *J Spec Oper Med*. 2019. 19(3): p. 71-75.
19. Adams BD, et al. Registry of emergency airways arriving at combat hospitals. *J Trauma*. 2008. 64(6): p. 1548-54.
20. Pugh HE, LeClerc S, McLennan J. A review of pre-admission advanced airway management in combat casualties, Helmand Province 2013. *J R Army Med Corps*. 2015. 161(2): p. 121-6.
21. Mabry RL. An analysis of battlefield cricothyrotomy in Iraq and Afghanistan. *J Spec Oper Med*. 2012. 12(1): p. 17-23.
22. Carius BM, April MD, Schauer SG. Procedural Volume Within Military Treatment Facilities-Implications for a Ready Medical Force. *Mil Med*. 2020.
23. Schauer SG, Varney SM, Cox KL. Garrison Clinical Setting Inadequate for Maintenance of Procedural Skills for Emergency Medicine Physicians: A Cross-Sectional Study. *J Spec Oper Med*. 2015. 15(4): p. 67-70.
24. Hill C, et al. Cricothyrotomy technique using gum elastic bougie is faster than standard technique: a study of emergency medicine residents and medical students in an animal lab. *Acad Emerg Med*. 2010. 17(6): p. 666-9.
25. Miller BM, Kinder C, Smith-Steinert R. Airway Management for Army Reserve Combat Medics: An Interdisciplinary Workshop. *J Spec Oper Med*. 2019. 19(3): p. 64-70.
26. Tuckey MR, Scott JE. Group critical incident stress debriefing with emergency services personnel: a randomized controlled trial. *Anxiety Stress Coping*. 2014. 27(1): p. 38-54.
27. Couper K, et al. Debriefing to improve outcomes from critical illness: a systematic review and meta-analysis. *Intensive Care Med*. 2013. 39(9): p. 1513-23.
28. O'Connor RE, Megargel RE. The effect of a quality improvement feedback loop on paramedic skills, charting, and behavior. *Prehosp Disaster Med*. 1994. 9(1): p. 35-8; discussion 38-9.
29. Dine CJ, et al. Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing. *Crit Care Med*. 2008. 36(10): p. 2817-22.

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Procedural Confidence and Usability of a Novel Lateral Canthotomy and Cantholysis Simulator Compared to a Traditional Porcine Model in Emergency Medicine Training

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Abstract

Introduction: Retrobulbar hemorrhage (RBH) occurs in only 0.45% of ocular trauma, but failure to provide timely lateral canthotomy and cantholysis (LCC) risks permanent visual deficits. With ocular trauma rates as high as 8.5-10% amongst modern combat injuries, and more than 2,000 severe eye injuries documented over a 10 year span, this concern increases.[12-15] However, given infrequent RBH occurrence in the non-combat environment, emergency medicine residents trained in stateside settings may not receive adequate LCC exposure prior to military deployment. Simulators should be evaluated for procedural confidence compared to expensive and cumbersome traditional live tissue training (LTT) options. We seek to compare procedural confidence and usability of emergency medicine military residents performing LCC on a novel simulator to those using LTT.

Methods: This study randomized 32 emergency physician and physician assistant residents to perform LCC on a simulator or LTT model. All received a standardized brief on RBH recognition and LCC, then completed an 11-question survey using a 100-mm visual numerical rating scale about their ability to correctly identify RBH and perform LCC. The survey was repeated after LCC completion. All volunteers additionally completed a 10-question survey utilizing a 5-point Likert scale on the usability of the model to which they were randomized.

Results: No significant difference in reported confidence changes between groups was found; however, significant increases were found across all reported confidence measures between pre- and post-trainer use in the overall sample population. LCC simulator users reported significantly higher usability in 7 of 10 ratings.

Conclusion: The lack of a statistically significant difference between groups in procedural confidence suggests artificial LCC simulators may offer an attractive alternative to logistically-complicated porcine models. Further research is needed to evaluate non-inferiority and procedural performance.

Keywords: procedure, skills, residency, retrobulbar hematoma

Introduction

Retrobulbar hemorrhage (RBH) describes the process of blood filling the closed space directly behind the eye, most commonly in the setting of trauma. With a small, fixed volume, onset of RBH forces forward movement of the globe against the inferior and superior canthal ligaments. Posterior pressure from as little as 7mL of fluid stretches the optic nerve, and can induce irreversible retinal ischemia and optic nerve damage in as little as 60 minutes after RBH onset.[1-4] Despite battlefield evacuation concepts such as "the Golden Hour," unique patient circumstances and diverse operational settings in austere locations necessitate consideration for increased point of injury (POI) interventions if evacuation is delayed. Failure to provide timely treatment for RBH can result in permanent blindness in up to 52% of cases.[3-5]

Epidemiological studies consistently find more than 2.4 million eye injuries present annually to American emergency departments (ED) for concerns of ocular trauma.[6,7] However, RBH may occur in as little as 0.45% of these cases, which in some studies is documented as 1 case per ED per year, decreasing the likelihood of trainee exposure and providing minimal opportunities for emergency medicine residents, who are preparing to serve

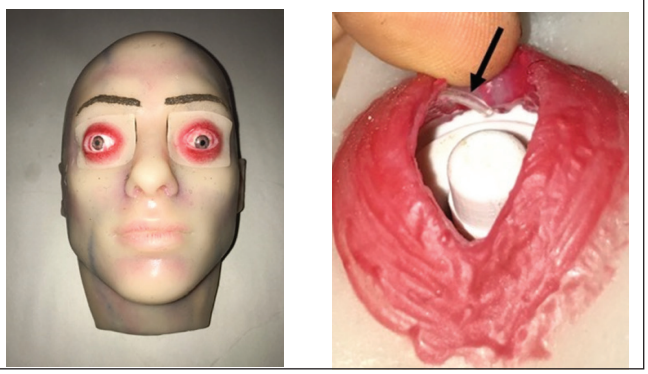
overseas, to recognize and treat RBH despite its high risk for causing blindness.[8-11] Ocular trauma occurs in an estimated 8.5-10% of modern combat injuries.[12-14] More than 2,000 severe eye injuries were documented over a 10-year span in the deployed setting from high risk mechanisms such as battlefield casualties and ordinance.[15] However, these focused on penetrating mechanisms and did not include civilians treated by coalition forces, suggesting the actual number of severe eye injuries that may be treated by the deployed clinician may be much higher.

Emergent treatment of RBH involves timely lateral canthotomy and cantholysis (LCC) to sever the canthal ligaments and thereby drain blood from the poster orbit, thus relieving pressure against the globe and strain on the optic nerve. The ability to perform LCC in the setting of RBH is one of two priority battlefield ocular care skills per Joint Trauma System guidelines.[16] It is essential that frontline medical officers such as physicians and physician assistants are comfortable and confident in performing this intervention.

The American Council for Graduate Medical Education (ACGME) sets minimum procedural numbers for resident clinicians to be considered qualified, and although there is a paucity of emergency medicine (EM) data, the available literature finds confidence and skill degradation with limited procedural volumes and conversely demonstrates improved patient outcomes in clinicians with higher procedure loads.[17-23] This suggests a need for continued procedural volume to enable EM clinicians, including emergency physicians (EP) and emergency medicine physician assistants (EMPA), the opportunity to increase confidence and skills in critical areas prior to training completion.

Despite research demonstrating increased procedural confidence with live tissue training (LTT) on porcine and human cadavers, these aids continue to be costly (as high as $3,000 per model) and logistically difficult to acquire and maintain with a limited amount of repetitions per cadaver or animal.[11,24] Inexpensive alternatives are needed, and while other tissue models such as animal heads, may be less expensive, their logistical acquisition, storage, and disposal may nevertheless prove equally challenging. Multiple commercial and handmade models have previously been proposed; however, literature has been largely limited to descriptions of the models themselves.[25-28] One prior study comparing a simulator to LTT demonstrated limited findings of improvement on a LCC procedural knowledge quiz without examination of clinical confidence or competency, while another examined knowledge and comfort level without comparison to other models such as LTT.[27,28] Procedural confidence comparisons must be made directly between LTT and simulators to evaluate whether the latter is viable for EM training curriculums.

Figure 1. Novel lateral canthotomy and cantholysis (LCC) simulator manikin head with replaceable ocular inserts; a single thread located along the inferior-lateral aspect of the orbit, when severed, decreases a pressure device posterior to the artificial globe simulating the release of pressure when the LCC procedure is successfully performed.



We seek to compare procedural confidence between participants who practiced on a novel LCC simulator and those using a traditional LTT model. Secondarily, we evaluate LCC time to completion and performance between groups.

Methods

Ethics: The Regional Health Command–Central regulatory office reviewed protocol C.2019.045e and determined it to be exempt from Institutional Review Board oversight. We obtained only de-identified data from volunteers for analysis. A single LCC simulator model was utilized through an ongoing Department of Defense testing contract (Sonalyst, Inc.; Waterford, CT). All participants were informed that investigation team members held no business relationship or conflict of interest.

Subjects and Setting: All volunteers were solicited from the EP and EMPA residencies. EP residents included physicians in all stages of emergency medicine residency training. EMPA residents were certified physician assistants enrolled in an 18-month doctoral residency in emergency medicine training. Basic volunteer demographics were obtained during enrollment. All study activities were conducted in conjunction with monthly LTT performed under approved Institutional Animal Care and Use Committee (IACUC) protocols.

Materials: The LCC simulator consists of a manikin head with removable eye inserts (Figure 1). The eye

Table 1. Volunteer year group demographics.

Group	EMPA	PGY-1	PGY-2	PGY-3	Total
Porcine	6 (54.6, 33.3)	7 (58.3, 38.9)	3 (60.0, 16.7)	2 (50.0, 11.1)	18
LCC Simulator	5 (45.4, 35.7)	5 (41.7, 35.7)	2 (40.0, 14.3)	2 (50.0, 14.3)	14
Total	11	12	5	4	32

* Data displayed as *n* (% of total year group, % of total arm)

inserts have a single thread located along the inferior-lateral aspect of the orbit that, when severed, decreases a pressure device posterior to the artificial globe simulating the release of pressure when LCC is successfully performed. Procedure tools for both the LCC simulator and LTT included 1 needle driver, 1 set of iris scissors, 1 set of tissue forceps, and a 1 mL syringe (to simulate local anesthetic injection).

Protocol: Prior to study activities, we provided a standardized PowerPoint instruction to all volunteers on recognition and treatment of RBH. Volunteers completed an 11-question survey rating their confidence to identify and treat RBH on a 100-mm visual numerical rating scale. We then randomized volunteers into two groups using a random number generator. The experimental group performed LCC on the simulator, while the control group performed LCC on the LTT only. We permitted volunteers in the experimental group up to three attempts on the LCC simulator, as they had no prior experience on the simulator and had previously had at least 3 separate exposures to the porcine model LTT. Per IACUC protocols, all animals were euthanized prior to LCC performance. We induced RBH by the injection of 15 mL of blood (previously drawn from the same animal) into the retrobulbar space. Control volunteers then completed the LCC on the porcine, while experimental volunteers did not. All volunteers repeated the 11-question confidence survey at the conclusion of their use of the LCC simulator or the LTT, as well as a 10-question survey utilizing a 5-point Likert scale on the usability of their respective LCC model. The primary outcome was the difference in reported procedural confidence ratings between the experimental and control groups at the conclusion of training. Secondary outcomes included changes in volunteers' procedural confidence in the group as a whole and differences in usability ratings.

Statistical Analysis: A power analysis was conducted to detect a 10-point difference in the confidence score assuming a standard deviation of 10 units, with the ability to detect a statistically significant difference with 80% power and alpha set at 0.05, resulting in a sample population of 32 needed. We performed all statistical analysis and reported descriptive statistics to include numbers with percentages for nominal variables; and means with and without standard deviations for ordinal and scale variables. Parametric t-tests were used to evaluate for differences between the experimental and control groups. A pre-study power analysis found that a sample size of 32 could detect differences with 80% confidence.

Table 2. Volunteer medical experience demographics.

Group	Civilian Medical (years)	Trauma Medical (years)
Porcine	1.16 (0, 10.17)	0.89 (0, 10.00)
LCC Simulator	1.16 (0, 4.00)	0.86 (0, 4.00)
P	0.995	0.962

*Data displayed as average (min, max)

Table 3. Confidence survey data comparisons between arms.

	Intra-Arm Mean	*P*	Post-Trainer Δ	*P*
#1 – Confirm a retro-orbital hemorrhage with manual exam				
Porcine	67.76	0.556	13.28	0.643
LCC Simulator	64.11		16.79	
#2 – Cutting Tendons				
Porcine	66.94	0.815	14.44	0.786
LCC Simulator	65.18		12.50	
#3 – Visually differentiate between a normal and propotic eye				
Porcine	71.94	0.298	8.89	0.304
LCC Simulator	77.50		2.14	
#4 – Differentiate between a normal and propotic eye by touch (i.e. pressure)				
Porcine	68.33	0.870	14.44	0.848
LCC Simulator	69.29		15.71	
#5 – Perform a lateral canthotomy and cantholysis of the inferior canthal tendon				
Porcine	69.03	0.780	18.06	0.414
LCC Simulator	66.96		11.79	
#6 – Reassess intraocular pressure digitally				
Porcine	65.53	0.235	15.50	0.466
LCC Simulator	73.57		8.57	
#7 – If decompression is inadequate, proceed to cut superior canthal tendon				
Porcine	62.92	0.827	19.17	0.116
LCC Simulator	61.25		7.50	
#8 – Recognize a properly treated and decompressed eye				
Porcine	69.44	0.955	18.33	0.331
LCC Simulator	69.82		11.07	
#9 – Diagnose an ocular trauma that requires the LCC in the field				
Porcine	69.86	0.866	15.83	0.317
LCC Simulator	70.89		9.64	
#10 – Administer the LCC treatment in the field				
Porcine	67.50	0.850	16.67	0.972
LCC Simulator	66.07		16.43	
#11 – Determine whether decompression is adequately achieved				
Porcine	70.00	0.957	20.56	0.319
LCC Simulator	69.64		13.57	

Results

A total of 32 EP and EMPA residents volunteered for this study. Fourteen residents were assigned to the experimental group and 18 to the control group. The majority of volunteers were EMPA and intern EP residents, with lesser numbers of more senior EP residents (Table 1). Residency experience distribution was grossly equivocal between experimental and control groups. No statistically significant

difference was found between groups with regards to reported years of trauma or general medical experience (Table 2). Likewise, there were no significant differences found in reported baseline LCC procedural confidence (Table 3). After utilizing their respective models, both groups reported statistically significant increases across all reported confidence measures; however, there was no significant difference between groups in reported confidence (Table 4). Seven of the 10 usability survey questions demonstrated statistically significant differences in response, all in favor of the LCC simulator (Table 5).

Discussion

Overall, EP and EMPA resident confidence increased after completing LCC on a simulator or LTT model with no significant difference in confidence between groups throughout testing. These findings support that procedural confidence may increase with practice regardless of whether the resident utilizes the LCC simulator or LTT model. Furthermore, 70% of usability questions demonstrated significant differences in favor of the LCC simulator, suggesting the LCC simulator is more user-friendly without sacrificing procedural confidence.

Our results support the limited literature for using artificial simulators in LCC procedural training. Our findings support prior literature demonstrating significantly increased usability feedback from those using novel LCC simulators over the traditional LTT model.[27] While our results corroborate data showing improved procedural confidence following the use of an LCC simulator in general, our findings demonstrate for the first time increased LCC confidence after using a novel simulator compared to the traditional LTT model.[27,28]

LCC performance is rare in stateside EDs, as low as 7 procedures in 7 years at one trauma center.[11] This can produce challenges to gain hands-on experience in this critical skill.[8-11] A prior case series noted that two of three patients suspected of RBH were not properly treated, one due to poor performance and the second aborted due to provider discomfort with the procedure.[24] Given that LCC can be a rare, high stakes procedure with documented failures attributed to lack of confidence and skill suggests a need to find alternative practice methods to build and maintain both competency and confidence. This is especially true when clinicians whose medical experiences are only from stateside EDs are thrust into the severe trauma of battlefield medicine. Our findings encourage simulator consideration to gain and maintain both procedural competency and confidence for LCC.

Our study is limited primarily by its isolated population at a single trauma center. We presumed all demographic survey questions and confidence level scoring to be truthful and an accurate reflection of volunteers' perceptions of their diagnostic and procedural skills; however, this methodology could lead to a perception

Table 4. Comparison of pre- and post-lateral canthotomy and cantholysis simulator confidence of arms combined.

Confidence Survey Question	Pre-Sim		Post-Sim		Pre vs Post *P*
	Porcine	LCC Simulator	Porcine	LCC Simulator	
#1 – Confirm a retro-orbital hemorrhage with manual exam	61.1± 21.2	55.7±23.1	74.4±16.1	72.5±20.3	0.0003
#2 – Cutting Tendons	59.7±26.9	58.9±25.3	74.2±19.9	71.4±19.6	0.0005
#3 – Visually differentiate between a normal and propotic eye	67.5±19.1	76.4±19.1	76.4±12.8	78.6±17.9	0.0732
#4 – Differentiate between a normal and propotic eye by touch (i.e. pressure)	61.1±18.8	61.4±22.8	75.6±15.4	77.1±17.7	**<0.0001**
#5 – Perform a lateral canthotomy and cantholysis of the inferior canthal tendon	60.0±25.4	61.1±27.5	78.1±19.3	72.9±19.4	**0.0003**
#6 – Reassess intraocular pressure digitally	57.8±18.3	69.3±29.7	73.3±23.4	77.9±18.9	**0.0111**
#7 – If decompression is inadequate, proceed to cut superior canthal tendon	53.3±22.6	57.5±28.9	72.5±17.0	65.0±25.9	**0.0006**
#8 – Recognize a properly treated and decompressed eye	60.3±21.9	64.3±25.0	78.6±15.1	75.4±22.4	**0.0002**
#9 – Diagnose an ocular trauma that requires the LCC in the field	61.9±20.5	66.1±24.8	77.8±10.7	75.7±18.7	**0.0001**
#10 – Administer the LCC treatment in the field	59.2±25.6	57.9±25.2	75.8±19.9	74.3±21.0	**<0.0001**
#11 – Determine whether decompression is adequately achieved	59.7±24.3	62.9±23.3	80.3±14.6	76.4±19.5	**<0.0001**

* Data displayed as *mean* ± SD

Table 5. User feedback of lateral canthotomy and cantholysis simulator compared to porcine model.

Please check the box that reflects your immediate response to each statement (1 = Strongly Disagree, 5 = Strongly Agree)		
	Mean Score	*P*
1. I think that I would like to use this system frequently.		
Porcine	4.28	0.351
LCC Simulator	4.47	
2. I found this system unnecessarily complex.		
Porcine	1.66	**0.048**
LCC Simulator	1.38	
3. I though the system was easy to use.		
Porcine	3.91	0.832
LCC Simulator	4.41	
4. I think that I would need the support of a technical person to be able to use this system		
Porcine	2.53	**0.005**
LCC Simulator	1.56	
5. I found the various functions in this system were well integrated.		
Porcine	3.91	0.063
LCC Simulator	4.28	
6. I thought there was too much inconsistency in this system.		
Porcine	2.44	**0.003**
LCC Simulator	1.72	
7. I would imagine that most people would learn to use this system very quickly.		
Porcine	4.00	**0.032**
LCC Simulator	4.38	
8. I found the system very awkward to use.		
Porcine	2.06	**0.002**
LCC Simulator	1.44	
9. I felt very confident using the system.		
Porcine	3.84	**0.011**
LCC Simulator	4.34	
10. I needed to learn a lot of things before I could get going with this system.		
Porcine	2.09	**0.003**
LCC Simulator	1.47	

bias. While researchers asked volunteers if they had performed LCC on human patients before, we did not ask about all possible exposures to the procedure (such as assisting in the procedure or more generally observing), which may have influenced individual level of comfort as well. Similarly, a user's confidence in their ability, while supportive of undertaking future procedures, does not equate competence, and objective criteria to assess skill metrics should be evaluated in future studies. This study utilized a single LCC simulator model in a non-crossover randomized trial, and without prior data for comparison, it may be underpowered to analyze for true non-inferiority status of this model compared to the porcine model. Therefore, future research should be directed at expanding the size and locations of the sample population, as well as incorporating a skills assessment for further analysis, most ideally a human cadaver for realistic standardization.

Conclusion

Our study illustrated, for the first time, improved overall procedural confidence in LCC in both a novel LCC simulator and traditional LTT model in a military resident EM physician and EMPA population. Additionally, we found increased usability reported with simulator users compared to the LTT model in this population. These findings suggest that LCC simulators offer a less expensive alternative to more logistically-complicated LTT models. Further research is needed to expand populations and models and evaluate for procedural competency and speed in these simulators compared to LTT models as well as human cadavers.

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References

1. Akar Y, Apaydin KC, Ozel A. Acute orbital effects of retrobulbar injection on optic nerve head topography. *Br J Ophthalmol.* 2004;88:1573-6.
2. Ballard SR, Enzenauer RW, O'Donnell T, et al. Emergency lateral canthotomy and cantholysis: a simple procedure to preserve vision from sight threatening orbital hemorrhage. *J Spec Oper Med*. 2009;9(3):26-32.
3. Ansari MH. Blindness after facial fractures: a 19-year retrospective study. *J Oral Maxillofac Surg.* 2005;63(2):229-37.
4. Amagasaki K, Tsuji R, Nagaseki Y. Visual recovery following immediate decompression of traumatic retrobulbar hemorrhage via transcranial approach. *Neurol Med Chir (Tokyo).* 1998;38:221–4.
5. Zachariades, N., Papavassilious, D., and Christopoulos, P. Blindness after facial trauma. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1996;81(1):34-7.
6. Feist RM, Farber MD. Ocular trauma epidemiology. *Arch Ophthalmol*. 1989;107(4):503-4.
7. Feng K. Epidemiology of Ocular Trauma. In: Yan H. (eds) Anatomy and Examination in Ocular Trauma. *Ocular Trauma*. 2019, Springer, Singapore.
8. Fattahi T, Brewer K, Retana A, Ogledzki M. Incidence of retrobulbar hemorrhage in the emergency department. *J Oral Maxillofac Surg.* 2014;72(12):2500-2.
9. Lewis CD, Perry JD. Retrobulbar hemorrhage. *Expert Rev Opthalmol*. 2007;2(4):557-70.
10. Kloss BT, Patel R. Orbital compartment syndrome from retrobulbar hemorrhage. *Int J Emerg Med*. 2010;3(4):521-2.
11. Suner S, Simmons W, Savitt DL. A swine model for instruction of lateral canthotomy. *Acad Emerg Med*. 2000;7(7):837-8.
12. Sotomayor TM, Bailey MP, Dorton SL. Using simulation to address a training gap in battlefield ocular trauma: A lateral canthotomy and cantholysis (LCC) prototype training system. *Mil Med*. 2019;184(Suppl 1):335-41.
13. Burns GD, DeLellis SM. Lateral canthotomy in orbital compartment syndrome: special operations medics on the battlefield can save the eye. *J Spec Oper Med*. 2008;8(1):54-7.
14. Blanch RJ, Bindra MS, Jacks AS, Scott RA. Ophthalmic injuries in British Armed Forces in Iraq and Afghanistan. *Eye (Lond).* 2011;25(2):218-23.
15. Armed Forces Health Surveillance Center. Medical Surveillance Monthly Report (MSMR) 2011;18(5).
16. Gensheimer W, Mazzoli R, Reynolds M, Davies B, Pasternak J, Ellis J, et al. Eye trauma: Initial care. Joint Trauma System Clinical Practice

Guideline. Published online August 28, 2019. Accessed at: https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs.

17. Emergency medicine defined key index procedure minimums. Accreditation Council for Graduate Medical Education website. 2017. Accessed Sept 7, 2019. https://www.acgme.org/Portals/0/PFAssets/ProgramResources/EM_Key_Index_Procedure_Minimums_103117.pdf?ver=2017-11-10-130003-693.
18. Wen LS, Nagurney JT, Geduld HI, et al. Procedure competence versus number performed: a survey of graduate emergency medicine specialists in a developing nation. *Emerg Med J*. 2012;29:822-825.
19. Kovacs G, Bullock G, Ackroyd-Stolarz S, Cain E, Petrie D. A randomized controlled trial on the effect of educational interventions in promoting airway management skill maintenance. *Ann Emerg Med*. 2000;36(4):301–9.
20. De Jong A, Molinari N, Conseil M, Coisel Y, Pouzeratte Y, Belafia F, et al. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review and meta-analysis. *Intensive Care Med*. 2014;40(5):629-639.
21. Glance LG, Dick AW, Osler TM, Mukamel DB. The relation between surgeon volume and outcome following off-pump vs on-pump coronary artery bypass graft surgery. *Chest*. 2005;128(2):829-37.
22. Nallamothu BK, Saint S, Hofer TP, et al. Impact of patient risk on the hospital volume-outcome relationship in coronary artery bypass grafting. *Arch Intern Med*. 2005;165(3):333-37.
23. Sowden AJ, Deeks JJ, Sheldon TA. Volume and outcome in coronary artery bypass graft surgery: true association or artefact? *BMJ*. 1995;311(6998):151-55.
24. Ferguson IM. A human cadaveric workshop: one solution to competence in the face of rarity. *Emergency Medicine Australasia*. 2016;28(6):752-54.
25. Kong R, Kaya DP, Cioe-Pena E, Greenstein J. A low fidelity eye model for lateral canthotomy training. *Afr J Emerg Med*. 2018;8(3):118-122.
26. Sotomayor TM, Bailey MP, Dorton SL. Using simulation to address a training gap in battlefield ocular trauma: A lateral canthotomy and cantholysis (LCC) prototype training system. *Mil Med*. 2019;184(Suppl 1):335-341.
27. Herder PAP, Lu MM, LaPorta AJ, et al. Comparison of a novel trainer to a traditional swine model for training providers in lateral canthotomy and cantholysis. *Mil Med*. 2019;184(Suppl 1):342-346.
28. Herman L, Koch B, Benauer-Benning J. A low fidelity model for teaching lateral canthotomy procedure. *W J Emer Med*. 2017;18(Suppl 1):S34-S35.

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Special Operations Medics Test the Novel iView Video Laryngoscope: A Prospective, Randomized, Crossover Trial

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Abstract

Background: Airway compromise is the second leading cause of preventable death on the battlefield. Special operations medic comprise the majority of medics trained to perform endotracheal intubation (ETI), mostly by way of direct laryngoscopy (DL). The iView is a disposable, low-cost video laryngoscopy (VL) device, enabling its distribution to prehospital medical providers. We seek to compare time to intubation between DL and iView VL among special operations combat medics (SOCM).

Methods: We conducted a prospective, randomized, crossover trial. We enrolled special operations medics assigned to Joint Base Lewis McChord, WA. We randomized subjects to first performing VL or DL. Subjects performed a total of 10 ETI, 5 by VL and 5 by DL, on adult airway manikins. The primary outcome was time (in seconds) for ETI completion.

Results: A total of 32 medics completed 160 with DL ETIs and 160 VL ETIs. A total of 10 of 32 (31.3%) medics reported no previous experience with VL devices. We found a significant difference in time to intubation between VL and DL (20.4 (95% CI 20.6 - 26.1) seconds versus 23.4 (95% CI 18.7 - 22.2) seconds; $p = 0.03$) in favor of VL. All VL attempts were successful while 96.9% of DL were successful ($p = 0.10$). With respect to end-user appraisal of devices, a significant number of medics preferred the iView VL over DL (23 versus 9; $p < 0.00001$). Additionally, medics considered iView VL easier to use (5 [5-6] versus 5 [4-5]; $p = 0.0004$) and easier to learn, remember, and perform by combat medics (5 [5-5] versus 4 [4-5]; $p = 0.008$).

Conclusions: Special operations medics naïve to VL rapidly learned how to effectively utilize iView VL, as evidenced by a significant difference in time to intubation in favor of iView VL. Additionally, most medics favored iView VL and considered it easy to use, learn, and remember.

Keywords: airway, video laryngoscope, iView, intubation, prehospital, military

Introduction

Background: Airway compromise is the second leading cause of preventable death on the battlefield.[1,2] Tactical Combat Casualty Care (TCCC) guidelines recommend endotracheal intubation (ETI) if the prehospital medical provider possesses the skills and equipment to perform this life-saving intervention.[3] Among US Army medics, only Special Forces medical sergeants (military occupational specialty (MOS) 18D, Special Operations Combat Medic (SOCM) trained combat medics, MOS 68W additional skill identifier (ASI) W1, and Flight Paramedic trained combat medics, MOS 68W ASI F2, undergo ETI training. This instruction and skill maintenance, however, is limited to traditional direct laryngoscopy (DL) and subordinated to surgical cricothyroidotomy proficiency.

Video laryngoscopy (VL) offers potential advantages over DL with respect to ETI training and performance by non-physician medical providers.[4,5] During training, VL provides instructors and students a shared visualization of the intubating anatomy and conditions, which facilitates individualized coaching and learning for each procedural attempt.[6] This distinct feature of VL likely

Figure 1. iView video laryngoscope.

explains improved ETI performance by paramedic students reported in previously published studies.[7-9] Additionally, this feature of VL may permit telemedicine consultation of prehospital ETI, which may prove useful in the prolonged field care (PFC) setting.[10,11] DL relies on unobstructed, direct visualization of the intubating anatomy, while VL may overcome some obstacles (e.g. cervical immobilization preventing airway axes alignment) as the video camera is situated at the tip of the intubating device which is positioned proximal to the glottis.

This attribute of VL may account for multiple, published data demonstrating VL superiority to DL for vocal cord visualization and improved ETI success rates among civilian paramedics with limited ETI experience, infrequent performance of ETI, or in the setting of difficult airways.[12-22] Although numerous published data exist comparing VL to DL among civilian, non-physician, prehospital medical providers, we were unable to find any studies incorporating military medics as participants. Furthermore, there are no published studies evaluating the novel VL device called the iView (Intersurgical, Ltd. (Figure 1)).

The iView VL offers several advantages over another contemporary VL devices currently fielded by the US Army: the GlideScope Ranger (Verathon, Inc.). The iView is less expensive. An iView costs approximately $110, while a single GlideScope costs $12,292.67 (National Supply Number 6515-01-572-7262). The GlideScope is purchased as a multi-use device, while the iView is intended for single use. Unlike the GlideScope, the iView does not require an external power supply and is battery powered. Specific to visualization, the iView view finder is situated on the device handle along the intubator's visual axis, while the GlideScope view finder is connected by a cable to the device handle and is typically placed on or near the patient, but away from the intubator's visual axis. This can increase challenges with regards to hand-eye coordination. The GlideScope Ranger has a hyperangulated blade that requires a manufacturer-specific stylet, while the iView's blade mimics a MacIntosh blade and is compatible with generic stylets. Such a shape may make it useful as a DL device if necessary. The GlideScope, however, cannot be used as a DL device given its hyperangulated shape. The iView is smaller and weighs less than the GlideScope which enables packing it in a medical aid bag. The US Army Material Command may categorize the iView as expendable since it is a single-use, disposable item. The GlideScope, by contrast, is a durable, hand-receipted, property book item requiring periodic inventory. Like most durable equipment, the GlideScope requires periodic medical maintenance, while the iView does not. These characteristics of the iView make its distribution to military prehospital medical providers potentially favorable.

Goals of the Investigation: We seek to compare performance of ETI between traditional DL and a novel VL device (iView) among military medics with procedural training and experience. Secondarily, we will assess end-user appraisal of ETI, by device.

Methods

Ethics: The Regional Health Command - Pacific regulatory office reviewed protocol #219071 and determined it was exempt from institutional review board oversight. We received command approval for all participants prior to enrollment. All subjects consented to participation.

Subjects and Materials: We enrolled active duty US Army SOCMs assigned locally to Joint Base Lewis McChord, WA with previous training and experience in ETI and a current MOS of 18D, 68W W1, or 68W F2. We had no exclusion criteria. Subjects completed the study in groups of no more than 10 individuals to optimize available resources.

All subjects performed ETI on adult airway training

manikins. Airway models replicated normal anatomy, and we did not institute any measures to create a difficult airway scenario. Subjects performed DL with a MacIntosh blade size 4. Subjects performed VL with an iView (Item #8008000; Intersurgical, Ltd; Berkshire, UK). All subjects utilized a cuffed 7.5 mm endotracheal tube with generic endotracheal tube stylet and 10-cc syringe to inflate the cuff.

We conducted all study activities inside environmentally controlled buildings. We utilized a classroom for the training intervention and survey completion. We utilized simulated trauma bays that were lighted and temperature controlled for ETI iterations. We placed airway models on a gurney at waist height, with all airway equipment placed in standardized fashion to the side of it. Prior to participation, the participants could rearrange the equipment based on their preference. The iView VL was powered off and the DL laryngoscope was collapsed before each attempt. Subjects wore military or civilian attire, but did not wear or carry their combat gear. We did not simulate prehospital, combat conditions in order to reduce potential confounders and to maximize subject enrollment.

Protocol: We conducted a prospective, randomized, crossover trial. At the outset, all subjects completed a demographic worksheet and a pre-study ETI procedural confidence survey. Then, a single investigator (PC) provided subjects a 15-minute block of instruction on the iView VL only as medics are not trained in VL. The training intervention consisted of a standardized instructional video on device utilization and a hands-on practice period during which each subject performed 2 VL ETIs supervised by a single study investigator (PC). Afterwards, we randomized subjects utilizing an online randomization program (https://www.randomizer.org/) into 1 of 2 groups: VL first or DL first. Then, subjects moved to simulated trauma bays and performed a total of 5 ETIs with the initial intervention they were randomized to, followed by 5 ETIs with the remaining intervention. This crossover design replicates methods utilized in previously published studies comparing DL and VL ETI.[8,15,23-25] For each attempt, an investigator recorded the total time for ETI completion, assessed procedural success, and obtained from the subject whether the vocal cords were visualized or not during the procedure. We utilized a minimal washout period between interventions to reduce participant loss to follow-up since there is no published data delineating the optimal washout period for ETI. After performing all 10 ETIs, subjects returned to the classroom to complete post-study ETI procedural confidence and end-user device appraisal surveys.

Outcomes: The primary outcome of our study was time in seconds for ETI. Time started after the subject touched any of the equipment, and time ended once the cuff of the endotracheal tube was inflated. We did not end time when the endotracheal tube passed the cords, as was done in some previous studies, as investigators could not observe this event during DL attempts.

Our secondary outcomes included successful intubation, vocal cord visualization, subject confidence to perform ETI, and subject appraisal of intubating devices. We defined success as the endotracheal tube placed within the trachea and inflation of manikin lungs with bag valve mask compression. Placement was verified by an emergency medicine physician resident, emergency medicine physician assistant (EMPA), or emergency medicine physician assistant fellow. Investigators assessed each attempt as a success or failure while blinding subjects to this outcome to prevent confounding of self-confidence ratings. We assessed subject confidence to perform ETI pre- and post-study activities utilizing a continuous 0-100 Bandura scale.[26] We evaluated end-user assessments of ETI devices utilizing 6-point Likert items. We obtained vocal cord visualization verbally from subjects and recorded it as a yes or no. We relied on subject reports since DL attempts could not be visualized by investigators. We did not utilize a grading system for vocal cord visualization as DL attempts could not be verified by investigators, and medics are not trained in vocal cord grading schemes, such as Cormack-Lehane.

Data Analysis: We performed all statistical analyses using standard statistical software. We present 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 Sample t-Test, ordinal data with the Two-Sample t-Test, and dichotomous data with the Chi-Square test. We performed period and sequence analyses to assess for crossover effects. Pre-study power analysis for the primary outcome of time determined a sample size of 32 measurements was required to detect a difference of 10 seconds between interventions. Statistical significance was set at $p < 0.05$.

Results

From January to June of 2020, 32 medics volunteered for this study and all met inclusion criteria. All medics were male with an average age of 31.2 years and 9.5 years of active duty service in the US Army (Table 1). Subjects reported previous performance of ETI on median number of 50 (IQR 30-100) airway models, 14 (6-20) living patients, and 0 (0-1) casualties while deployed for military operations. A total of 10 of 32 (31.3%) medics

reported no previous experience with VL devices—6 of 10 (60%) were 68W W1 and the remainder were 18D. Of those with VL experience, medics reported a median of 2 (0-5) previous VL enabled ETI by the following devices in order of frequency: unknown (38%), GlideScope (28%), and another specified VL device (3%).

Table 1. Participant demographic data.

Characteristic	Total (%)	DL First Total (%)	VL First Total (%)
Gender			
Male	32 (100)	19 (59)	13 (41)
Age (years)			
20-30	15 (47)	9 (60)	6 (40)
31+	17 (53)	10 (59)	7 (41)
MOS			
18D	11 (34)	7 (64)	4 (36)
68W W1	21 (66)	12 (57)	9 (43)
Unit			
1st Special Forces Group	8 (25)	5 (63)	3 (37)
19th Special Forces Group	4 (12.5)	0 (0)	4 (100)
2nd Battalion, 75th Ranger Regiment	16 (50)	12 (75)	4 (25)
160th Special Operations Aviation Regiment	4 (12.5)	2 (50)	2 (50)

DL – direct laryngoscopy
VL – video laryngoscopy
MOS – Military Occupational Specialty
18D – Special Forces medic
68W W1 – Combat medic, Special Operations Combat Medic trained

We evaluated a total of 320 ETIs (160 by DL, 160 by VL) (Table 2). We found a significant difference in time for ETI performance between VL and DL (20.4 [95% CI 20.6 – 26.1] seconds versus 23.4 [95% CI 18.7 – 22.2] seconds; p = 0.03) in favor of VL. We performed sequence and period analyses to evaluate for crossover effects and we found no differences, which substantiates the results with respect to time. Additionally, we found no differences between devices with respect to procedural success and vocal cord visualization rates (Table 2).

Table 2. ETI performance between devices.

Performance factor	DL (n = 160)	VL (n = 160)	p-value
Time (seconds)	23.4 [95% CI 20.6 – 26.1]	20.4 [95% CI 18.7 – 22.2]	0.03
Success	100%	97%	0.10
Vocal cord visualization	99%	100%	0.28

ETI – Endotracheal intubation
DL – direct laryngoscopy
VL – video laryngoscopy

With respect to end-user appraisal of devices, we found a significant number of medics preferred the VL over the DL (23 versus 9; p < 0.00001) (Table 3). Additionally, we found medics considered the iView VL easier to use (5 [5-6] versus 5 [4-5]; p = 0.0004) and easier to learn, remember, and perform by combat medics (5 [5-5] versus 4 [4-5]; p = 0.008). We also found a significant increase in medic self-confidence to perform ETI with both VL (84.0 pre-study versus 90.1 post-study; p = 0.008) and DL (82.2 pre-study versus 89.1 post-study; p = 0.002).

Discussion

We evaluated the performance of a new VL device, the iView, in the hands of military medics who may perform ETI in the prehospital, combat setting. Despite participants being naïve to VL, we found a significant difference in ETI completion time in favor of the iView. We did not find a difference between VL and DL with respect to both procedural success and vocal cord visualization; however, we observed high rates for both measures. These findings suggest military medics can rapidly learn and implement the VL technology. Furthermore, an overwhelming majority of medics favored the iView VL over DL. Given the potential logistical and procedural advantages of the iView VL over the current device. Additional research evaluating this novel device is warranted to determine its suitability for military fielding.

Table 3. End-user appraisal of devices.

Interrogatory	DL	VL	p-value
Device preferred: DL or VL?	9 (28%)^	23 (72%)^	<0.00001
Device ease of use	5 [4-5]*	5 [5-6]*	0.0004
Device easily learned, remembered, and performed by combat medics	4 [4-5]*	5 [5-5]*	0.008

^ Reported as total (percentage); evaluated with Chi-square Goodness-of-Fit test
* Reported as median (IQR); evaluated with Two-Sample t-Test
DL – direct laryngoscopy
VL – video laryngoscopy

We found a significant difference in time for ETI completion between iView VL and DL, while multiple studies of civilian paramedics performed VL reporting procedural times found no difference in ETI completion times between VL and DL.[14,15,24] Nasim, et al. compared two VL devices to DL in airway manikins. They measured time from the passage of the laryngoscope blade past the model's teeth to the participant's vocalization of procedural completion. Among manikins with normal airway anatomy, they reported ETI completion times of 7 seconds for Pentax Airway Scope VL, 11 seconds for GlideScope VL, and 8 seconds for DL.14 Yun, et al. reported ETI completion times of 27.7 seconds for one VL device, 24.7 seconds for another VL device, and 26.6 seconds for DL on manikins with normal airway anatomy; however, they did not report the parameters of their time measurement.[24] Piepho, et

al. graphically reported times for all ETI attempts on manikin models with normal airway anatomy, and they found no difference in ETI completion times between two VL devices and DL by the third iteration, which they attributed to learning.[15] The difference between the findings of these studies and ours may be explained by civilian paramedics possessing more experience with ETI as it is their primary definitive airway intervention, while military medics prioritize cricothyroidotomy skill maintenance over ETI due to limited availability of rapid sequence intubation (RSI) medications in the combat, prehospital environment, and TCCC guideline recommendations.[3] Another contributing factor may be the novel iView device itself as it has different design features than the other VL devices used in the previous trials. Our findings, however, are consistent with previous studies in demonstrating medical providers with previous ETI training, but naïve to VL techniques, rapidly learn VL enabled ETI.[9,14,15,23-25] Consequently, our findings suggest military medics with previous ETI training can quickly learn and utilize the iView VL device which may enable its fielding to military medics.

We found no difference in ETI success rates between iView VL and DL. Published data comparing ETI success rates between VL and DL performed by paramedics on airway manikins with normal airway anatomy also found no differences in success rates.[8,14-16,24] These studies reported overall success rates of 94-100% for VL and 94-100% for DL.[8,14,15,24] Our findings are consistent with these results. All these findings suggest the use of mannequins has some limitations in translation to real airway management.[27-29] Some of these studies, however, also compared VL to DL in manikins with simulated difficult airways.[14-16] VL may offer advantages over DL in the setting of difficult airways since DL requires direct visualization of intubating anatomy which may not be possible in a difficult airway scenario. Woollard, et al. found VL performed better than DL among both novice and experienced paramedics on a difficult airway model. They reported novice ETI success rates of 78% for VL and 30% for DL, and experienced intubator success rates of 84% for VL and 25% for DL.[16] On the other hand, Nasim, et al. found no difference in ETI success rates between VL and DL in simulated difficult airways, but reported DL resulted in more dental complications and required more optimization maneuvers.[14] Piepho, et al. also found no difference in ETI success rates for difficult airways, but noted VL enabled superior glottic views and was clearly preferred over DL by participants.[15] Difficult airways are expected among trauma casualties, whether due to cervical immobilization, maxillofacial trauma, inhalation injury, or oropharyngeal debris. In the combat prehospital setting, successful airway management may be further complicated by environmental factors such as patients recumbent on the ground (not elevated on gurneys) and medical providers wearing body armor with equipment mounted on their chest that prevents them from lying flat on the ground in a position that suits DL ETI. Consequently, a VL capability in the military prehospital setting may be advantageous to address difficult intubating conditions. Future research evaluating military prehospital VL ETI should replicate combat point-of-injury conditions and difficult airway situations to compare VL and DL performance.

Published data for live patients intubated by paramedics in the prehospital setting demonstrate differences in favor of VL over DL.[7,12,13,21,22] Jarvis, et al. retrospectively evaluated 514 ambulance-based ETI attempts and reported overall ETI success rates of 91.5% for VL and 64.9% for DL.[12] Additionally, they found first-pass success rates differed between devices: 74.2% for VL and 43.8% for DL.[12] Wayne, et al. also retrospectively compared VL to DL for 615 ambulance-based ETI, but did not find a difference in overall ETI success rates (97% for VL, 95% for DL); however, they found differences in the number of ETI attempts (1.2 for VL, 2.3 for DL) and time for procedural completion (21 seconds for VL, 42 seconds for DL).[13] Boehringer, et al. retrospectively compared VL to DL among 790 aeromedical evacuation patients that underwent ETI.[22] They found differences in favor of VL with respect to overall ETI success rates (99% for VL, 95% for DL) and first-pass success rates (94.9% for VL, 75.4% for DL).[22] Guyette, et al. also retrospectively compared VL to DL for 858 life-flight patients, but they did not find any difference in first-pass success rates (85.6% for VL, 86.1% for DL).[21] Levitan, et al. compared VL to DL among paramedics learning ETI in hospital operating rooms and found success rates favored VL (88.1% for VL, 46.7% for DL).[7] Multiple reviews of literature conclude that VL outperforms DL in the hands of inexperienced paramedics or among experienced paramedics that infrequently perform ETI.[9,18-20] Military medics infrequently perform ETI and airway sustainment training prioritizes cricothyrotomy proficiency. Consequently, military medics may benefit from a VL capability.

We found that an overwhelming majority of medics preferred the iView VL over the traditional DL. Their survey responses indicated that they found the iView easy to use, learn, and remember. Additionally, multiple medics voiced their preference for the iView since it would enable ETI at or near the point-of-injury when they are wearing tactical equipment and the patient is recumbent on the ground. Previous studies comparing VL to DL that assessed end-user appraisals of devices also found

that VL was preferred over DL, especially in difficult airway scenarios.[15,30]

Our study has several important limitations. First, we did not simulate combat conditions that medics would be expected to perform ETI within. We conducted study activities in well-lit trauma bays, with manikins on gurneys, and medics not wearing combat gear. Consequently, our findings for both VL and DL ETI should not be considered to be representative of expected performance in an armed conflict setting. Second, we utilized airway training manikins for all ETI attempts. Simulation models do not fully replicate living human tissue and physiology. Furthermore, our models possessed normal airway anatomy, and we did not institute any measures to replicate difficult intubation conditions. Consequently, we were not able to assess differences between VL and DL in difficult airway situations. Third, we did not institute a significant washout period between crossover arms. There is no published data outlining optimal washout periods for ETI; we elected a minimal washout period to optimize participation as we only had access to the medics for a limited period. Therefore, outcomes of the second intervention may have been improved by virtue of iterations completed during the first intervention attempted. We attempted to control for this by randomizing the initial intervention performed. Furthermore, we performed multiple statistical evaluations of period, sequence, and iteration groupings which validated the treatment effects observed. Lastly, study population is limited to special operations medics at a single US Army installation. Consequently, findings are not generalizable to all military medics with previous ETI training.

Conclusion

Special operations medics naïve to VL rapidly learned how to effectively utilize the iView VL, as evidenced by a significant difference in time for ETI completion in favor of the iView VL over traditional DL. Additionally, most medics favored the iView VL over the traditional DL and considered it easy to use, learn, and remember.

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References

1. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J of trauma and acute care surgery*. 2012;73(6):S431-S437.
2. Kelly JF, Ritenour AE, McLaughlin DF, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. *J of Trauma and Acute Care Surg*. 2008;64(2):S21-S27.
3. CoTCCC J. Tactical Combat Casualty Care Guidelines. Deployed Medicine. https://deployedmedicine.com/content/40. Published 1 August 2019. Accessed 24 October 2019, 2019.
4. Aziz MF, Abrons, Ron O., Cattano, Davide, Bayman, Emine O., Swanson, David E., Hagberg, Carin A., Todd, Michael M., Brambrink, Ansgar M. First-Attempt Intubation Success of Video Laryngoscopy in Patients with Anticipated Difficult Direct Laryngoscopy A Multicenter Randomized Controlled Trial Comparing the C-MAC D-Blade Versus the GlideScope in a Mixed Provider and Diverse Patient Population. *Anesthesia & Analgesia*. 2016;122(3):740-750.
5. Rombey T, Schieren, M, Pieper, D. Video Versus Direct Laryngoscopy for Inpatient Emergency Intubation in Adults A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Deutsches Arzteblatt International*. 2018 115(26):437-444.
6. Hurford WE. The video revolution: a new view of laryngoscopy. *Respiratory care*. 2010;55(8):1036-1045.
7. Levitan RM, Goldman TS, Bryan DA, Shofer F, Herlich A. Training with video imaging improves the initial intubation success rates of paramedic trainees in an operating room setting. *Annals of emergency medicine*. 2001;37(1):46-50.
8. Aziz M, Dillman D, Kirsch JR, Brambrink A. Video laryngoscopy with the macintosh video laryngoscope in simulated prehospital scenarios by paramedic students. *Prehospital Emergency Care*. 2009;13(2):251-255.
9. Vanderbilt AA, Mayglothling J, Pastis NJ, Franzen D. A review of the literature: direct and video laryngoscopy with simulation as educational intervention. *Advances in medical education and practice*. 2014;5:15.
10. de Barbara AHA. The Spanish Ministry of Defence (MOD) Telemedicine System. *Advances in Telemedicine: Technologies, Enabling Factors*

and Scenarios. 2011:379.

11. Sakles JC, Mosier J, Hadeed G, Hudson M, Valenzuela T, Latifi R. Telemedicine and telepresence for prehospital and remote hospital tracheal intubation using a GlideScope videolaryngoscope: a model for tele-intubation. *Telemed and e-Health*. 2011;17(3):185-188.
12. Jarvis JL, McClure SF, Johns D. EMS intubation improves with king vision video laryngoscopy. *Prehosp Em Care*. 2015;19(4):482-489.
13. Wayne MA, McDonnell M. Comparison of traditional versus video laryngoscopy in out-of-hospital tracheal intubation. *Prehospital Emergency Care*. 2010;14(2):278-282.
14. Nasim S, Maharaj CH, Malik MA, O'Donnell J, Higgins BD, Laffey JG. Comparison of the Glidescope and Pentax AWS laryngoscopes to the Macintosh laryngoscope for use by Advanced Paramedics in easy and simulated difficult intubation. *BMC emergency medicine*. 2009;9(1):9.
15. Piepho T, Weinert K, Heid FM, Werner C, Noppens RR. Comparison of the McGrath Series 5 and GlideScope Ranger with the Macintosh laryngoscope by paramedics. *Scandinavian j of trauma, resuscitation and emergency medicine*. 2011;19(1):4.
16. Woollard M, Lighton D, Mannion W, et al. Airtraq vs standard laryngoscopy by student paramedics and experienced prehospital laryngoscopists managing a model of difficult intubation. *Anaesthesia*. 2008;63(1):26-31.
17. Woollard M, Mannion W, Lighton D, et al. Use of the Airtraq laryngoscope in a model of difficult intubation by prehospital providers not previously trained in laryngoscopy. *Anaesthesia*. 2007;62(10):1061-1065.
18. Arulkumaran N, Lowe J, Ions R, Mendoza M, Bennett V, Dunser M. Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. *British journal of anaesthesia*. 2018;120(4):712-724.
19. Jacobs P, Grabinsky A. Advances in prehospital airway management. *International journal of critical illness and injury science*. 2014;4(1):57.
20. Savino PB, Reichelderfer S, Mercer MP, Wang RC, Sporer KA. Direct versus video laryngoscopy for prehospital intubation: a systematic review and meta-analysis. *Academic Emergency Medicine*. 2017;24(8):1018-1026.
21. Guyette FX, Farrell K, Carlson JN, Callaway CW, Phrampus P. Comparison of video laryngoscopy and direct laryngoscopy in a critical care transport service. P*rehospital Emergency Care*. 2013;17(2):149-154.
22. Boehringer B, Choate M, Hurwitz S, Tilney PV, Judge T. Impact of video laryngoscopy on advanced airway management by critical care transport paramedics and nurses using the CMAC pocket monitor. *BioMed Research International*. 2015;2015.
23. Szarpak Ł, Czyżewski Ł, Kurowski A, Truszewski Z. Comparison of the TruView PCD video laryngoscope and macintosh laryngoscope for pediatric tracheal intubation by novice paramedics: a randomized crossover simulation trial. *European j of pediatrics*. 2015;174(10):1325-1332.
24. Yun BJ, Brown CA, Grazioso CJ, Pozner CN, Raja AS. Comparison of video, optical, and direct laryngoscopy by experienced tactical paramedics. *Prehospital Emergency Care*. 2014;18(3):442-445.
25. Berg BW, Vincent DS, Murray WB, Boedeker BH. Videolaryngoscopy for intubation skills training of novice military airway managers. *Studies in health technology and informatics*. 2009;142:34-36.
26. Bandura A. Guide for constructing self-efficacy scales. *Self-efficacy beliefs of adolescents*. 2006;5(1):307-337.
27. Toda J, Toda, A., Arakawa, J. Learning curve for paramedic endotracheal intubation and complications. *Intl J of Em Med*. 2013;6(38).
28. Bradley JS, Billows, GL, Olinger, ML., Boha, SP., Cordell, WH., Nelson, DR. Prehospital Oral Endotracheal Intubation by Rural Basic Emergency Medical Technicians. *Annals of Em Med*. 1996;32:26-32.
29. Brownstein D, Shugerman R, Cummings P, Rivara F, Copass M. Prehospital Endotracheal Intubation of Children by Paramedics. *Annals of Em Med*. 1995;28(1):34-39.
30. Wallace MC, Britton ST, Meek R, Walsh-Hart S, Carter CTE, Lisco SJ. Comparison of five video-assisted intubation devices by novice and expert laryngoscopists for use in the aeromedical evacuation environment. *Mil Med Res*. 2017;4(1):20.

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An Analysis of US Africa and Indo-Pacific Commands Military Working Dog Medical Transportation, 2008-2018

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Abstract

Introduction: Military working dogs (MWD) deploy with diverse tasks. Given significant utilization in Central Command (CENTCOM) for combat operations, the majority of MWD medical literature centers on combat trauma from this theater. Other commands, to include Indo-Pacific Command (INDOPACOM) and Africa Command (AFRICOM) utilize MWDs for low-intensity operations. To date, there is no analysis of medical evacuations of MWDs from the INDOPACOM and AFRICOM theaters. We seek to analyze MWD medical evacuations from these theaters utilizing the Transportation Command (TRANSCOM) Regulating and Command & Control Evacuation System (TRAC2ES).

Methods: We performed a retrospective review of all TRAC2ES medical records for MWD medical evacuations from the INDOPACOM and AFRICOM theaters conducted between January 2008 and December 2018. We abstracted free text data entry in TRAC2ES for diagnostic and therapeutic interventions performed prior to movement requests.

Results: MWD evacuations constituted 0.2% (n=10) of 4,217 documented medical evacuations from INDOPACOM and 0.3% (n=3) of 962 individually documented medical evacuations from AFRICOM. Most were routine precedence (n=8). All MWDs were evacuated for disease and non-battle injury including bone (n=4) and dental (n=2) fractures. Some had more than one provisional diagnosis and/or poly trauma. Analgesia was the most common intervention prior to evacuation (n=4).

Conclusions: MWDs accounted for a small proportion of TRAC2ES evacuations in AFRICOM and INDOPACOM theaters from 2008-2018, most due to non-battle traumatic injuries. Future studies should consider more focused MWD medical evaluations in these theaters to develop a broader understanding of medical treatment trends.

Keywords: evacuation, transport, canine, trauma

Introduction

Background: Military working dogs (MWD) serve alongside service members as integral team members in domestic and international force protection efforts. Utilization of an estimated 2,600 MWDs throughout the Central Command (CENTCOM) theater demonstrates their operational importance, including reviews on medical evaluation and treatment of canine injuries.[1-3] However, previous military literature largely focuses on expected combat trauma during the course of high-risk duties like explosive detection or patrols, or otherwise relates to austere climates exclusive to the CENTCOM theater.[1-6] Other forward-deployed areas, to include the Indo-Pacific Command (INDOPACOM) and Africa Command (AFRICOM) theaters likewise employ MWDs but largely away from direct combat threats and with an absence of available data to guide planning.

Modern study of MWD injuries and management

centers on CENTCOM cases with trends varying between regions within the theater. A 12-year review of 92 MWD deaths during Operation Iraqi Freedom (OIF) and Operation Enduring Freedom in CENTCOM found two-thirds occurred from trauma, most from combat.[2] Most MWD injuries in Iraq occurred secondary to trauma, while those in Kuwait split between trauma, heat stress, and gastrointestinal issues.[6] These limited findings within CENTCOM may indicate that once removed from a combat environment, disease and non-battle injury (DNBI) mechanisms increase proportionally. Despite low incidence in the literature, the ongoing use of MWDs throughout this environment with decreased access to rapid veterinary care results in canine evaluation and treatment at medical facilities intended for humans. Subsequently, the Joint Trauma System (JTS) released MWD clinical practice guidelines (CPG) in 2018, and in 2019, the Canine Combat Casualty Care Committee (CCCCC) formed as an affiliate of the Committee on Tactical Combat Casualty Care (CoTCCC) and released their own CPGs to increase human-based medical providers versatility to care for MWD.[7,8] Largely citing the CENTCOM theater, these CPGs focus on initial battlefield care.

The geography, climate, and operational focus of the INDOPACOM and AFRICOM areas is significantly different and heterogenous from that of smaller homogenous CENTCOM. INDOPACOM stretches across the entire Pacific Ocean, at its largest approximately 12,000 miles (19,300 kilometers). It contains seasonal shifts in freezing temperatures of Northern Japan to year-long tropical humidity in Fiji, as well as varying environments of China. Medical facilities are scattered, with larger hospitals only in the Republic of Korea and Hawaii. Likewise, AFRICOM covers an area 3 times the size of the continental United States with diverse climates ranging from the arid Saharan Desert to dense Congolese rain forests. Formally established in 2008, AFRICOM additionally lacks a mature medical logistical supply with a single role 2 hospital.[9,10] Both areas therefore rely heavily on host nation facilities for immediate specialty care, or face prolonged basic care given extensive transport times to US-based facilities.

The US Air Force, through their Transportation Command (TRANSCOM), oversees the medical evacuation patient movements throughout military areas of operation as part of the military missions. The TRANSCOM Regulating and Command & Control Evacuation System (TRAC2ES) provides the electronic platform of medical coordination for all Department of Defense (DoD) patients.[11] As an automated information system, TRAC2ES assembles, assesses, and prioritizes patient movement requirements, assigns resources, and distributes data to relevant parties.[12] Human and canine patients are included in this system.

Despite demographic differences between theaters, limited MWD literature remains focused on prehospital combat trauma care in CENTCOM. There is no published studies on MWD medical trends in other theater commands, including medical evacuation to higher echelons of care. Previous literature identifies knowledge gaps in human medical evacuation in low-intensity conflict areas within INDOPACOM and AFRICOM, but no similar studies in MWDs exist.[9]

Goals of this Investigation: We seek to analyze MWD medical care transport demographics within the INDOPACOM and AFRICOM areas.

Methods

Data for this study was as part of a larger analysis on patient movements through the AFRICOM and INDOPACOM area of operations previously described. The 59th Medical Wing regulatory office reviewed protocol FWH20180147N and determined it was exempt from institutional review board oversight. We obtained only de-identified data for analysis.

We extracted the data from TRAC2ES patient movement reports and present it using descriptive methods for this case series. Within the datasets from AFRICOM and INDOPACOM we use the following search terms: dog, MWD, K9, and canine to identify cases for analysis. Some data descriptors are designated by the TRAC2ES system. In differentiating battle injury (BI) and non- battle injury (NBI), we defined BI as an injury sustained from hostile action or mission-oriented tasks indicated by mechanism of injury, including gunshot wounds (GSW), improvised explosive devices (IED), mortars, rockets, other ordinance, or motor vehicle accidents or collisions. Nonbattle injury (NBI) was defined as any injury not defined under BI mechanisms. Disease was defined as any illness not defined by BI or NBI mechanisms.

We performed all statistical analysis, and used descriptive statistics, reporting categorical variables as numbers with percentages and ordinal variables as medians with interquartile ranges.

Results

From 2008-2018, MWDs comprised 0.2% (n = 10) of 4,217 individually documented medical evacuations from INDOPACOM and 0.3% (n = 3) of the 962 individually documented medical evacuations from AFRICOM

(Table 1). Overall, the median age of MWD evacuees was 5 years old, although INDOPACOM MWD evacuees were approximately 1 year older. Only 2 records contained breed identification, specifying Belgian Malinois for both. Most evacuations had routine precedence (n = 8); however, there were no routine evacuations from the AFRICOM area of operations. All dogs were transported via military aircraft.

Table 1. Baseline characteristics.

	Overall (13)	INDOPACOM (10)	AFRICOM (3)
Demographics			
Age (mean, range)	5 (3-9)	6 (3-9)	4 (4)
Male	69% (9)	70% (7)	67% (2)
Evacuation Status			
Routine	62% (8)	80% (8)	0% (0)
Priority	15% (2)	10% (1)	33% (1)
Urgent	23% (3)	10% (1)	67% (2)
Transportation Method			
Military	100% (13)	100% (10)	100% (3)
Origin Country			
Japan	54% (7)	70% (7)	0% (0)
Guam	23% (3)	30% (3)	0% (0)
Djibouti	15% (2)	0% (0)	67% (2)
Other AFRICOM	8% (1)	0% (0)	33% (1)
Destination Country			
Japan	62% (8)	80% (8)	0% (0)
Other INDOPACOM	15% (2)	20% (2)	0% (0)
Germany	23% (3)	0% (0)	100% (3)

*All data are presented as percentage (total number) unless otherwise specified.

All MWDs were medically evacuated for DNBI concerns (Table 2). Most evacuations were for musculoskeletal diagnoses, either from non-battle physical injuries or chronic issues. These most frequently centered on fracture of bone (n = 4) or dental (n = 2); some had more than one provisional fracture diagnosis. Prior to evacuation, the most commonly documented intervention was analgesia (n = 4), followed by antibiotics (n = 2), whole blood (n = 1), and muscle relaxers (n = 1).

Discussion

We describe the first demographic analysis of MWD medical evacuations within the TRAC2ES database for the INDOPACOM and AFRICOM theaters. All evacuations within this dataset were for DNBI concerns, most due to non-battle injury pertaining to fractures. It is important to note that we analyzed encounters documented in the TRAC2ES database only, and therefore cannot evaluate MWDs medical care without evacuation, either from local military treatment facilities or host nation care, or those who may have been evacuated outside of TRAC2ES (e.g. casualty evacuation via non-regulated movement). Although limited comparison can be made with prior analysis CENTCOM operations given a larger focus on mortality etiologies, our findings nevertheless reflect a strong disparity in trends given the absence of combat-related injuries in INDOPACOM or AFRICOM requiring evacuation.

While CENTCOM-based literature estimates up to 2,600 MWDs deployed to OIF and OEF from 2001-2014, there are no similar established personnel strength estimates for the INDOPACOM and AFRICOM theaters, including a notable gap in medical descriptions.[1-3] This uneven focus on combat theaters may produce a battlefield trauma-centered approach to MWD care with the JTS and CCCCC CPGs. In contrast, the predominant medical concern necessitating evacuation in the INDOPACOM and AFRICOM theaters was non-battle injury in nature. The overlap of care for musculoskeletal trauma with battle and non-battle injuries allows reference to these CPGs in some respects; however, utilization remains unclear. In this aspect, while JTS CPGs for analgesia MWDs stress the use of opioid medications (morphine, fentanyl, hydromorphone), these were absent in all cases of evacuation in our dataset.[7] Conversely, JTS strongly advises against the use of NSAIDs, used in 1 case of bone fracture, and supports the use of ketamine for sedation only, whereas a laceration case notes the use of ketamine specifically for pain in our analysis.[7] These disparities may reflect asymmetrical priorities of prehospital care between theaters.

Prior study identifies issues of scattered veterinary specialty care throughout theater commands, necessitating the use of forward surgical teams to modify practice and treat canine patients.

Table 2. Reason for transport and documented diagnostic and therapeutic interventions

Variable	% (n)*
Chief Complaint	
Battle Injury	0% (0)
Non-Battle Injury**	53% (7)
Extremity fracture	28% (2)
Dental fracture	28% (2)
Ligament rupture	28% (2)
Other fracture	28% (2)
Laceration	14% (1)
Disease	47% (6)
Gastrointestinal	8% (1)
ENT	8% (1)
Respiratory	8% (1)
Chronic MSK	15% (2)
Coagulopathy	8% (1)
Diagnostics	
Any radiograph	23% (3)
Extremity radiograph	8% (1)
Chest radiograph	8% (1)
CT scan	8% (1)
Interventions	
Antibiotics	15% (2)
NSAID	8% (1)
Tramadol	8% (1)
Ketamine	8% (1)
Diazepam	8% (1)
Whole blood	8% (1)

*All data are presented as percentage (total number) unless otherwise specified.
**Some patients had multiple injuries from a single event; numbers presented are not exclusive.

These include DNBI concerns as well, primarily gastrointestinal surgical concerns of volvulus.[13,14] Veterinary facilities are located in INDOPACOM areas with large established military bases (Republic of Korea, Japan, Hawaii), but smaller outlying facilities may not have surgical capabilities, necessitating medical evacuation. This is evident with 60% of INDOPACOM evacuations transporting MWDs between sites in Japan. Furthermore, given the immense territory and wide range of operational tasks within the AFRICOM theater, the evacuation of all MWDs to Landstuhl Regional Medical Center in Germany for advanced care indicates a possible need for increased intratheater veterinary capabilities. Otherwise, these evacuations highlight the need for increased canine healthcare training for human healthcare personnel, given the low likelihood that a veterinarian will be available at sites of initial care.

Of note, given the origin of the data coming from TRAC2ES we can only highlight the cases that required transport via this regulated patient movement system. Thus, we are unable to describe any cases that died before transport or those that were moved via non-regulated movement such as local casualty evacuation via non-standard means. Our number therefore likely underrepresents the actual number of dogs that were injured and either died prehospital or were treated locally. Moreover, our study is limited due to TRAC2ES data entry methods. As noted in prior literature, data entry is largely performed by non-medical personnel for the purpose of supporting patient movements, which creates potential sources of error including incomplete records.[8] The database does not exist for the purposes of performance improvement. This is furthered by the free form entry of patient history and treatment within the system, establishing uneven details of care with varying granularity. Our study supports the need to develop a more robust performance improvement system for MWDs. Patient movements in TRAC2ES are for live transport only, and thus if any MWDs died before transport, they were not captured in this database. Our volume was relatively low, and as such our study carries with it the usual limitations associated with a case series.

Our analysis establishes the first review of all INDOPACOM and AFRICOM MWDs medically evacuated utilizing TRAC2ES. Like previous literature on human medical evacuations from INDOPACOM and AFRICOM, the focus on DNBI in these populations highlights the unique nature of these theaters compared to CENTCOM. Identified limitations in data capture demonstrate a need for enhanced collection systems in INDOPACOM and AFRICOM.

Conclusion

MWDs accounted for a small proportion of TRAC2ES evacuations in AFRICOM and INDOPACOM theaters from 2008-2018, most due to non-battle traumatic injuries. Future studies should consider more focused MWD medical evaluations in these theaters to develop a broader understanding of medical treatment trends.

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References

1. Baker JL, Havas KA, Miller LA, Lacy WA, Schlanser J. Gunshot wounds in military working dogs in Operation Enduring Freedom and Operation Iraqi Freedom: 29 cases (2003-2009). *J Vet Emerg Crit Care (San Antonio)*. 2013 Jan-Feb;23(1):47-52.
2. Miller L, Pacheco GJ, Janak JC, Grimm RC, Dierschke NA, Baker J, Orman JA. Causes of Death in Military Working Dogs During Operation Iraqi Freedom and Operation Enduring Freedom, 2001-2013. *Mil Med*. 2018 Sep 1;183(9-10):e467-e474.
3. Lagutchik M, Baker J, Balser J, et al. Trauma management of military working dogs. *Mil Med*. 2018;183(Suppl 2):180-189.
4. Mey W, Schuh-Renner A, Anderson MK, Stevenson-LaMartina H, Grier T. Risk factors for injury among military working dogs deployed to Iraq. *Prev Vet Med*. 2020;176:104911.
5. Baker JL, Truesdale CA, Schlanser JR. Overview of combat trauma in military working dogs in Iraq and Afghanistan. *J Spec Oper Med*. 2009;9(2):105-108.
6. Toffoli CA, Rolfe DS. Challenges to military working dog management and care in the Kuwait theater of operation. *Mil Med*. 2006;171(10):1002-1005.
7. Lagutchik M, Baker J, Brown J. Joint Trauma System Clinical Practice Guidelines: Clinical Practice Guidelines for Military Working Dogs. December 12, 2018. Accessed September 19, 2020 at: https://jts.amedd.army.mil/assets/docs/cpgs/Military_Working_Dog_CPGs/MWD_CPG_ 12_Dec_2018_ID16.pdf.
8. Edwards TH, Palmer LE, et al. Canine tactical combat casualty care (K9TCCC) guidelines. *J Spec Oper Med*. 2020;20(1):101-111.
9. Carius BM, Davis WT, Linscomb CD. An analysis of US Africa command area of operations military medical transportations, 2008-2018. *Afr J Emerg Med*. 2020;10(1):13-16.
10. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of casualties evacuated from the Africa area of operations. *Afr J Emerg Med*. 2019;9(Suppl):S43–S46. https://doi.org/10.1016/j.afjem.2018.09.004.
11. Rasmussen T, Baer DG, Cap AP, et al. Ahead of the curve: sustained innovation for future combat casualty care. *J Trauma Acute Care Surg.* 2015;79:S61-63. https://doi.org/10.1097/TA0000000000000795.
12. Clark P. MC4 Systems Support TRAC-2ES, DoD's Joint Patient Movement Process. *The Gateway–MC4 News*. October 2017, https://www.mc4.army.mil/Media/news.aspx?pName=MC4_Systems_Support_TRAC-2ES,_DoD%E2%80%99s_Joint_Patient_Movement_Process [accessed 18 June, 2019].
13. Andrews SJ, Thomas TM, Hauptman JG, Stanley BJ. Investigation of potential risk factors for mesenteric volvulus in military working dogs. *J Am Vet Med Assoc*. 2018;253(7):877-885.
14. Beitler AL, Jeanette JP, McGraw AL, Butera JR, Vanfosson CA, Seery JM. Emergency canine surgery in a deployed forward surgical team: a case report. *Mil Med*. 2011;176(4):477-480.

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Femoral Pulse Ultrasound Assessment Accuracy by Emergency Medicine Trainees on a Porcine Model

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Abstract

Background: Rapid and accurate pulse interpretation is critical to algorithmic treatment in cardiac arrest. Point of care ultrasound (POCUS) is increasingly used in emergency medicine (EM), including EM physician residents and EM physician assistant (EMPA) residents. Scant literature assesses accuracy and duration of POCUS pulse assessment by this group during cardiac resuscitation given recommendations for minimal pauses in chest compressions. Evaluation is needed for accuracy and duration of pulse interpretation in EM trainees utilizing POCUS.

Methods: We conducted a double-blind observational study of EM clinician trainee POCUS assessment of pulses using porcine models. Volunteers were blinded to the cardiac status of 5 porcine models randomized as deceased or living and performed femoral artery evaluation using color power Doppler POCUS. The primary outcome was accuracy of pulse assessment. Secondary outcomes included time to verbalization and differences based on reported duration of EM training, experience with ultrasound, and cardiac arrest resuscitation experience.

Results: 17 EM and EMPA trainees completed 85 total POCUS pulse assessments with 98.82% accuracy (n=84). Mean verbalization time was 6.95 seconds, and most verbalized interpretations were within 10-seconds (82.4%, n=70). This was grossly consistent between living and deceased models. Subgroup analysis found no significant differences of accuracy or verbalization time based on reported demographics.

Conclusion: EM clinician trainees demonstrate a high degree of accuracy and low average time for verbalized interpretation of femoral artery pulse assessment, most within recommended time guidelines. Further study is needed to correlate these findings in human patients.

Keywords: trauma, military, cardiac arrest, performance, resuscitation

Introduction

Effective care in cardiac arrest necessitates "minimally interrupted chest compressions" during cardiopulmonary resuscitation (CPR) to maintain active peripheral blood flow and minimize the chance of neurological injury.[1-3] While timely and accurate pulse interpretation is critical during periods of reassessment, manual palpation is prone to inaccuracy and inappropriate treatment.[4-6] Emergency medicine (EM) trainees, including physician residents and EM physician assistant (EMPA) residents, continue to recognize the value of point of care ultrasound (POCUS), which can provide direct anatomical visualization to identify potentially reversible causes of cardiac arrest.[7,8] Given the lack of palpation accuracy for pulse assessment, POCUS is being increasingly utilized in EM to direct cardiac arrest resuscitation.[9-17]

The use of POCUS offers direct visualization of intravascular flow and therefore has potential to improve pulse assessment accuracy over palpation. However, recent studies caution excessive pauses in compression continue when POCUS is employed in lieu of palpation.[18-20] These studies did not include the use of blinded participants or investigating teams, which may confound final analysis. To date, no published research exists

describing the use of POCUS evaluation for pulse assessment with model randomization and blinded participants. We sought to conduct a double-blind observational study to assesses the accuracy and speed of femoral artery pulse interpretation by EM trainees using POCUS in live tissue models.

Methods

The Brooke Army Medical Center (BAMC) institutional review board (IRB) reviewed and approved protocol C.2019.005.e, which was then reviewed and approved by the local International Animal Care and Use Committee (IACUC). All aspects of this study were conducted at Joint Base San Antonio-Lackland Air Force Base, TX. Volunteers consisted of EM physician residents and EMPA residents. For convenience, study participation occurred during routine procedural skills training. At time of enrollment, all volunteers completed a pre-study demographic questionnaire including ultrasound and cardiac resuscitation experience.

Figure 1. Marking of the left inguinal crease.

At least two investigation team members independently confirmed femoral artery and vein presence at the left inguinal crease during general anesthesia induction of 5 porcine models and marked the surrounding 5x10cm area with sterile drapes (Figure 1). All models were marked identically. Lab personnel then selected three porcine models for the deceased group, discontinuing life support measures and ensuring termination of cardiac function according to local IACUC protocols, while maintaining support and cardiac function with general anesthesia in the remaining two models. All cardiac monitors and life support devices were silenced and otherwise obscured from volunteers and the investigation team. All volunteers proceeded in sequential fashion between porcine models using identical ultrasound models with a linear probe set at 5cm depth in color power Doppler mode and were directed not to adjust settings on the device (Figure 2). Once determined, volunteers verbally stated presence or absence of an arterial pulse to the investigation team member. Elapsed time was recorded as the number of seconds from skin contact with the ultrasound probe to verbalization of pulse status. Volunteers were isolated in their iterations to minimize interference.

The primary outcome was accuracy of femoral pulse interpretation. Secondary outcomes included time to verbalization and comparison of accuracy and verbalization times between groups based on reported demographics. Given the stated goal of no more than 10 seconds for interruption of chest compressions per cardiac resuscitation recommendations, this was recorded categorically as 'less than 10 seconds' or 'more than 10 seconds', as well as a continuous variable.

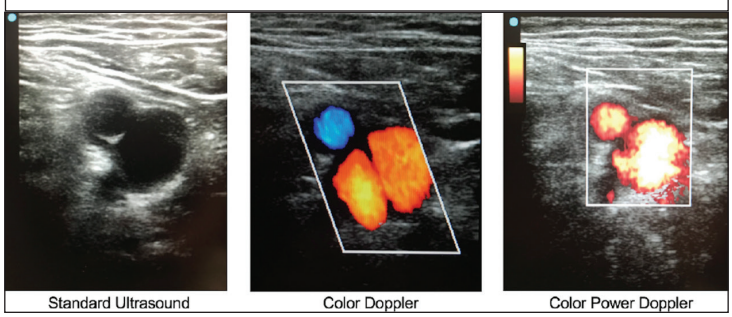
We performed all statistical analysis using embedded calculation functions of a common commercial computer-based spreadsheet, and a common medical research data analysis application. We reported descriptive statistics to include numbers and percentages for nominal variables.

Results

A total of 17 EM physician and EMPA residents were enrolled over three lab iterations in a 3-month period. Volunteers reported an average of 10.8 months of EM experience (range=1-15 months), while reported ultrasound and cardiac arrest resuscitation experience varied (Table 1). All volunteers completed POCUS evaluation of 5 porcine models for arterial pulse interpretation.

Participants correctly interpreted 98.8% (n=84) of evaluations (Table 2). Despite a wide range, the average time of interpretation of 6.95 seconds was consistent between living and deceased models, as was the absolute number of interpretations less than 10 seconds. Subgroup analysis demonstrated no significant difference in time to determine femoral pulse activity based on volunteers' reported time in residency, POCUS experience, or cardiac resuscitation experience.

Figure 2. Femoral vessel ultrasound (L to R) without color, color Doppler, and color power Doppler.



Discussion

Our novel study of POCUS femoral pulse assessment demonstrates a high

percentage of accurate interpretation by EM trainees largely within current AHA time recommendations for effective cardiac resuscitation. These findings also demonstrate no significant difference based upon reported EM residency duration or POCUS or cardiac resuscitation experience.

Table 1. Volunteer reported demographics.

EM Trainee (n = 17)	Months in EM Training	POCUS Experience	Cardiac Resuscitation Experience
Physician (n = 8)	13.5 (11 – 15)	Minimal 0% (n = 0)	0 – 5 25% (n = 2)
		Intermediate 50% (n = 4)	6 – 10 25% (n = 2)
		Extensive 50% (n = 4)	> 10 25% (n = 4)
EMPA (n = 9)	8.5 (1 – 15)	Minimal 44% (n = 4)	0 – 5 55% (n = 5)
		Intermediate 22% (n = 2)	6 – 10 11% (n = 1)
		Extensive 34% (n = 3)	> 10 34% (n = 3)

*all numbers reported as percentage (total number)

Proper pulse assessment during cardiac resuscitation efforts is vital to algorithmic treatments, and previous studies performed on human subjects reveal abysmally low accuracy of palpated pulse interpretation.[4,5,21,22] The 98% accuracy of femoral pulse assessment with ultrasound is well above the reported manual palpation accuracies of 78% by Tibballs and Russell[4] and 83.8% by Moule et al.[22] Minimizing duration and frequency of pauses in chest compressions to assess for pulse is likewise critical to maintain organ perfusion and improving outcomes, yet recent studies suggest difficulty in meeting these goals with and without ultrasound use.[23-26] Despite the anticipated and reported benefits of ultrasound use in cardiac arrest resuscitations, prior literature finds an association between prolonged compression pauses and POCUS in human cardiac arrest resuscitations.[18-20]

Difficulty in pulse identification during CPR efforts using traditional palpation methods encourages novel methods to determine cardiac activity. This includes transthoracic echocardiography (TTE) and transesophageal echocardiography. However, both of these methods could require a excessive disruption of chest compressions, either through hands off time to acquire a sonographic image on the chest with TTE, or esophageal introduction of a TEE probe which could interfere with aspects of ventilation with bag valve mask equipment. In their 2016 studies Huis in't Veld et al. and Clattenburg et al.[18,19] did not attempt to identify the cause of prolonged compression pauses with ultrasound use. However, Clattenburg et al.'s 2018 study found improved compression pause times after implementing several techniques by the resuscitation team. Still, these improvements failed to acheive the AHA goal of 10 seconds or less.[20] Despite their focused efforts, they reported post-intervention compression pause lengths of 16 seconds when ultrasound was used and 11 seconds when not used.

Table 2. Femoral pulse accuracy and verbalization times.

Model	Verbalization Accuracy	Verbalization Time (sec)**	Verbalization Time < 10 sec
Living (n = 34)	97% (n = 33)	6.91 (2.00 – 21.32)	80.5% (n = 27)
Deceased (n = 51)	100% (n = 51)	6.99 (1.91 – 33.59)	84.4% (n = 43)
Overall (n = 85)	98.8% (n = 84)	6.95	82.4% (n = 70)

*all numbers reported as percentage (total number) unless otherwise specified
**numbers reported as mean (range)

While evaluation of the femoral artery is not as comprehensive as TTE, in conjunction with cardiac monitor equipment, it does answer the clinical question of pulse activity sought by AHA guidelines. Furthermore, the employment of color power Doppler could improve in assessment during low-flow states (i.e. peri-arrest). Despite this simple substitution, scant literature describes accurate pulse evaluation using POCUS in cardiac arrest. Previously, Zengin et al. compared pulse evaluation accuracy and time to interpretation using POCUS, but was limited in that the three volunteers were not blinded to the patient status.[15] Our increased sample population, randomization of actual cardiac status, and blinding of both participants and investigating team members demonstrates further support for POCUS employment during cardiac resuscitation pulse assessments.

Limitations

This study was limited in several ways, primarily with the use of a non-cardiac arrest porcine model in place of a human patient. Although done deliberately to limit cofounders, the lack of other personnel and additional stressors often found in a cardiac arrest scenario further limit broader application of results. Areas for assessment were deliberately marked by the investigation team, which limited volunteers need to search for vasculature. Despite similarities, porcine vasculature may have subtle differences in depth and appearance both between models and with that of humans. The decision to limit volunteers' ability to adjust settings on the ultrasound machines could remove other confounders of user error when using POCUS. Finally, all volunteer demographic

information was self-reported, which could be masked by reporting bias.

Conclusion

Our randomized double-blinded observational study demonstrates a high degree of accuracy in femoral pulse assessment by EM trainees, largely within time recommendations for cardiac arrest assessment. These findings support the use of POCUS in cardiac arrest evaluation, in coordination with further research. Future studies should seek to validate our findings using larger populations and human cardiac arrest patients to assess for accuracy and actual length in the pause of chest compressions.

References

1. American Heart Association. *Advanced Cardiac Life Support Provider Manual*. First American Heart Association Printing; 2016.
2. Link MS, Berkow LC, Kudenchuk PJ, et al. Part 7: Adult Advanced Cardiovascular Life Support: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132(18 Suppl 2):S444-464. doi:10.1161/CIR.0000000000000261.
3. Kleinman ME, Goldberger ZD, Rea T, et al. 2017 American Heart Association Focused Update on Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2018;137(1). doi:10.1161/CIR.0000000000000539.
4. Tibballs J, Russell P. Reliability of pulse palpation by healthcare personnel to diagnose paediatric cardiac arrest. *Resuscitation*. 2009;80(1):61-64. doi:10.1016/j.resuscitation.2008.10.002.
5. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. *Resuscitation*. 1996;33(2):107-116.
6. Ochoa FJ, Ramalle-Gómara E, Carpintero JM, García A, Saralegui I. Competence of health professionals to check the carotid pulse. *Resuscitation*. 1998;37(3):173-175. doi:10.1016/S0300-9572(98)00055-0.
7. Ullemark E, Ilicki J, Djärv T. Focused ultrasound during advanced life support as a part of a structured approach to the resuscitation of PEA. *Resuscitation*. 2018;129:e3-e4. doi:10.1016/j.resuscitation.2018.05.009.
8. Lien W-C, Hsu S-H, Chong K-M, et al. US-CAB protocol for ultrasonographic evaluation during cardiopulmonary resuscitation: Validation and potential impact. *Resuscitation*. 2018;127:125-131. doi:10.1016/j.resuscitation.2018.01.051.
9. Schuster KM, Lofthouse R, Moore C, Lui F, Kaplan LJ, Davis KA. Pulseless Electrical Activity, Focused Abdominal Sonography for Trauma, and Cardiac Contractile Activity as Predictors of Survival After Trauma. *J Trauma Inj Infect Crit Care*. 2009;67(6):1154-1157. doi:10.1097/TA.0b013e3181c303e8.
10. Breitkreutz R, Price S, Steiger HV, et al. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: A prospective trial. *Resuscitation*. 2010;81(11):1527-1533. doi:10.1016/j.resuscitation.2010.07.013.
11. Prosen G, Križmarić M, Završnik J, Grmec Š. Impact of Modified Treatment in Echocardiographically Confirmed Pseudo-Pulseless Electrical Activity in Out-of-Hospital Cardiac Arrest Patients with Constant End-Tidal Carbon Dioxide Pressure during Compression Pauses. *J Int Med Res*. 2010;38(4):1458-1467. doi:10.1177/147323001003800428.
12. Hernandez C, Shuler K, Hannan H, Sonyika C, Likourezos A, Marshall J. C.A.U.S.E.: Cardiac arrest ultra-sound exam—A better approach to managing patients in primary non-arrhythmogenic cardiac arrest. *Resuscitation*. 2008;76(2):198-206. doi:10.1016/j.resuscitation.2007.06.033.
13. Gardner KF, Clattenburg EJ, Wroe P, Singh A, Mantuani D, Nagdev A. The Cardiac Arrest Sonographic Assessment (CASA) exam – A standardized approach to the use of ultrasound in PEA. *Am J Emerg Med*. 2018;36(4):729-731. doi:10.1016/j.ajem.2017.08.052.
14. Zengin S, Yavuz E, Al B, et al. Benefits of cardiac sonography performed by a non-expert sonographer in patients with non-traumatic cardiopulmonary arrest. *Resuscitation*. 2016;102:105-109.

doi:10.1016/j.resuscitation.2016.02.025.

15. Zengin S, Gümüşboğa H, Sabak M, Eren ŞH, Altunbas G, Al B. Comparison of manual pulse palpation, cardiac ultrasonography and Doppler ultrasonography to check the pulse in cardiopulmonary arrest patients. *Resuscitation*. 2018;133:59-64. doi:10.1016/j.resuscitation.2018.09.018.
16. Mallemat H. Beyond the H's and the T's: Ultrasound in Cardiac Arrest. Presented at the: SEMPA 360; May 6, 2018; San Antonio, TX.
17. Swaminathan A. Beyond ACLS – POCUS in Cardiac Arrest. Published August 20, 2015. Accessed June 21, 2018. http://rebelem.com/beyond-acls-pocus-in-cardiac-arrest/.
18. Huis in 't Veld MA, Allison MG, Bostick DS, et al. Ultrasound use during cardiopulmonary resuscitation is associated with delays in chest compressions. *Resuscitation*. 2017;119:95-98. doi:10.1016/j.resuscitation.2017.07.021.
19. Clattenburg EJ, Wroe P, Brown S, et al. Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: A prospective cohort study. *Resuscitation*. 2018;122:65-68. doi:10.1016/j.resuscitation.2017.11.056.
20. Clattenburg EJ, Wroe PC, Gardner K, et al. Implementation of the Cardiac Arrest Sonographic Assessment (CASA) protocol for patients with cardiac arrest is associated with shorter CPR pulse checks. *Resuscitation*. 2018;131:69-73. doi:10.1016/j.resuscitation.2018.07.030.
21. Liberman M, Lavoie A, Mulder D, Sampalis J. Cardiopulmonary resuscitation: errors made by pre-hospital emergency medical personnel. *Resuscitation*. 1999;42(1):47-55. doi:10.1016/S0300-9572(99)00082-9.
22. Moule P. Checking the carotid pulse: diagnostic accuracy in students of the healthcare professions. *Resuscitation*. 2000;44(3):195-201. doi:10.1016/S0300-9572(00)00139-8.
23. Christenson J, Andrusiek D, Everson-Stewart S, et al. Chest Compression Fraction Determines Survival in Patients With Out-of-Hospital Ventricular Fibrillation. *Circulation*. 2009;120(13):1241-1247. doi:10.1161/CIRCULATIONAHA.109.852202.
24. Bobrow BJ, Clark LL, Ewy GA, et al. Minimally Interrupted Cardiac Resuscitation by Emergency Medical Services for Out-of-Hospital Cardiac Arrest. *J Am Med Assoc*. 2008;299(10):1158-1165.
25. Vaillancourt C, Everson-Stewart S, Christenson J, et al. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. *Resuscitation*. 2011;82(12):1501-1507. doi:10.1016/j.resuscitation.2011.07.011.
26. Cunningham LM, Mattu A, O'Connor RE, Brady WJ. Cardiopulmonary resuscitation for cardiac arrest: the importance of uninterrupted chest compressions in cardiac arrest resuscitation. *Am J Emerg Med*. 2012;30(8):1630-1638. doi:10.1016/j.ajem.2012.02.015.

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Army Emergency Medicine: Advancing the Vison for Army Medicine

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Abstract

The US Army Medical Department (AMEDD) is facing unprecedented changes brought on by legislative directives and a renewed emphasis on operational readiness. This article explores the impact of the Medical Corps (MC) survey results, media attention on military trauma readiness, and congressional mandates on military medicine. It highlights the work of emergency medicine (EM) physicians across the Army and the impact of the EM community on helping shape the future of Army medicine. Emergency Physicians at the Medical Center of Excellence are leveraging medical simulation to reduce a reliance on real-life experience, leading the development of new and increased opportunity for simulated operational medical training in order to meet the demands of deploying units. EM leadership at the Program Executive Officer for Simulation, Training & Instrumentation (PEO STRI) is helping ensure medical simulation capabilities developed meet the needs of the medical end user. The AMEDD Military-Civilian Trauma Team Training (AMCT3) partnerships developed as a line of effort under the Army Medical Skills Sustainment Program (AMSSP) are developing partnership to place military trauma teams in Level 1 civilian trauma centers to optimize real-world training. And EM physicians are serving as key leaders in the Army Ready Surgical Force Task Force tackling issues like central management of critical wartime specialties and legislative changes to lift caps on military physician bonuses to improve salary parity with the civilian sector.

"One of the most important words on the battlefield when a Soldier is injured is medic. And when that word is screamed out, the warfighters are counting on Army Medicine to be able to respond."
— Lt. General R. Scott Dingle, The Army Surgeon General

The 2020 Army Medicine Strategy lays out the mission of the Army Health System which is to "provide ready and sustained health services support and force health protection in support of the Total Force to enable readiness and to conserve the fighting strength while caring for our People and their Families." While this mission still harkens to the proud legacy of military medicine, the environment within which we operate today as Army physicians is facing unprecedented changes brought on by congressional mandates and a renewed emphasis on operational readiness. In order to meet these changes, The Surgeon General's (TSG) vision of the Army Medical Department (AMEDD) is a department that is "Ready, Reformed, Reorganized, Responsive and Relevant."[1] AMEDD senior leaders are also facing challenges within the ranks and must address physician retention, skill sustainment, and civilian sector pay parity as evidenced by the latest Medical Corps (MC) survey results and current media attention challenging the military's trauma readiness. This article will review how current events are impacting Army physicians and specifically how Emergency Medicine, as a specialty and as a community, is helping to shape the future.

In 2018, the US Army Medical Center of Excellence (MEDCoE), formerly the US Army Medical Department Center and School, developed the "Army Medical Corps Engagement/Satisfaction Survey," [2] in order to better assess the impact of ongoing changes effecting Medical Corps (MC) physicians and to understand the influencers driving physician retention. Approximately 2,000 MC officers (47% of the population) completed an anonymous on-line survey, which was used to develop a picture of the current state of job satisfaction, readiness, administrative support, and the likelihood to stay on active duty. Results of the survey showed that while most had a positive attitude toward serving the country as a MC officer/physician, a majority expressed dissatisfaction with the ability to stay current in one's specialty, the level of administrative support, and the lack of recognition from their unit of assignment in the

form of awards. The survey also produced data in areas concerning the likelihood of continuing service beyond one's active duty service obligation (ADSO), job satisfaction, perceived opportunities for career growth, and the ability to meet personal career goals. Of 371 current EM physicians on active duty, 146 participated in the survey (33%), representing 7% of the total respondents. When the results of the survey were evaluated by the EM cohort only, it revealed that 80% of EM MC captains were unlikely to stay on active duty past their ADSO or expiration of current retention bonus; a response also echoed by 69% of the EM majors, 61% of lieutenant colonels and 63% colonels, which was consistent with the MC respondents as a whole. The survey went on to find that career satisfaction was correlated with increasing rank, with 64% of EM MC captains, 58% of majors, 78% of lieutenant colonels, and 76% of colonels responding that they were satisfied or neutral with their career; results also align with the total cohort. Other issues addressed in the survey included the negative impact of unknowns surrounding the implementation of the National Defense Authorization Act (NDAA) of 2017 and concerns about achieving comparable physician compensation with the civilian sector. MC officers indicated that their decision to stay on active duty past their ADSO would be most influenced by changes that made salaries more competitive and minimized the potential for skill degradation, both of which caught the attention of the senior AMEDD leadership.

In response to the MC Survey and in alignment with the TSG's vision, Major General Telita Crosland, the Deputy Surgeon General and Medical Corps Chief, established the MC vision,

> "Clinically and operationally proficient Medical Corps Officers who role model leadership, embody professional excellence as soldiers, clinicians, scientists, and scholars; and prosper personally and within their relationships/family."[3]

The MC survey results also helped develop the MC priorities which include provider readiness, recruiting and retaining talent, developing leaders and enhanced communication. Within the EM community, physicians are heavily involved in activities that support the MC vision/priorities and are operationalizing them across the Army. Readiness, for a MC physician, means skill sustainment, a topic that came across in the MC survey as a serious concern. Individual Critical Task Lists (ICTLs) have been developed over the last few years as an attempt to quantify wartime skill sets by specialty in order to establish clinical competencies and measures to drive training. However, they have yet to achieve widespread implementation, and until commanders are held accountable for meeting these requirements, they may not be universally met. In the EM Community, 50% of physicians not in training (residents, fellows, etc.) are assigned to operational billets and approximately 25% of those physicians are designated as modification table of organization and equipment (MTOE) assigned personnel (MAP) with duty at a medical treatment facility (MTF). Additionally, a total of 33% of non-trainees are assigned to MTFs. Since Brooke Army Medical Center (BAMC) is the only military Level 1 trauma center in the US,[5] reliance solely on MTF based care is unlikely to provide enough trauma exposure for EM physicians and other physicians to meet their required ICTLs. Thus, medical simulation training and military-civilian partnerships targeting wartime skills is required.

Emergency physicians at the MEDCoE are leading the development of new and increased opportunity for simulated operational medical training in order to meet the demands of deploying units. EM Physician Rob Hennessy serves as director of a newly established directorate within the MEDCoE called the Directorate of Simulation (DoS). The DoS is leveraging medical simulation which has always served as a cornerstone for physician operational training as real-life opportunities are limited and often do not replicate the combat environment. This training enables all physicians, not just EM physicians, to have exposure to combat-like injuries, in a combat-like environment utilizing combat medical equipment and operational Clinical Practice Guidelines. The DoS concept is to leverage medical simulation for ICTL training requirements that are not regularly obtained through patient encounters and to be able to perform these critical skills individually or as a team in an operational environment. The DoS is currently putting this concept into action by aiding in the development of a reconfigurable Forward Resuscitative Surgical Teams (FRST) mobile medical simulation training platform that will allow for operational medical training at the point of need. The Department of Operational Medicine (DoM), also within the MEDCoE, led by EM physicians, Director Kathleen Samsey, and Chief of the Combat Medic Division, LTC Nadia Pearson, is charged with developing a holistic training strategy for Army prehospital and field hospital multi-disciplinary health care team members who will deploy to a Role I-III. The DoM must also put strategy into action on a daily basis by providing professional expertise and quality instruction at all levels of care for military providers from Army Medical Command (MEDCOM), US Army Training and Doctrine Command (TRADOC), US Army Forces Command (FORSCOM), US Army Special Operations Command (USASOC), the National Guard Bureau, US Army Reserve Command, the Joint Trauma System'

our sister services, and civilian Emergency Medical Services (EMS). DoM has also recently partnered with BAMC's Strategic Trauma Readiness Center (STaRC) to establish enhanced surgical team training support through scenario based field exercise for deploying Forward Resuscitative Surgical Teams (FRSTs).

High quality medical simulation is key to ensure medical personnel are ready to provide excellent patient care in the hospital and casualty care on the battlefield. LTC Ben Baker, an emergency physician, serves as Clinical Advisor to The Program Executive Officer for Simulation, Training & Instrumentation (PEO STRI), whose mission is to develop, acquire, provide and sustain simulation, training, testing and modeling solutions to optimize Warfighter Readiness. He provides subject matter expertise and medical advocacy across PEO STRI's approximately $2.8B portfolio which spans the entire Army training and testing environment. LTC Baker's input ensures that the medical simulation capabilities developed meet the needs of the medical end user. Recently, he worked with the Soldier Lethality and Synthetic Training Environment Cross Functional Teams (CFT) on the representation and significance of wounds for the Integrated Visual Augmentation System (IVAS). IVAS is a Heads-Up Display that uses augmented reality to increase lethality, mobility, and situational awareness in combat and will enable soldiers to train in synthetic environments. In his role as Clinical Advisor, LTC Baker meets with Army organizations, members of Congress, international allies, industry partners, and academia to promote the enhancement and incorporation of medical simulation to save lives.

Military-civilian partnerships have long been recognized as another potential solution to increase exposure to wartime skills for trauma related specialties. Section 708, Joint Trauma Education and Training Directorate, NDAA 17 called for the Secretary of Defense to "enter into partnerships with civilian academic medical centers and large metropolitan teaching hospitals that have Level 1 civilian trauma centers in order to provide integrated combat trauma teams, including forward surgical teams, with maximum exposure to a high volume of patients with critical injuries."[6] The Army Medical Skills Sustainment Program (AMSSP) was established to meet the intent of the NDAA2017, Section 708, utilizing this congressional mandate and the real need for more trauma exposure for its physicians to develop two primary lines of effort (LOE), the AMEDD Military-Civilian Trauma Team Training (AMCT3) and the Strategic Medical Asset Readiness Training (SMART) LOE. Chartered in 2017, the AMCT3 LOE has been working with civilian institutions to develop partnerships with MEDCOM, Human Resources Command (HRC) and FORSCOM to integrate training spots into the Army's manning construct. In 2018, two EM positions were embedded in trauma centers at Cooper University in Camden, NJ, and at Oregon Health and Science University in Portland, OR. Since then, five more partnership site agreements have been signed at the Medical College of Wisconsin, Vanderbilt University Medical Center, Harborview Medical Center, the University of North Carolina, and the University of Chicago. The program is developing in a phased approach with the goal of aligning positions against the authorizations within the FRST to provide for a team based training platform for units slated to deploy on a regular basis. In its early phases, the concept is to embed a portion of the FRST including the emergency physician, surgeons, medical and intensive care unit (ICU) section within the partner location for up to 3 years as a permanent duty station, while retaining their full-time active duty service affiliation. As the phases ramp up, rotators from the FRST and other units would join or replace other team members with the experienced team members serving as cadre to continue to shape the training. The individuals selected to fill these important positions will be chosen through a collaboration between the Unit, the AMCT3 program, the consultant and the civilian institution, and will target mid-career physicians with experience beyond residency, and the career longevity to continue their contributions and leadership into the future for Army medicine.

In order to continue to develop solutions to issues like skill sustainment for surgical teams and also partly in response to media attention on trauma readiness,[7] The Surgeon General chartered the Army Ready Surgical Force Task Force or "Surgical Tiger Team," which includes MC, surgical and EM leadership. So far, this group has addressed a laundry list of issues facing wartime specialties including skill sustainment, optimal surgical team composition and is also moving toward successful re-establishment of centralized management of surgical areas of concentration (AOC), whereby the 61 series professionals are managed for deployments as a single group. While surgical specialties face some different constraints than the EM community, there are many overlapping issues including the need for skill sustainment, equitable balance of deployment opportunities, and centrally managed dwell times. Currently, MAP assigned personnel and organic FORSCOM assigned soldiers are expected to deploy for the full duration of the unit's time in theater, and mid-tour swaps occur only through an exception to policy. Centrally managed specialties in the proposed construct will be

projected for a mid-tour split with personnel identified ahead of time based on dwell time and not on unit of assignment. With skill sustainment at the center of the argument, EM physicians follow the same logic, but the lengthy time for exception to policy approval leads to last minute deployment substitution, and the stove piped management between FORSCOM and MEDCOM adds a layer of complexity that only central management can solve. Senior leaders have offered assurances that as the surgical series stands up central management, the options will be soon evaluated for other specialties with EM considered in the next group. It is clearly an issue that needs continued focus.

Last but certainly not the least in importance, the lack of salary parity with civilian counterparts came across as another clear concern in the MC survey and is a targeted issue nested under the MC priority to recruit and retain officers. Section 335(e)(1)(C) of Title 37, United States Code 8 caps the health professions retention bonuses for military health professionals at $75,000. In order to alleviate this cap, the Army leadership has submitted a legislative proposal for fiscal year (FY) 22 to increase the current statutory bonus rate cap to $200,000. The proposal is currently in the DoD review stage, and if recommended for approval by Office of Secretary of Defense, will go to Congress for consideration in Spring 2021. While legislative proposals can take up to 3-5 years to become law, and while the recipients of a changed bonus rate have not been worked out yet, the development holds promise, especially for critical wartime specialties like emergency medicine.

Army medicine has a proud legacy that will endure through the transition of the military health system, as it has through other periods of change in its 237 years of existence. Emergency medicine serves a vital role from the front lines of care on the battlefield to our military treatment facilities, from delivering primary care to soldiers as Level 1 providers to commanding FRSTs or MTFs and as general officers shaping the Army of the future.

References

1. Army Medicine Strategic Vision. https://armymedicine.health.mil/ Accessed September 25, 2020.
2. Wojcik B, Stein C, Guerrero K, et al. Army Physician Career Satisfaction Based on a Medical Corps Survey. *Military Medicine*. 2020; 185: 1200-1208.
3. Army Medical Corps. https://armymedicine.health.mil/Medical-Corps. Accessed September 25, 2020.
4. Cobiskey O. WBAMC first to train medical personnel for battlefield medicine validation. https://www.army.mil/article/226748/wbamc_first_to_train_medical_personnel_for_battlefield_medicine_validation. Accessed September 25, 2020.
5. Sanchez E. BAMC re-verified as Level 1 Trauma Center. https://www.army.mil/article/199770/bamc_re_verified_as_level_i_trauma_center, Accessed September 25, 2020.
6. Joint Trauma Education and Training Directorate. https://health.mil/Reference-Center/Reports/2018/02/14/Joint-Trauma-Education-and-Training-Directorate, Accessed September 25, 2020.
7. Sternberb S. Top Army Surgeon Blasts Military's Capability to Handle War Traumas. https://www.usnews.com/news/health-news/articles/2019-10-28/top-army-surgeon-blasts-militarys-capability-to-handle-war-traumas, Accessed September 25, 2020.
8. Legal Information Institute, Cornell Law School, 37 U.S. Code 335. Special bonus and incentive pay authorities for officer in health professions. https://www.law.cornell.edu/uscode/text/37/335, Accessed September 25, 2020.

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An Analysis of Prehospital Blood Administration in the Indo-Pacific Command

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Abstract

Background: Blood products are often a life-saving intervention for both traumatic and medical indications. The United States Indo-Pacific Command (INDOPACOM) is the largest Geographic Combat Command (GCC). Procurement of blood products that meet the US military healthcare standards throughout this region is challenging. Yet, the frequency to which this life-saving intervention is administered remains unclear. We seek to describe blood product administration throughout INDOPACOM.

Methods: This is a secondary analysis of a previously described dataset from the US Transportation Command (TRANSCOM) Regulating Command & Control and Evacuation System (TRAC2ES) from 2008 to 2018.

Results: Between 2008 and 2018, there were 4,217 cases in TRAC2ES originating within INDOPACOM, of which 173 (4%) cases involved blood product transfusion. The largest percentage for patients receiving a blood transfusion was 19-29 years old (29%), followed by patients under a year (21%). Most (66%) of the patients classified as male. Almost half of the patients (49%) were dependents of members of service in parallel with the young patient ages. Anemia (23%) and trauma (20%) , mostly non-combat related, were the largest proportions of indications. The common blood product used was packed red cells (72%) followed by fresh frozen plasma (16%).

Conclusions: Blood products were administered to nearly 1 out of every 25 patients transported within INDOPACOM, which highlights the need for reliable methods for obtaining and maintaining blood products. Given INDOPACOM's vast area of responsibility and possibility for a peer-to-peer war, finding optimal methods to transport and store blood and blood products is imperative.

Keywords: blood, pacific, military, transport, plasma, platelets, INDOPACOM, blood transfusion

Background

The United States Indo-Pacific Command (INDOPACOM) is the largest of the six Geographic Combatant Commands (GCC) under the Department of Defense (DoD). It spans 36 countries in the Asia-Pacific region with more than 50% of the world's surface within this region.[1] The medical system, including fixed facilities and Naval vessels, within INDOPACOM spans this entire area and actively serve military combat soldiers, dependents of military combatants, retirees, government civilians, and contractors spanning ages from birth to geriatric populations. Due to the diverse patient population and non-combat injury etiologies, a wide variety of medical interventions are used which are unique and specific to the injury or condition.

The Armed Services Blood Program (ASBP) provides blood products worldwide.[2] The ASBP low titer group O whole blood (LTOWB) program is touted as optimal due to the superior hemostatic potential, oxygen-carrying capability, and ease of use.[3,4] Currently, the ability to obtain LTOWB in INDOPACOM is tenuous. Providers, nurses, and medics in the INDOPACOM area of responsibility (AOR) may have experience using fresh whole blood, but until the 2017-2018 timeframe LTOWB was hard to obtain and/or store due to the regional regulations and constraints.[5] In the continental US, administration

of packed red blood cells (PRBC) or fresh frozen plasma (FFP) are used frequently due to the ease of obtaining and storing. These components are also frequently used in INDOPACOM.

Data and information about the ease of blood products transfused into military personnel, retirees, and other government personnel in the INDOPACOM are scarce. Previously published studies have highlighted the challenges to maintain an optimal medical logistical capability.[6,7] It remains difficult to verify how often and what types of blood products are transfused within INDOPACOM.

Goal of this Investigation: We are seeking to describe blood product administration throughout the INDOPACOM theater of operations within the US Transportation Command (TRANSCOM) Regulating Command & Control and Evacuation System (TRAC2ES) data repository.

Table 1. Description of patients receiving blood products.

	Description	Number	Percentage
Age (years)	<1	36	20.8
	1-18	28	16.2
	19-29	50	28.9
	30-39	19	11
	40-49	7	4
	50-59	14	8.1
	>60	19	11
	Total	**173**	**100**
Sex	Male	114	65.9
	Female	58	33.5
	Unknown	1	0.6
	Total	**173**	**100**
Type of Personnel	Dependent	84	48.6
	Active Duty	61	35.3
	Veteran	21	12.1
	Contractor	5	2.9
	Other	2	1
	Total	**173**	**100**
Origin Location	Okinawa	45	26
	USN Guam	45	26
	Tripler Army Medical	21	12.1
	USNH Yokosuka	12	6.9
	121st Army Hospital	11	6.4
	35th Med GRP Misawa	9	5.2
	374th Med GRP Yokota	6	3.5
	Kwajalein Hosp	5	2.9
	Other	19	11
	Total	**173**	**100**
Destination	Tripler Army	87	50.3
	NMC San Diego	27	15.6
	Ft. Sam Houston	10	5.8
	Okinawa	8	4.6
	Other	41	23.7
	Total	**173**	
Mechanism of Injury	Anemia	39	22.5
	Trauma	34	19.7
	Gastrointestinal	17	9.8
	Bacteria	17	9.8
	Cancer	12	6.9
	Condition	12	6.9
	Liver issues	11	6.3
	Premature Birth	5	2.9
	Cardiac	5	2.9
	Sepsis	4	2.3
	Mass	4	2.3
	Other	13	7.5
	Total	**173**	

Methods

Ethics: The US Air Force 59th Medical Wing regulatory office reviewed protocol FWH20180147E and determined it was exempt from institutional review board oversight. We obtained only de-identified data.

Subjects and Setting: We conducted a retrospective review of prospectively entered transit records of patient care into TRAC2ES in the INDOPACOM theater of operations from January 1, 2008 to December 31, 2018. We included all military and civilian patients that were tracked for transport by TRAC2ES during this timeframe. We sought all available evacuation data on the initial search to create the dataset. In this sub-analysis of the overall dataset, we searched for the free text entries for the following terms: "rbc," "ffp," "blood," "transfusion," "plasma," and "platelets."

Database Description: Data was collected using TRAC2ES, an electronic platform that coordinates regulated medical transport of all (DoD) patients worldwide. Data entered in TRAC2ES includes patient demographics, primary diagnosis, origin, destination, and evacuation priority level. There is also the ability to enter a patient's history through a free text entry which can be used to provide relevant information about the patient's clinical course. Data were extracted from these free text entries which are previously described.[6]

Data Analysis: We performed all statistical analyses and used descriptive statistics, reporting categorical variables as numbers with percentages and ordinal variables as medians with interquartile ranges.

Results

Between 2008 and 2018, there were 4,217 cases recorded in TRAC2ES originating within INDOPACOM, of which 173 cases (4%) involved blood product administration. The largest percentage for patients receiving a blood transfusion was 19-29 years old (29%), followed by patients under a year (21%) (Table 1). Most (66%) of the patients were male. Almost half of the patients (49%) were dependents of active duty service members with active duty service members

making up the second largest proportion (35%).

Table 2. Blood components administered.

Blood Components	Number	Percentage of Patients
Packed Red Blood Cells	125	72.3
Fresh Frozen Plasma	28	16.2
Platelets	17	9.8
Cryoprecipitate	1	0.5
Not specified	27	15.6
Total	**197**	

Anemia (22%) and trauma (20%), mostly non-combat related, were the largest proportions of indications. The most common blood product used was packed red blood cells (72.3%) (Table 2), followed by fresh frozen plasma (16%). Amongst trauma patients, the most commonly administered blood product was packed red blood cells (58.8%) as well (Table 3). Very few trauma patients received more than one blood product. Two patient records were identified as not having enough blood available at the support hospital, so that patient transported to receive blood at another location. (Table 4).

TRAC2ES records patient transport between military medical treatment facilities (MTFs). The original medical location of most patients was US Naval Hospital (USNH) Okinawa (26%) and USNH Guam (26%). USNH Okinawa and USNH Guam are small Role 3 naval hospitals with a wide variety of services for families and children.[1] The most common destination facility for patients who received a transfusion (50%) is Tripler Army Medical Center in Oahu, Hawaii, designated as a Role 4 army hospital with higher surgical capabilities.[1]

Discussion

Within the INDOPACOM during our study period, we found that nearly 1 in 25 patients transported received blood products, a substantial portion of patients within this dataset. Compared to data from the Africa Command (AFRICOM) GCC, this is four-fold more frequent.[6] This is likely multifactorial including the lack of blood products in many areas within AFRICOM but more likely is related to the lack of dependents accompanying the service members during their tours in Africa with the exception of a few larger locations that often serve as medical logistic hubs. Moreover, AFRICOM is a relatively new GCC with just over a decade since it was established by President George W. Bush. Comparatively, INDOPACOM was established circa World War II. With nearly half of the patients receiving blood products documented as dependents, which emphasizes the differences in the healthcare needs of dependents versus the heavily screened service members; it also shows that a robust medical care system is required to support accompanied tours. Moreover, the INDOPACOM area has service members stationed in areas with healthcare systems that at least match that of US-based military healthcare system, such as Korea and Japan, which is different than most of the duty locations in Africa. There are also US military Role 3 facilities throughout the region unlike Africa. As such, we must be prepared to provide a large gamut of care in this setting including the need to deliver blood products. In a retrospective study paper using the TRAC2ES data repository, only 11 cases of blood administration were identified within the AFRICOM dataset which represented 1% of the total cases, one-fourth of the reported volume in our dataset.[6] INDOPACOM theater saw a significantly higher use of blood products, but a lower amount of trauma-related injuries. Seven out of the 11 patients who received blood products (64%) from AFRICOM were trauma-related, but INDOPACOM only saw 34 trauma cases out of the 173 patients who received blood (20%) in the TRAC2ES database (unpublished data). This highlights the differences in patient presentations in the largely non-combat, low-intensity INDOPACOM theater.

Seventy-two percent of patients in INDOPACOM were administered PRBCs. These are consistently used for blood transfusions, indicating the importance of providing an adequate supply of PRBCs to all INDOPACOM hospitals, including field hospitals. We also identified two cases in which blood products were unattainable particularly in small hospitals. Transport was required for these patients to get blood transfusions, indicating an increased need for supplying blood products to all hospitals.

Table 3. Blood Products administered to trauma patients.

Blood Components	Number	Percentage of Trauma Patients
Packed Red Blood Cells	20	58.8%
Packed Red Blood Cells and Fresh Frozen Plasma	3	8.9%
Fresh Frozen Plasma	2	5.9%
Packed Red Blood Cells, Plasma, and Platelets	1	2.9%
Cryoprecipitate, Packed Red Blood Cells, Fresh Frozen Plasma, and Platelets	1	2.9%
Not Specified	7	20.6%

Of the trauma patients, very few received a balanced regimen of blood products, mostly due to decreased availability of

platelet containing blood products (apheresis platelets or LTOWB as examples). Using the Korean peninsula as an example, platelets are only available at one US military treatment facility, and that same facility only began to receive LTOWB in December of 2019. There were only five records of patients who received more than one type of blood product, with none receiving whole blood. Packed red blood cells alone were administered to 58.8% of the trauma patients which does not reflect current research on best practices for hemodynamic stability. Current recommendations suggest administering whole blood or blood products that replicate the normal ratios of whole blood.[8] The lack of use of whole blood or platelets is in large part due to only changing the logistical requirement as early as 2016 with the addition of platelets to the transfusion practice guidelines.[9] With this change, LTOWB and apheresis platelets (to include cold stored platelets) have become more prevalent in US military treatment facilities, to include as far forward in some GCCs as point of injury. It is possible the use of whole blood equivalent and non-PRBC transfusions will increase in INDOPACOM GCC during the 2018-2028 decade because of these advancements.

Table 4. Cases where limited blood resulted in the need for transport.

Cases	Location	Blood Limitations
Case 1	374th Medical Group Yokota Air Base, Japan	Thrombocytopenia and sepsis in a 0-day old male. Patient needs to transfer to Kadena for natal intensive care unit care. Patient requires platelet transfusion and continuous monitoring which is unavailable at this facility.
Case 2	US Navy Hospital Guam	Patient with anemia and progressive thrombocytopenia refractory to transfusion. Patient exhausted the island's platelets and currently exceeds the island's capacity for care. Transfer to Tripler Army Medical Center required for continued evaluation and management.

Sixty percent of patients were listed as dependents or veterans. The largest proportion (37%) of this patient population were minors (< 18 years old). Pediatric patients often received blood for anemia, or as early newborns within the neonatal intensive care unit (NICU) which is likely a contributing factor to the number of children <1 year who received a blood product. Premature and low-weight infants are often transfused blood to compensate for low hematocrit and prevent chronic anemia sequelae.[10] Blood transfusions in pediatric patients differ from transfusions in adults, as one must account for children's larger physiological reserve leading to a decreased need for blood transfusions and estimating blood volume based on weight.[11]

Patients above the age of 50 accounted for 23% of patients. Healthcare professionals within the INDOPACOM region should therefore be knowledgeable of the possible complications for blood transfusions in populations at higher risk for events such as acute respiratory distress syndrome, transfusion associated circulatory overload, transfusion related acute lung injury, or pulmonary embolus.[12]

While the patient population in INDOPACOM are largely dependents, the real concern comes in the name of conflict in the INDOPACOM AOR. During the Korean War, in 1952, over 60,000 blood products were transfused.[13] If there were a peer-to-peer conflict, the Armed Services Blood Program would have to restructure many aspects of their operations to meet the most recent clinical practice guidelines of transfusing whole blood or components at whole blood ratios. While the INDOPACOM region is generally low intensity with little in the way of combat operations, there is a high potential for that to rapidly change with little notice. Stability on the Korean peninsula and safety in Japan continues to be challenged by the North Korean government. Interactions between US, Chinese, and Russian militaries has been reported in recent years. Extremist groups have significant activity in the Philippines as evidenced by the 2017 Battle of Marawi. While the US involvement was by way of advise and assist, there is a high risk for escalation into direct combat with US forces. As such, a logistical supply chain that can rapidly adjust to accommodate must continue to be supported.

Our study also highlights several gaps that exist in the region. Future research could benefit from looking into the amount of blood products given within the INDOPACOM region for a better understanding of the blood supply needed in this region. The TRAC2ES system did not provide this information consistently. Within CENTCOM, entries into the Department of Defense Trauma Registry (DODTR) are a theater mandate, and thus, the data capture is relatively robust, albeit with some limitations.[7] However, within INDOPACOM and AFRICOM, there is less regulation on data collection systems. The development of a performance improvement system or implementation of DODTR documentation mandate would greatly enhance data-driven solutions. TRAC2ES is primarily designed for tracking patient transports and thus is not built to collect objective data for performance improvement. Such a mandate would also greatly aid in mission planning and supply distribution.

Limitations include the TRAC2ES system. It only provides information on interfacility transfers. As such, we can only describe patients that survived to transport or

who were not treated by local hospitals and discharged/expired. To that end, we are unable to describe those who died prior to transport that received a blood transfusion, that received a transfusion and were discharged without need for evacuation, or were too unstable for transport to a US MTF and had to be moved to a local medical facility. The abstracted medical records were widely varied in detail, resulting in differences of reliability and the granularity of data available within the entries. There was limited information on how many units of blood were given and the ratios of blood given. While some providers chose to enter this information in the free text, most did not. This limited our analysis of blood products given. The data collection system is designed for managing patient transport, not for performance improvement or research. Frequently, the records are entered by non-medical personnel who may miss relevant information from diagnoses or interventions. We also lack information regarding patient outcomes, complications, and those who received additional blood products at the receiving facility where resources were presumably more available.

Conclusion

Blood products were administered to nearly 1 out of every 25 patients transported within INDOPACOM, which highlights the need for reliable methods for obtaining and maintaining blood products. Given INDOPACOM's vast area of responsibility and possibility for a peer-to-peer war, finding optimal methods to transport and store blood and blood products is imperative. The use of a more robust system of record that allows better tracking of patient conditions and supplies used could improve the quality of care and data-driven solutions with our study highlighting shortcomings in the use of this tracking system.

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References

1. Walker JJ, Stockinger ZT, Chinn CG. Establishing a Joint Theater Trauma System During Phase Zero Operations. *Mil Med*. 2017; 182(S1):41-46.
2. Taylor AL, Corley JB. Theater Blood Support in the Prehospital Setting. *US Army Med Dep J*. 2016; (2-16):43-7.
3. Fisher AD, Miles EA, Broussard MA, et al. Low titer group O whole blood resuscitation: Military experience from the point of injury. *J Trauma Acute Care Surg*. 2020; 89(4):834-41.
4. Fisher AD, Miles EA, Shackelford S. Slow and Risky to Safe and Briskly: Modern Implementation of Whole Blood. *J Spec Oper Med*. 20(1):21-25.
5. Perkins JG, Cap AP, Spinella PC, et al. Comparison of platelet transfusion as fresh whole blood versus apheresis platelets for massively transfused combat trauma patients (CME). *Transfusion*. 2011; 51(2):242-52.
6. Carius B, Davis WT, Linscomb CD, et al. An analysis of US Africa command area of operations military medical transportations, 2008-2018. *Afr J Emerg Med*. 2020; 10(1):13-16.
7. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of data from the Department of Defense Joint Trauma System Prehospital Trauma Registry. *US Army Med Dep J*. 2017; (3-17):92-97.
8. Gurney JM, Spinella PC. Blood transfusion management in the severely bleeding military patient. *Curr Opin Anaest*. 2018; 31(2):207-14.
9. Bohan PMK, Yonge JD, Schreiber MA. Update on the massive transfusion guidelines on Hemorrhagic shock: after the wars. *Current Surgery Reports*. 2016; 4(5):16.
10. Whyte R, Kirpalani H. Low versus high haemoglobin concentration threshold for blood transfusion for preventing morbidity and mortality in very low birth weight infants. *Cochrane Database Syst Rev*. 2011; (11):CD000512.
11. Dehmer JJ, Adamson WT. Massive transfusion and blood product use in the pediatric trauma patient. *Semin Pediatr Surg*. 2010; 19(4):286-91.
12. Mador B, Nascimento B, Hollands S, Rizoli S. Blood transfusion and coagulopathy in geriatric trauma patients. *Scand J Trauma Resusc Emerg Med*. 2017; 25(1):33.
13. Crosby WH, Akeroyd JH. Some

immunohematologic results of large transfusions of group O blood in recipients of other blood groups; a study of battle casualties in Korea. *Blood*. 1954; 9(2):103-16.

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Warfighter Personal Protective Equipment and Combat Wounds

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Abstract

Background: Personal protective equipment (PPE) is crucial to force protection and preservation. Innovation in PPE has shifted injury patterns, with protected body regions accounting for decreased proportions of battlefield trauma relative to unprotected regions. Little is known regarding the PPE in use by warfighters at the time of injury.

Methods: We queried the Prehospital Trauma Registry (PHTR) for all encounters from 2003-2019. This is a sub-analysis of casualties with documented PPE at the time of medical encounter. When possible, encounters were linked to the Department of Defense Trauma Registry (DODTR) for outcome data. Serious injuries are defined as an abbreviated injury scale of 3 or greater.

Results: Of 1,357 total casualty encounters in the PHTR, 83 were US military with documented PPE. We link 62 of this cohort to DODTR. The median composite Injury Severity Score (ISS) was 6 (Interquartile range (IQR) 4-21), and 11 casualties (18%) had an ISS >25. The most seriously injured body regions were the extremities (21%), head/neck (16%), thorax (16%), and abdomen (10%). PPE worn at time of injury included helmet (91%), eye protection (73%), front (75%) and rear plates (77%), left/right plates (65%), tactical vest (46%), groin protection (12%), neck protection (6%), pelvic shield (3%), and deltoid protection (3%).

Conclusion: Our data set demonstrates that the extremities were the most commonly injured body region, followed by head/neck, and thorax. PPE designed for the extremities and neck are also among the least commonly worn protective equipment.

Keywords: personal, protective, equipment, body, armor, military, combat

Introduction

Warfighter protective gear often evolves alongside the weapons inflicting injury, revealing a complex dichotomy between armament and armor development. Innovations in injury prevention and/or reduction seek to counteract the increasing lethality of modern warfare. Individual body armor is one such advancement with demonstrated efficacy in injury reduction.[1-4] Current personal protective equipment (PPE) covers vital areas (cranium, thorax, and upper abdomen), but affords limited protection to other crucial areas like the face, neck, and junctional areas. The result is a shift in observed injury patterns where these unprotected areas account for increased injury burden.[5,6] Consequently, there is renewed concern and interest in novel solutions to mitigate these deficiencies.

Several important modifications have emerged: soft armor yoke and collar assemblies shield the vulnerable neck and throat regions; the deltoid axillary protection system (DAPS) covers the proximal upper extremities; and the pelvic protection system (PPS) protects the lower urogenital system and proximal femoral arteries. Pelvic protection and collar assemblies are associated with decreased rates of urogenital injury and neck injury, respectively.[1,3,7-10] Data on DAPS efficacy is lacking; a single study evaluated upper extremity injury patterns correlated to DAPS use, reporting inconclusive results.[11]

Increased warfighter protection must balance the needs for mobility, comfort, and heat exchange while preventing exhaustion.[12] The modular nature of modern body armor enables commanders to tailor the armor system according to mission needs when deployed and achieve

this balance. However, it remains unclear which body armor components are worn by casualties at the time of injury.[13] Here, we describe warfighter PPE usage at the time of combat-related injury in US military personnel and identify serious injury by body region.

Methods

This is a descriptive study consisting of a secondary analysis of a dataset from the Prehospital Trauma Registry (PHTR). The intended outcome is an improved understanding of the types of PPE most commonly worn by casualties at the time of injury and the injuries most often sustained using the PHTR dataset. Protocol H-19-018 submitted to the USAISR regulatory office on behalf of this study was determined to be exempt from institutional review board oversight. We obtained only de-identified data. For this analysis, we searched within our dataset for US military service members with documented PPE use.

Table 1. Prehospital Trauma Registry demographic data (n=83).

Demographic*	18-25 years	48% (40)
	26-33 years	39% (33)
	34-41 years	2% (2)
	42-49 years	4% (3)
	Male	83 (100%)
Rank	Officer	5% (4)
	Enlisted	90% (75)
	Unspecified	5% (4)
Unit	Conventional	80% (67)
	SOF	12% (10)
	Unspecified	7% (6)
Battle status	Battle injury	83% (69)
	Non-battle injury	17% (14)
Country	Afghanistan	95% (79)
	Iraq	5% (4)
Mechanism of injury**	Explosive	56% (47)
	Firearm	15% (13)
	Fragmentation	1% (1)
	Aircraft mishap	12% (10)
	Burn	1% (1)
	Blunt unspecified	2% (2)
	Fall	5% (4)

*5 casualties had no age recorded
**casualties could have more than one documented injury mechanism

Prehospital Trauma Registry: The Joint Trauma System (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. This database facilitates reduced morbidity and mortality through performance improvement in the areas of primary (tactics, techniques, and procedures dictating PPE use), secondary (identifying PPE capability gaps), and tertiary prevention (establishing a casualty response system and Tactical Combat Casualty Care (TCCC)).[14] The US Central Command JTS Prehospital Directorate collected TCCC cards and after action reviews (AARs), then transcribed the information into the PHTR. The origins of the PHTR are previously described.[15,16]

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.[17-23] The DODTR documents demographics, injury-producing incidents, diagnoses, treatments, and outcomes following injuries. The registry includes data for 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, or 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: We used commercially available software for organizing and analyzing the data. We report continuous variables as means and standard deviations, ordinal variables as medians and interquartile ranges (IQR), and nominal variables as numbers and percentages. We define serious injury on the Abbreviated Injury Scale (AIS) as 3 or greater by body region.[24] AIS and Injury Severity Score (ISS) are calculated within the DODTR.

Results

We obtained 1357 casualty encounters from the PHTR, identifying 98 casualties with documented PPE use. Of these, 83 were U.S. military meeting inclusion criteria; 62 subjects (75%) were linked to the DODTR for outcome data. The median composite Injury Severity Score (ISS) was 6 (IQR 4-21) and 11 casualties (18%) possessed an ISS >25.

The majority of the 83 subjects were enlisted (90%), assigned to conventional units (80%), wounded in battle (83%), and injured during operations in Afghanistan (95%). The most frequent mechanism of injury was blast at 56%, followed by firearms at 15% (Table 1). The most common seriously injured body region was the extremities (21%), followed by head/neck (16%), thorax (16%),

and abdomen (10%) (Table 2). PPE worn at time of injury included helmet (91%), eye protection (73%), ear protection (21%), neck protection (6%), front plate (75%) and rear plate (77%), left and right plates (65%), tactical vest (46%), groin protection (12%), pelvic shield (3%), deltoid protection (3%) (Table 3).

Table 2. Outcome data from the Department of Defense Trauma Registry (n=62).

Injury Severity Score*	Composite	6 (4-21)
Abbreviated injury scale**	Head/neck	1 (0-2)
	Face	0 (0-1)
	Thorax	0 (0-0)
	Abdomen	0 (0-0)
	Extremities	0 (0-2)
	Skin	1 (1-1)
Serious injuries by body region#	Head/neck	16% (10)
	Face	1% (1)
	Thorax	16% (10)
	Abdomen	10% (6)
	Extremities	21% (13)
	Skin	0% (0)
Hospital discharge status	Alive	97% (60)
	Dead	3% (2)

*median and interquartile range
**presented as median an interquartile range
#based on an abbreviated injury scale by body region of ≥3

Discussion

Recent accelerations in PPE innovation have resulted in the best-protected warfighters in US military history. Our data demonstrates that most casualties wore front/rear/side plates (75%, 77%, and 65%, respectively), helmet (91%), and eye protection (73%) at the time of injury. A minority wore neck collars (6%), DAPS (3%), and/or pelvic protection (3%) (Table 3). The most seriously injured body regions were the extremities, head/neck, thorax, and abdomen (Table 2).

Previous studies sought to determine the effectiveness of body armor modalities in terms of protection afforded and usage outcomes. The literature shows that body armor usage shifted injury patterns from penetrating chest and abdominal injuries to an increased prevalence of head/face/neck (HFN) and extremity injury.[2,25,26] Protection has been directly observed in prevention of penetration, and also implied via the global shift in injury prevalence according to body region.[5,6,27-33]

This shift in injury pattern toward HFN and body extremities led to increased interest in innovative solutions to protect these vital areas while balancing warfighter comfort, thermal management, and mobility.[7,8,12,34,35] The modularity of the armor system which enables mission-specific adaptation at the commander's discretion and individual warfighter preferences are confounding factors as well. Our results provide insight into the type of armor modalities assumed to be in use at time of injury and describes observed injury patterns. One unique finding is the low percentages of warfighters using neck protection (6%) at time of injury.

Table 3. Documented personal protective equipment present.

Helmet	91% (76)
Eye protection	73% (61)
Ear protection	21% (18)
Neck protector (yoke and collar)	6% (5)
Torso plate, rear	77% (64)
Torso plate, front	75% (63)
Side plate, right	65% (54)
Side plate, left	65% (54)
Tactical vest	46% (39)
Deltoid – right	3% (3)
Deltoid – left	3% (3)
Groin protection	12% (10)
Pelvic shield	3% (3)

The low rates of neck soft armor use are particularly remarkable given the availability of this armor component to U.S. forces. A previous study of coalition military forces also reported infrequent use of neck collars and stemmed from collar discomfort, preference for increased mobility, and the ability to stay cooler.[27]

Only 3% of casualties wore DAPS at the time of injury. Low DAPS use is consistent with a 2006 study which found that just two (2) of 41 casualties treated at Madigan Army Medical Center with upper extremity injuries had been issued DAPS; one casualty did not use the issued DAPS due to discomfort, and the other was hit in an area not protected by DAPS.[11] The authors noted it was plausible that low DAPS usage rates may partially stem from inconsistent central issue of the protection. However, they also attributed service member noncompliance to concerns over reduced ability to perform individual warfighter tasks, which is supported in a US Army technical report demonstrating extremity armor systems negatively impacting the performance of military tasks.[12]

Based on this study, the least commonly worn body armor at time of injury were neck protectors and DAPS, and likewise the most frequently seriously injured body regions were the neck (16%) and extremities (21%). The data suggests a trend whereby warfighters preferentially protect vital areas like the head and thorax, while also opting for less protection of the neck or extremities. Low usage rates for neck collars or DAPS may be attributed to several factors. One factor might have been a perception that such armor would not effectively stop projectiles and wearing such items was without any benefit, despite established armor performance standards and evidence of efficacy.[1,32,36,37] A second reason might be increased thermal burden on the warfighter, leading to more rapid exhaustion or risk of becoming a heat casualty. Another explanation may be the perception neck collars and DAPS reduce individual mobility essential for critical combat

activities, prompting unit commanders or individual warfighters to not wear these items. Additionally, casualties may not have had access to their full body armor kit because of the circumstances of the attack, such as in a warfighter at the mess hall or performing physical training. Lastly, the very low rates of neck collar and DAPS utilization observed could be the result of poor medical documentation, as noting these body armor components would be of little consequence to the prehospital medical provider attempting to stabilize trauma casualties.

The neck and extremities are often left exposed because full range of motion are critical for the quick reactions needed for survival during combat. This represents a significant challenge in terms of protection. Future body armor systems will likely require innovation both in design and materials in order to meet this challenge. Currently, the US Army is testing its Soldier Protection System, which among other improvements include integrated deltoid armor, as well as enhanced maxillofacial and groin protection.[38]

Our dataset has several limitations. The first issue is external validity due to the small sample size, likely the result of poor annotation of PPE worn at time of injury. The large majority of casualty encounters collected from the PHTR did not have PPE annotated. We simply do not know what the majority of casualties were wearing at the time of injury. This limits the conclusions we can draw from our study. With only 98 casualties within our dataset with PPE data, that represents far less than 1% of all combat casualties.[39] This limits the conclusions we can draw but more importantly speaks to the need for better performance improvement systems. It also highlights the needs for data to be captured in a systematic manner to assess deaths associate with PPE limitations.

A second limitation is the lack of information on the specific injury pattern with the exact PPE by each individual injured, which would be useful in building a correlation between PPE usage and injury pattern or severity. With only 62 casualties linked to the DODTR for outcome data our sample size was too small to perform regression analyses to seek robust associations and would largely create more questions than answers. Third, the data does not describe the exact location of injury relative to the area of the body actually protected by PPE. The data describes injuries to body regions broadly speaking, not to a specific area within that body region. This confounds interpretation of the data, for instance, in casualties who experience injury to the distal upper extremity not protected by DAPS, which is designed to protect the proximal upper extremity from fragments and blast debris. A fourth limitation can be found in the lack of description of the type of body armor system used. For instance, use of a plate carrier system would preclude the use of neck collars and DAPS. Lastly, our study is reliant on registry data sourced by prehospital medical documentation, and previous reports have demonstrated US military medical documentation rates are poor.[15] This is demonstrated by inconsistencies such as the torso plates being present 75+% of the time compared to the tactical vest at only 46%.

Conclusion

With our dataset, the extremities were the most commonly injured body region, followed by head/neck, and thorax. PPE designed for the extremities and neck were among the least commonly worn protection.

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References

1. Breeze J, Allanson-Bailey L, Hepper A, Midwinter M. Demonstrating the effectiveness of body armour: a pilot prospective computerized surface wound mapping trial performed at the Role 3 hospital in Afghanistan. *J of the Royal Army Med Corps*. 2015;161(1):36-41.
2. Post J. Impact of Body Armor on Head and Neck Injuries: Preventive Measures. In: Brennan JA, Holt GR, Thomas RW, eds. *Otolaryngology/Head and Neck Surgery Combat Casualty Care in Operation Iraqi Freedom and Operation Enduring Freedom*. Fort Sam Houston, TX: Office of the Surgeon General, Department of the Army. Borden Institute; 2015:61-75.
3. Paquette E. Genitourinary trauma at a combat support hospital during Operation Iraqi Freedom: the impact of body armor. *J of Urology*. 2007;177(6):2196-2199.
4. Mabry R, Holcomb J, Baker A, et al. United States Army Rangers in Somalia: An Analysis of Combat Casualties on an Urban Battlefield. *J of Trauma*. 2000;49(3):515-528.
5. Tong D, Beirne R. Combat Body Armor and Injuries to the Head, Face, and Neck Region: A Systematic Review. *Mil Med*. 2013;178(4):421-426.

6. Schoenfeld A, Dunn J, Bader J, Belmont PJ. The Nature and Extent of War Injuries Sustained by Combat Specialty Personnel Killed and Wounded in Afghanistan and Iraq, 2003-2011. *J of Trauma and Acute Care Surg*. 2013;75(2):287-291.
7. Oh J, Do N, Clouser M, et al. Effectiveness of the Combat Pelvic Protection System in the prevention of Genital and Urinary Tract Injuries: An Observational Study. *J of Trauma and Acute Care Surg*. 2015;79(4):S193-S196.
8. Breeze J, Horsfall I, Hepper A, Clasper J. Face, neck, and eye protection: adapting body armour to counter the changing patterns of injuries on the battlefield. *British J of Oral and Max Surg*. 2011;49(8):602-606.
9. Breeze J, Clasper J. Ergonomic Assessment of Future Methods of Ballistic Neck Protection. *Mil Med*. 2013;178(8):899-903.
10. Fox C, Gillespie D, Weber M, et al. Delayed Evaluation of Combat-Related Penetrating Neck Trauma. *J of Vasc Surg*. 2006;44(1):86-93.
11. Greer M, Miklos-Essenberg M, Harrison-Weaver S. A Review of 41 Upper Extremity War Injuries and the Protective Gear Worn During Operation Enduring Freedom and Operation Iraqi Freedom. *Mil Med*. 2006;171(7):595-597.
12. Hasselquist L, Bensel C, Corner B, Gregorczyk K. *An Investigation of Three Extremity Armor Systems: Determination of Physiological, Biomechanical, and Physical Performance Effects and Quantification of Body Area Coverage*. Natick, MA: U.S Army Natick Soldier Research, Development and Engineering Center;2012.
13. Potter A, Karis A, Gonzalez J. *Biophysical Characterization and Predicted Human Thermal Responses to U.S. Army Body Armor Protection Levels (BAPL)*. Natick, MA: U.S. Army Research Institute of Environmental Medicine;2013.
14. Kotwal RS, Butler FK, Edgar EP, Shackelford SA, Bennett DR, Bailey JA. Saving Lives on the Battlefield: A Joint Trauma System Review of Pre-Hospital Trauma Care in Combined Joint Operating Area ? Afghanistan (CJOA-A) Executive Summary. *J Spec Oper Med*. 2013;13(1):77-85.
15. Schauer SG, April MD, Naylor JF, et al. A descriptive analysis of data from the Department of Defense Joint Trauma System Prehospital Trauma Registry. *US Army Med Dep J*. 2017(3-17):92-97.
16. Robinson JB, Smith MP, Gross KR, et al. Battlefield Documentation of Tactical Combat Casualty Care in Afghanistan. *US Army Med Dep J*. 2016(2-16):87-94.
17. Glenn MA, Martin KD, Monzon D, et al. Implementation of a combat casualty trauma registry. *J Trauma Nurs*. 2008;15(4):181-184.
18. O'Connell KM, Littleton-Kearney MT, Bridges E, Bibb SC. Evaluating the Joint Theater Trauma Registry as a data source to benchmark casualty care. *Mil Med*. 2012;177(5):546-552.
19. Schauer SG, April MD, Hill GJ, Naylor JF, Borgman MA, De Lorenzo RA. Prehospital Interventions Performed on Pediatric Trauma Patients in Iraq and Afghanistan. *Prehosp Emerg Care*. 2018:1-6.
20. Schauer SG, Hill GJ, Naylor JF, April MD, Borgman M, Bebarta VS. Emergency department resuscitation of pediatric trauma patients in Iraq and Afghanistan. *Am J Emerg Med*. 2018.
21. Schauer SG, Naylor JF, Oliver JJ, Maddry JK, April MD. An analysis of casualties presenting to military emergency departments in Iraq and Afghanistan. *Am J Emerg Med*. 2018.
22. Spott MA, Kurkowski CR, Stockinger Z. The Joint Trauma System: History in the Making. *Mil Med*. 2018;183(suppl_2):4-7.
23. Spott MA, Kurkowski CR, Burelison DR, Stockinger Z. The DoD Trauma Registry Versus the Electronic Health Record. *Mil Med*. 2018;183(suppl_2):8-11.
24. Foreman BP, Caesar RR, Parks J, et al. Usefulness of the abbreviated injury score and the injury severity score in comparison to the Glasgow Coma Scale in predicting outcome after traumatic brain injury. *J Trauma*. 2007;62(4):946-950.
25. Belmont P, Schoenfeld A, Goodman G. Epidemiology of combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom: Orthopaedic Burden of Disease. *J of Sur Orth Adv*. 2010;19(1):2-7.
26. Xydakis M, Fravell M, Nasser K, Cater J. Analysis of battlefield head and neck injuries in Iraq and Afghanistan. *Otolaryngology–Head and Neck Sur*. 2005;133(4):497-504.

27. Breeze J, Allanson-Bailey L, Hunt N, Delaney R, Hepper A, Clasper J. Mortality and Morbidity from Combat Neck Injury. *J of Trauma and Acute Care Sur*. 2012;72(4):969-974.

28. Keneally R, Szpisjak D. Thoracic Trauma in Iraq and Afghanistan. *J of Trauma and Acute Care Sur*. 2013;74(5):1292-1297.

29. Hofmeister E, Mazurek M, Ingari J. Injuries Sustained to the Upper Extremity Due to Modern Warfare and the Evolution of Care. *J of Hand Sur*. 2007;32(8):1141-1147.

30. Patel T, Wenner K, Price S, Weber M, Leveridge A, McAtee S. A U.S. Army Forward Surgical Team's Experience in Operation Iraqi Freedom. *J of Trauma*. 2004;57(2):201-207.

31. Kosashvili Y, Hiss J, Davidovic N, et al. Influence of personal armor on distribution of entry wounds: lessons learned from urban-setting warfare fatalities. *J of Trauma*. 2005;58(6):1236-1240.

32. Prat N, Rongieras F, Sarron J, Miras A, Voiglio E. Contemporary Body Armor: Technical Data, Injuries, and Limits. *Eur J of Trauma and Em Sur*. 2012;38(2):95-105.

33. Sonden A, Rocksen D, Riddez L, et al. Trauma Attenuating Backing Improves Protection Against Behind Armor Blunt Trauma. *J of Trauma*. 2009;67(6):1191-1199.

34. Potter A, Gonzalez J, Karis A, Xu X. Biophysical Assessment and Predicted Thermophysiologic Effects of Body Armor. *PLOS ONE*. 2015;10(7):e0132698.

35. Kollock R, Hale D, Vogelpohl R, et al. The Influence of Body Armor on Balance and Movement Quality. *Intl J of Ex Sci*. 2018;11(1):648-656.

36. Purchase Description: Body Armor, Multiple Threat/Interceptor Improved Outer Tactical Vest (IOTV) Generation III. In: Army U, ed. Fort Belvoir, VA: Project Manager, Soldier Protection and Individual Equipment, Program Executive Office; 2012:20-21.

37. Defense Logistics: Army and Marine Corps' Body Armor Requirements, Controls, and Other Issues. In. *Committee on Armed Services*. Washington, D.C.: United States Government Accountability Office; 2007.

38. Gilmore J. *FY16 Army Programs: Soldier Protection System (SPS)*. The Office of the Director, Operational Test and Development;2016.

39. Howard JT, Kotwal RS, Stern CA, et al. Use of Combat Casualty Care Data to Assess the US Military Trauma System During the Afghanistan and Iraq Conflicts, 2001-2017. *JAMA Surg*. 2019;154(7):600-608.

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Educating the Leaders and Clinicians of Tomorrow: An Innovative Emergency Medicine Research Curriculum for Resident Physicians

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Abstract

Academic productivity is a requirement by the Accreditation Council for Graduate Medical Education (ACGME). In addition to the requirements by the ACGME, residency training programs are required to provide education on medical research with the end-goal of teaching physicians how to read, interpret, and apply medical evidence in the form of evidence-based medicine. An understanding of research design, evidence-based medicine, and critical appraisal of available literature is central to practicing medicine and applying new research to clinical practice. However, residency programs vary significantly in research curricula provided to residents. We describe an innovative integrated military-civilian emergency medicine research curriculum that provides foundational knowledge in research design and critical appraisal.

Keywords: research, education, emergency medicine, ACGME, curriculum

Introduction

Physicians must think critically, evaluate available literature, assimilate and synthesize knowledge, apply this knowledge at the bedside, and practice lifelong learning.[1] The Accreditation Council Graduate Medical Education (ACGME/GME) focuses on forming competent practicing physicians. GME incorporates several requirements of residency programs, including evidence of scholarly activity and advancing resident physician knowledge and practice of the scholarly approach to evidence-based medicine (Table 1).[2] Scholarly activity broadly includes activities encompassing discovery, integration, application, and teaching.[2] However, multiple barriers are present during residency that hamper resident physicians from acquiring such skills and performing scholarly activity (Table 2).[3,4]

Many residency programs include a scholarly requirement and some form of curriculum for critical appraisal of literature. This scholarly requirement may take many forms such as abstracts, poster presentations, conference lectures, case reports, or original research.[3-11] The means by which resident physicians learn skills and techniques necessary for critical appraisal also may vary, but often include some form of journal club sessions, in which they evaluate one or several original research projects.[4-7] However, this scholarly requirement and journal club sessions may not provide a foundational understanding of several components of literature, including research question design, literature searches, study design, protocol construction, and analysis of evidence.[4-7] Medicine, and residency in particular, has centered on an apprentice-based learning system for decades. This method of teaching persists today because passive learning does not provide the foundations active learning does. As such, a curriculum that provides these components exposes resident physicians to research opportunities and establishes a set of research milestones with a required scholarly project, which may enhance understanding of medical literature and allow learners to complete impactful scholarly projects.[4-11]

Significant variability exists across emergency medicine

residency programs with regards to the specific requirement for scholarly activity.[3-11] A national survey of scholarly activity requirements demonstrated that 39% of emergency medicine residency programs required residents to perform an original research project.[11] The principal research challenges identified by program directors were data collection and study design.[11,12] Although research is a core topic in the American Board of Emergency Medicine (ABEM) Model,[1] there is currently no standardized curriculum to teach these principles. The objective of this manuscript is to provide a description of an innovative integrated military-civilian emergency medicine research curriculum and provide pilot data regarding scholarly activity output before and after implementation of this program.

Table 1. Graduate medical education research objectives.

Knowledge	-Critically appraise research literature -Understand research process -Develop knowledge of research design
Attitudes	-Enhance residents' appreciation of research -Increase residents' intellectual curiosity
Skills	-Prepare research proposal -Increase residents' scholarly productivity -Increase residents' presentation skills -Devise methods for collecting and analyzing data -Develop clinical proficiency and critical thinking
Process	-Expose residents to successful researcher role models
Institutional	-Meet ACGME/RRC education core curriculum requirements -Provide an overview of the research being performed at the parent institution

Methods

This manuscript provides a description of an innovative longitudinal three year research curriculum that provides resident physicians with education on research questions, literature searches, study design, grant construction, evidence based medicine, and critical appraisal. We detail the following components of the curriculum: 1) problem identification and general needs assessment, 2) targeted needs assessment of the learners, 3) educational goals and objectives, 4) instructional strategies, 5) implementation, and 6) evaluation and feedback.

Problem Identification & General Needs Assessment: Emergency medicine (EM) is a dynamic field of medical practice requiring constant learning and an understanding of medical literature. However, to best critically appraise and apply medical literature as a foundation of evidence-based medicine, physicians must have an underlying set of skills and understanding of medical literature and research.[1,4,5] A military EM residency program located in San Antonio, TX, had a research curriculum in place for 20 years despite multiple deployments and multiple staff turnovers. A separate civilian EM program located within the same city did not. These centers currently represent the only two emergency medicine residency programs in San Antonio, TX. The military and civilian programs are both 3-year training programs, though the military program has 16 residents per year and the civilian program 12 residents per year. These two programs form our comparator and the justification for developing this review in which we developed a robust training program. The military's program primarily included lecture-based learning prior to 2016. This military research curriculum included a dedicated set of lectures during the first year of training with little active learning activities and an expectation that residents would create a research question and subsequent protocol, much of which was based around the same apprentice-based learning method where the research faculty identified the ideal mentor for the resident's desired scientific inquiry. We report on a set of significant modifications to the existing military EM residency research curriculum in 2016, which was combined in 2019 with the civilian program to build a joint academic research curriculum, incorporating active learning (i.e., activities and small groups sessions), utilizing resident assessments, and utilizing a requirement for protocol production.

Targeted Needs Assessment of Learners: The ABEM Model of Clinical Practice incorporates performance improvement and lifelong learning, evidence-based medicine, interpretation of medical literature, knowledge translation, and research.[1] Thus, graduates of EM residency programs should have an understanding of these components, not only to graduate their residency program, but also to enhance long-term practice and lifelong learning.[1,2] Per ACGME requirements, residents must

Table 2. Barriers to graduate medical education research.

Resident	-Poor knowledge of research methods -Lack of motivation -Misconceptions about research -Failure to meet deadlines
Faculty	-Lack of experience -Faculty resistance -Time/intensity demands -Lack of motivation -Expectations greater than what a resident could reasonably accomplish -Little authority to persuade residents
Institutional	-Lack of time in residency curriculum -Financial barriers -Resistance from department/hospital administration -Lack of support staff

also complete a scholarly project during residency training.[2-4]

Educational Goals & Objectives: The objective of the modified research curriculum was to provide resident physicians a foundation in knowledge and skills necessary for study design and critical appraisal, while completing a scholarly project. The research curriculum included six primary goals:[1,4,5]

1. Apply primary biomedical scientific data to clinical practice;
2. Critically appraise biomedical scientific research papers;
3. Summarize the hypothetic-deductive model of the scientific method;
4. Understand ethical considerations related to bio medical research;
5. Understand the logistical components of a research protocol;
6. Complete an original research project relevant to EM clinical practice.

Instructional Strategies: We extensively modified an established longitudinal curriculum beginning in 2016, comprising several components during each year of residency training. The first year incorporated research education and preparation with lectures, small group activities, and protocol creation. This didactic curriculum was modelled on the Emergency Medicine Basic Research Skills (EMBRS) workshop, and multiple faculty attended the EMBRS course to help ensure consistency of presentation. The second year of residency training incorporated protocol submission to our institutional regulatory office and the Institutional Review Board (IRB/if applicable) at the beginning of the academic year, with continued opportunities including journal club sessions. The final year included data collection, manuscript construction and submission to a peer-reviewed journal, and presentation of research findings at a conference locally. Moreover, residents were encouraged to present their findings at regional and national conferences for which travel costs are usually supported by the local GME programs.

Implementation: The two training programs implemented the research curriculum halfway through the first year of residency training with a skills-based research course in the 2019-2020 academic year. During this year, residents of both the military and civilian EM programs underwent a 4-day educational series on developing a research question, conducting a literature search, designing a protocol, academic writing, and critical appraisal including design and statistical analyses. This included pre- and post-course tests, lectures, and project-based learning with small group sessions. Attending physicians with experience in emergency medicine research were the primary lecturers, focusing on the topics detailed by day(Table 3). Residents participated in practical exercises to enhance learning. These included individual projects and small group sessions. Day 4 incorporated a detailed evaluation of critical appraisal, focusing on the literature behind thrombolytics for ischemic stroke. On the final day of the course, resident physicians submitted a research question with complete protocol to the course director.

The second and third years of residency training included nine journal club sessions per year during resident conference, which evaluated separate pieces of literature and completion of the research project. The residents also submitted their protocols to the institutional regulatory office and addressed needed revisions during these years of training. Following protocol approval, residents began the project with data collection, manuscript writing, and manuscript submission to a peer-reviewed journal.

Evaluation & Feedback: To complete the first year research course, we assessed residents based on a pre- and post-course test evaluating knowledge of basic research and statistical concepts. The pre-course and post-course tests included 25 short-answer questions. Each resident submitted a research protocol at the end of the course to answer a research question which they formulated. The course director assessed the protocol in terms of literature review, question novelty and clinical relevance, methodological rigor, logistical practicality, ethical considerations, and clarity of writing.

Table 3. Research course topics.

Day 1	Day 2	Day 3	Day 4
-Course Introduction **-Pre-Course Test** -Research Questions **-Question Practicum** -Study Designs Introduction -Terminology -Hypotheses -Literature Search **-Search Practicum** -Bibliographies -Introduction to Reading a Paper **-Reading a Paper Practicum**	-Informed Consent -Institutional Review Board Overview -Funding -Statistics -Regulations -Simulation Research -Animal Research -Survey Research **-Survey Practicum** -Cohort Study -Chart Review **-Chart Review Practicum**	-Randomized Controlled Trial (RCT) **-RCT Practicum** -Narrative Reviews **-Narrative Review Practicum** -Case Reports/Series -Free Open Access Medical Education Projects -Systematic Reviews/Meta-analyses -Grant Writing -Productivity	-Study Appraisal **-Appraisal Practicum** -Course Summary **-Post-Course Test**

After each day of the research course, the course director sent residents a survey, allowing resident physicians to provide feedback (Table 4). All survey responses were anonymous and based on a scale of 1-5, with 1 defined as "no", 3 as "somewhat", and 5 as "completely". Question six did not include

a scale but allowed learners to comment on components they would like to change. This survey was not mandatory for completion of the course but had the purpose of improving the course.

Table 4. Daily survey questions.
Did the lectures and activities meet the stated objectives?
Did the lectures and activities provide information relevant to your learning?
Was the content of the lectures and activities clear and easy to understand?
Was the time allowed for the lectures and activities adequate?
Were the lecture presentation style and activity structure helpful?
What would you like to change about the lectures and activities?

Scholarly Project Tracking: As a secondary objective, we evaluated the number of resident PubMed indexed publications prior to and after implementation of the modified research curriculum in the military EM residency program. We conducted only a preliminary analysis of these data. No data from the civilian program were available concerning the number of publications. There were no data available for type of publication, journal impact factor, or research presentation.

Results

Based on secondary analysis, the number of PubMed indexed publications significantly increased after 2016 by almost 750% (Table 5).

Discussion

This innovative and collaborative civilian-military research curriculum included a research skills course with research milestones. This curriculum sought to enhance resident physician understanding of evidence-based medicine and apply these skills to patient care. The curriculum included a skills-based research course, research milestones, and a scholarly project to improve research understanding, evidence-based medicine, and future scholarship. The first integrated course included 16 first year residents from the military EM residency program and 12 first year residents from the civilian EM residency program. All residents completed protocols at the end of the research course.

Table 5. PubMed Indexed resident publications based on time period.

Curriculum Period	PubMed Indexed Publications
Before Innovative Curriculum	
2012	2
2013	5
2014	1
2015	9
Total 2012-2015	17
After Innovative Curriculum	
2016	20
2017	11
2018	41
2019	55
Total 2016-2019	127

The EM milestones were developed to objectively measure feasible, impactful, and accountable education.[1,2] This research curriculum meets components of both systems-based practice and practice-based performance improvement. These two core competency domains have the most significant assessment tool gap in emergency medicine.[1,13] This unique curricular approach to incorporate research based milestones in emergency medicine may assist program directors in assessing their residents' ability to critically appraise scientific literature, apply evidence based medicine, perform data collection, and evaluate process improvement measures to optimize ED practice.[12]

Development of a specific EM resident research program has been shown to increase resident scholarly activity.[14] Students in other fields who participated in elective research are also more likely to successfully match in a postgraduate position and achieve full-time academic appointments.[13] A resident research curriculum may itself engender more interest in an academic career among residents who might otherwise be disinclined to consider such a career path. We found this innovated research curriculum significantly increased the number of resident PubMed indexed publications. However, these are preliminary data, and there may be several confounders. In particular, given the exploratory nature of this descriptive study, a cause-and-effect relationship cannot be established, and the findings may not be the direct result of the modification in the research curriculum. Another significant limitation is that there were no data recorded for the pre- and post-course test scores to evaluate knowledge retention. Future study is needed to determine the impact of research training on future scholarly activity as attending physicians, peer-reviewed publications, choice in academic careers, and knowledge retention.

Conclusion

An integrated military-civilian research curriculum is feasible and may improve understanding of research design, evidence-based medicine, and critical appraisal.

References

1. Beeson MS, Ankel D, Bhat R, et al. 2019 EM Model Review Task Force; American Board of Emergency Medicine. The 2019 Model of

the clinical practice of emergency medicine. *J Emerg Med*. 2020;59(1):96-120.

2. Accreditation Council for Graduate Medical Education. Common Program Requirements. Published February 3, 2020. Available at https://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/CPRResidency2020.pdf. Accessed September 19, 2020.
3. Levine RB, Hebert RS, Wright SM. Resident research and scholarly activity in internal medicine residency training programs. *J of Gen Internal Med*. 2005 Feb 1;20(2):155-9.
4. Yarris LM, Deiorio NM. Education research: a primer for educators in emergency medicine. *Acad Emerg Med*. 2011 Oct;18:S27-35.
5. Cline D, Henneman P, Van Ligten P, et al. A model research curriculum for emergency medicine. *Ann Emerg Med*. 1992;21(2):184-192.
6. Hebert RS, Levine RB, Smith CG, Wright SM. A systematic review of resident research curricula. *Acad Med*. 2003;78(1):61-8.
7. Nocera R, Ramoska EA, Hamilton RJ. Building a resident research program in emergency medicine. *Intern Emerg Med*. 2016;11(2):245-8.
8. Wood W, McCollum J, Kukreja P, et al. Graduate medical education scholarly activities initiatives: a systematic review and meta-analysis. *BMC Med Educ*. 2018;18(1):318.
9. Fischer JL, Cation LJ. Developments: Impact of a residency research program on research activity, faculty involvement, and institutional cost. *Teaching and Learning in Med*. 2005 Apr 1;17(2):159-65.
10. Abramson E, Bostwick S, Green C, DiPace J. A longitudinal residency research curriculum. *MedEdPORTAL*. 2013 Aug 5;9.
11. Geyer B, Kaji A, Katz E, et al. A National Evaluation of the Scholarly Activity Requirement in Residency Programs: A Survey of Emergency Medicine Program Directors. *Acad Emerg Med*. 2015 Nov;22(11):1337-44.
12. Oliver J, Ross J, Davis WT, et al. The Development of an Emergency Medicine Resident Research Program in the United States Military. *Mil Med*. 2019 Dec 1;184(11-12):e622-e625.
13. Kessler C, Leone K. The current state of core competency assessment in emergency medicine and a future research agenda: recommendations of the working group on assessment of observable learner performance. *Acad Emerg Med*. 2012;19(12):1354-59.
14. Obcourne K, Woods K, Maxwell W, et al. Outcomes of Student-Driven, Faculty-Mentored Research and Impact on Postgraduate Training and Career Selection. *Am J Pharm Educ*. 2018 May;82(4):6246.

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End-of-Shift Evaluations: Experiences Over a Quarter-Century

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Abstract

For the past 25 years, the San Antonio Uniformed Services Health Education Consortium (SAUSHEC) Emergency Medicine Residency has used an end-of-shift evaluation (ESE) to provide formative feedback and assess resident progress. The instrument has evolved from a simple half-sheet of paper to a more complex electronic milestones assessment. The length and detail of the evaluation form has grown appreciably, but the precise impact of these changes on the effectiveness of formative feedback unknown. The authors present a narrative description of the evolution of this instrument in response to changing requirements and efforts to optimize its utility. Our experiences over the past quarter-century are presented in the context of now-common utilization of similar evaluation tools among emergency medicine (EM) training programs. The evolution of our ESE instrument may be of historical interest to EM educators and provide examples for those seeking to develop or adapt their own evaluation tools.

Introduction

For the past 25 years, the San Antonio Uniformed Services Health Education Consortium (SAUSHEC) Emergency Medicine Residency has used an end-of-shift evaluation to gather formative data on resident performance. Our end-of-shift evaluation (ESE) was instituted in the 1980s in an effort to provide timely and frequent assessment of resident performance. In response to faculty and resident feedback and requirements from the Accreditation Council for Graduate Medical Education (ACGME), the instrument has evolved from a simple half-sheet of paper to an electronic Milestones-based evaluation. The ACGME outlines requirements for emergency medicine (EM) residency evaluations as such: "Faculty members must directly observe, evaluate, and frequently provide feedback on resident performance during each rotation or similar educational assignment."[1] Programs are given latitude to develop internal mechanisms that address this requirement, and the ACGME suggests end-of-shift evaluations as one of several methods to evaluate EM Milestones.[2] Internally, our ESE has provided program leadership with useful metrics of trainee performance in an evolving landscape of graduate medical education.

ESEs are currently in common use in EM training programs and medical student clerkships,[3-8] though little is known regarding the effectiveness of these instruments compared to other methods of formative resident evaluation. Here, we describe several examples of our ESE instrument, compiled from historical program records. The authors' experience with end-of-shift evaluations over the past 25 years may provide EM educators with examples of the ways we have adapted our tool to fit the needs of our program. We provide this narrative description to that end, as well as to give context for future directions of formative evaluation of EM trainees.

End-of-Shift Evaluations through the Years: The early iterations of our ESE were relatively short paper forms, which by the mid-1990s, had been stratified along five major axes: enthusiasm and interest, information gathering, processing, knowledge base, and interpersonal skills (Appendix 1). The evaluation was revised and expanded in 2001, and to improve feedback and encourage faculty-resident discussion, a prompt on the instrument asked if the evaluation was discussed with the resident. In 2003, ACGME Core Competency categories were retrofitted to the revised instrument (Appendix 2). In 2005, the instrument was adapted again, this time to incorporate the six Core Competency categories as the primary evaluation axes (Appendix 3). By 2008, the residency program had migrated to a commercial electronic system, and the evaluation form was updated to accommodate the new format. The prior numerical scale was replaced by radio buttons denoting scores such as "satisfactory" or

"good" (Appendix 4). In 2013, EM residency programs began reporting milestones data to the ACGME, and the shift evaluation was revised to include milestones subcompetencies. At that time, the scoring system also changed to reflect competency levels in terms such as "progressing intern" or "at third-year level" (Appendix 5). In 2016, the tool was changed to include 13 milestones assessment questions that would be evaluated on each shift and five additional milestones categories to be randomly generated by the software. Additionally, the grading scale was simplified for this version, utilizing terms such as "needs improvement" or "meets expectations" (Appendix 6). The shift evaluation in current use was introduced in 2020 and includes revised question phrasing and scoring, and the "overall comments" free-text section was moved from the end of the form to the beginning to encourage more substantive narrative comments (Appendix 7).

Table 1. Summary of the evolution of our evaluation instrument over a nearly 25-year period.

Year	Evaluation Categories	Point Scale	Notes
1996	5	5	Half page of paper in length
2001	17	6	Full pager of paper in length
2005	11	6	Revised to reflect ACGME competencies
2008	10	7	Electronic form introduced
2013	17	8	Revised to reflect ACGME Milestones
2016	18*	3	Milestones based with revisions
2020	20*	10	Version in current use

Performance trends from shift evaluations are tracked within each residency class, allowing comparison of performance within year-groups. Aggregate ESE data, as well as that compiled from other evaluation sources, allows program leaders to provide meaningful summative feedback to individual trainees.

Experiences to Date: As our evaluation instrument has evolved, faculty remain challenged in assessing the precise level of performance for a given episode of observation. Likewise, residents are challenged to perceive themselves on a performance continuum that includes the possibility of strong and weak performance. Faculty may be reluctant to provide detailed, critical feedback when needed, and residents may be unenthusiastic about knowing their performance in relation to their peers.

The length and detail of our evaluation instrument has grown considerably over the past 25 years, generally reflecting changes in residency requirements. The number of evaluation categories has increased from 5 to 20, and the grading scale is relatively detailed compared with earlier versions (Table 1). However, it is difficult to precisely state the impact these changes have had on the effectiveness of our formative evaluation process. It is entirely feasible that early, shorter versions of the instrument provide as much delineation of individual resident performance as later, lengthier versions.

At times, ESE completion rates by faculty and the quality of narrative evaluation comments have lagged, perhaps reflecting "form fatigue" as the evaluation tool increased in length. We have attempted to offset this in our current ESE version by moving the free-text comment section to the top of the form. Subjectively, we have seen an improvement in the quality of comments after instituting this change. In effort to improve faculty completion rates, residency leadership established an expectation that faculty complete one ESE per shift worked. Faculty supervise a variable number of trainees per shift, and they may select which resident to evaluate on a given shift. Over the past 10 years, residents have received an average of 47 shift evaluations per academic year. In the context of 6-7 home-institution EM blocks per year, this represents approximately 40% of emergency department shifts for which a formative written evaluation can be expected.

Discussion

The end-of-shift evaluation serves a valuable function within our program, as it allows for formative resident assessment that is timely, frequent and specific. However, data is lacking as to the effectiveness of the ESE compared with other methods of resident evaluation. Additionally, specific challenges related to milestones assessments have been described by some authors, with regard to faculty understanding of milestones,[9] inter-rater reliability,[10] and misalignment of ESE Milestones scores with those determined by the Clinical Competency Committee.[7]

Within our program, we have sought to accrue a steady quantity of end-of-shift evaluations for each resident and have set faculty standards for evaluation completion. Our experience has been that frequent assessment allows for a more comprehensive picture of resident progress and helps identify early trends. However, it is a challenge to strike the correct balance between quantity and quality of feedback, and future study should aim to determine the optimal timing and frequency of evaluation and the factors that improve resident perception of feedback. Existing data suggest that evaluation quantity does not improve resident perception of feedback. Blakush, et al. reviewed data from 87 residency programs and found no correlation between the number

of evaluations per resident (mean = 53) and resident satisfaction with feedback.[11] Thus, improving quality of assessment is critical. Our current ESE version, in which the "overall comments" prompt appears at the beginning of the form, has seemed to encourage higher quality free-text commentary, however, the precise impact of this change has not yet been measured and presents an opportunity for future analysis.

We present this narrative description of our 25-year experience using end-of-shift evaluations in the context of now-widespread use of such instruments. This work is limited in scope, as we do not present comprehensive analysis of our evaluation process in terms of outcomes, such as program survey results or measures of resident performance, and these represent areas of potential future study. However, our historical examples illustrate the evolution of resident assessment in response to systems changes, ACGME requirements, and our own efforts to improve the usefulness and effectiveness of the instrument. The chronology and samples presented here may simply be of historical interest to EM educators, but they may also serve as examples for those seeking to develop or modify their own end-of-shift evaluation instruments.

Appendices

Appendix 1. Evaluation instrument, 1996.

Shift Evaluation Form					
Date:	Staff/Resident:				
Resident:	Please place comments on back.				
	Outstanding 100 points	Excellent 80 points	Average 70 points	Marginal 60 points	Poor 50 points
Enthusiasm and Interest					
Information Gathering • History and Physical • Labs, X-ray, EKG's etc. • Awareness					
Processing • Differential diagnosis • Pathophysiology • Treatment					
Knowledge base • Medicine in general • Emergency Medicine					
Interpersonal Skills • Patients • Staff • Consultants					
Patient Count					
Procedures					

Appendix 2. Shift Evaluation Instrument, 2001. The Accreditation Council for Graduate Medical Education (ACGME) core competency categories were added in 2003.

SAUSHEC Emergency Medicine

Resident Evaluation

Resident	Level	Faculty / Senior Resident	Date	Shift
	EM-1 EM-2 EM-3			BAMC WHMC Day Eve Night Support Shift

	Scoring:	1	2	3	4	5	6
		Low					High
	Compare resident to peers in same class	5%	15	30	30	15	5%
Patient Evaluations							
Recognition/stabilization of emergent patients *(PC)*		1	2	3	4	5	6
History & information gathering *(PC, IC)*		1	2	3	4	5	6
Physical examination *(PC)*		1	2	3	4	5	6
Formulation of differential dx *(PC, MK)*		1	2	3	4	5	6
Test ordering & data interpretation *(PC, MK)*		1	2	3	4	5	6
Formulation of treatment plans *(PC, PBL)*		1	2	3	4	5	6
Disposition and patient instructions *(PC, IC, PBL)*		1	2	3	4	5	6
Skills							
Documentation completeness & readability/legibility *(IC)*		1	2	3	4	5	6
Patient presentations *(IC, MK)*		1	2	3	4	5	6
Efficiency of care (speed, multiple patients) *(PC, SBP)*		1	2	3	4	5	6
Effectiveness of care (thoroughness, accuracy) *(PC, SBP)*		1	2	3	4	5	6
Knowledge of Tricare and Civilian Medical Systems *(SBP)*		1	2	3	4	5	6
Bedside manner and family interaction *(PRO, IC)*		1	2	3	4	5	6
Interactions with ED team *(PRO, IC, SBP)*		1	2	3	4	5	6
Interaction with consultants *(PRO, IC, SBP)*		1	2	3	4	5	6
Supervision of other providers (EM-2s & EM-3s) *(SBP)*	NA	1	2	3	4	5	6
Managing overall ED (EM-2s & EM-3s) *(SBP)*	NA	1	2	3	4	5	6
Overall Impression							
Performance adequate for level of training on this shift?	Yes		No	(comment required)			
Did you discuss this evaluation with the resident?	Yes		No				

Signature of Faculty/Senior Resident Performing the Evaluation_____

Additional comments on back. Return completed forms to Residency Coordinator. Document procedural skills on separate forms.

ACGME Core Competencies
PBL = Practice Based Learning *IC = Interpersonal & communication*
PC = Patient Care *MK = Medical Knowledge*
PRO = Professionalism *SBP = Systems Based Practice*

Appendix 3. Shift evaluation instrument, 2005.

Daily Resident shift evaluation 2013

[Subject Name]
[Subject Status]
[Evaluation Dates]
[Subject Rotation]

Evaluator
[Evaluator Name]
[Evaluator Status]

Evaluate resident based on appropriate milestone that you feel they will meet in 95% of patient encounters.

DATE

1 Date, shift or sim case

Comment

Remaining Characters: 5,000

General Provisions of Patient Care

2 Overall patient assessment

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN (1.5)	SECOND YEAR LEVEL	PROGRESSING SECOND YEAR (2.5)	THIRD YEAR LEVEL	PROGRESSING THIRD YEAR (3.5)	LEVEL OF EM RESIDENCY GRADUATE (4)
○	○	○	○	○	○	○	○

3 Emergency Stabilization

BELOW INTERN LEVEL	AT INTERN LEVEL Describes a primary assessment on a critically ill or injured patient Recognizes abnormal vital signs	PROGRESSING INTERN	AT SECOND YEAR LEVEL Recognizes the unstable patient who needs immediate intervention Prioritizes initial actions in a resuscitation Performs primary assessment on a critical patient	PROGRESSING 2ND YEAR	AT THIRD YEAR LEVEL Formulates a diagnostic impression and plan for a critical patient Reassess after implementing a stabilizing intervention	PROGRESSING 3RD YEAR	GRADUATE LEVEL manages multiple critical patients Identifies when further clinical intervention is futile Involves system resources into a strategy for a problematic stabilization	N/A
○	○	○	○	○	○	○	○	○

4 Performance of a Focused history and Physical Examination

BELOW INTERN	AT INTERN LEVEL Performs and communicates	PROGRESSING INTERN	AT SECOND YEAR Performs and communicates a focussed H&P reliably	PROGRESSING 2ND YEAR	AT 3RD YEAR LEVEL Prioritizes essential components of a history	PROGRESSING 3RD YEAR	GRADUATE LEVEL Uses prior medical records to	N/A

Appendix 4. Shift evaluation instrument, 2008.

SAUSHEC Emergency Medicine
Daily Resident Evaluation

[Subject Name]
[Subject Status]
[Subject Program]
[Evaluation Dates]
[Subject Rotation]

Evaluator
[Evaluator Name]
[Evaluator Status]
[Evaluator Program]

In evaluating the resident's performance, use as your standard the level of knowledge, skills and attitudes expected from the clearly satisfactory resident at this stage of training. Please provide specific comments and recommendations. Be as specific as possible, including reports of critical incidents and/or outstanding performance. Global adjectives or remarks, such as "good resident," do not provide meaningful feedback to the resident.

Administration

1 Date of Daily Rotation Evaluation

DATE:

Remaining Characters: 5,000

Patient Care

2 Recognition/stabilization of emergent patients
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

3 History & Physical Exam
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

4 Generation & implementation of diagnostic/treatment plans
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

MEDICAL KNOWLEDGE

5 Interpretation of data & formulation of differential dx
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

Practice Base Learning

6 Use of EBM to guide clinical presentations
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

Communication & Interpersonal Skills

7 Documentation & patient presentations
Unsat Marginal Satisfactory Satisfactory Very Good Outstanding N/A

Appendix 5. Selection of shift evaluation instrument, 2013.

Daily Resident shift evaluation 2013

[Subject Name]
[Subject Status]
[Evaluation Dates]
[Subject Rotation]

Evaluator
[Evaluator Name]
[Evaluator Status]

Evaluate resident based on appropriate milestone that you feel they will meet in 95% of patient encounters.

DATE

1 Date, shift or sim case

Comment

Remaining Characters: 5,000

General Provisions of Patient Care

2 Overall patient assessment

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN (1.5)	SECOND YEAR LEVEL	PROGRESSING SECOND YEAR (2.5)	THIRD YEAR LEVEL	PROGRESSING THIRD YEAR (3.5)	LEVEL OF EM RESIDENCY GRADUATE (4)
○	○	○	○	○	○	○	○

3 Emergency Stabilization

BELOW INTERN LEVEL	AT INTERN LEVEL Describes a primary assessment on a critically ill or injured patient Recognizes abnormal vital signs	PROGRESSING INTERN	AT SECOND YEAR LEVEL Recognizes the unstable patient who needs immediate intervention Prioritizes initial actions in a resuscitation Performs primary assessment on a critical patient	PROGRESSING 2ND YEAR	AT THIRD YEAR LEVEL Formulates a diagnostic impression and plan for a critical patient Reassess after implementing a stabilizing intervention	PROGRESSING 3RD YEAR	GRADUATE LEVEL manages multiple critical patients Identifies when further clinical intervention is futile Involves system resources into a strategy for a problematic stabilization	N/A
○	○	○	○	○	○	○	○	○

4 Performance of a Focused history and Physical Examination

BELOW INTERN	AT INTERN LEVEL Performs and communicates	PROGRESSING INTERN	AT SECOND YEAR Performs and communicates a focussed H&P reliably	PROGRESSING 2ND YEAR	AT 3RD YEAR LEVEL Prioritizes essential components of a history	PROGRESSING 3RD YEAR	GRADUATE LEVEL Uses prior medical records to	N/A

Appendix 6. Selection of shift evaluation instrument, 2016.

Subject Name
Status
Employer
Program
Rotation
Evaluation Dates

Evaluated by: **Evaluator Name**
Status
Employer
Program

Daily Shift Evaluation AY 2016-2017

Instructions

Score the resident's performance today in the following domains. The scale refers to meeting or exceeding expectations commensurate with training level.

1* Data gathering

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

2* Diagnostic plan development

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

3* Treatment plan development

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

4* Medical knowledge

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

5* Efficiency/Multi-tasking

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

6* Patient follow-up and reassessment

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

7* Responsiveness to feedback (teachable)

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

8* Professionalism

Needs Improvement	Meets Expectations	Exceeds Expectations
○	○	○

Comment

Appendix 7. Selection of shift evaluation, 2020.

Subject Name
Status
Employer
Program
Rotation
Evaluation Dates

Evaluated by: **Evaluator Name**
Status
Employer
Program

Emergency Medicine Daily Shift Evaluation for ED Rotation New Version

Instructions:
This evaluation will serve as a daily shift evaltuation for emergency medicine residents while completing a rotation in the emergency department. The evaluation is based on the ABEM Emegency Medicine Milestone Project and is organized by the 6 ACGME Core Competencies.

1* Please provide your overall comments about this resident's performance on this shift.

2 Were there any red flags on this shift? If so, please provide confidential comment to Program Director at the end of this evaluation form.

◯ Yes
◯ No

3 Would you trust this resident to care for you or your family (with appropriate supervision)? If no, please provide confidential comment to Program Director at the end of this evaluation form.

◯ Yes
◯ No

4* Recognition and stabilization of critical patients:
Appropriately focused assessment; targeted attention to immediate threats to health; timeliness and appropriateness of interventions

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

5* Data Gathering:
Focus of H&P is concise, with attention to pertinent details; appropriate use of ancillary sources of information (EMS, family, EHR);tailors patient interview with emergency differential diagnosis in mind

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

6* Diagnostic plan development:
Plan is oriented to assessment of potentially emergent conditions based of H&P; utilizes resources efficiently; considers limitations and risks/benefits of diagnostic testing; and considers alternatives when tests are unavailable or unobtainable.

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

7* Treatment Plan Development:
Treatments are prioritized appropriately; patient factors such as age, allergies and comorbidities are considered, and treatment approach is adjusted accordingly; considers risks/benefits of ED treatments.

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

8* Patient Reassessment and Follow-up:
Patient reassessment is timely and prioritized based on severity and stability of medical condition. Changes in patient status are identified and treated without delay. Patients and family are kept abreast of progress through their ED stay.

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

9* Efficiency and Multi-tasking:
Manages workflow and interruptions in a dynamic environment: task-switches fluidly; prioritizes critical tasks and patient disposition without unnecessary delay; reassesses workflow as situations change.

BELOW INTERN LEVEL	AT INTERN LEVEL	PROGRESSING INTERN	AT SECOND YEAR LEVEL	PROGRESSING SECOND YEAR	AT THIRD YEAR LEVEL	PROGRESSING THIRD YEAR	LEVEL OF EM RESIDENCY GRADUATE	LEVEL OF EM ATTENDING PHYSICIAN	LEVEL OF EM FACULTY MENTOR
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

References

1. ACGME Program Requirements for Graduate Medical Education in Emergency Medicine. Accredidation Council for Graduate Medical Education, 2020.
2. The Emergency Medicine Milestones Project. 2015.
3. Kovach RA, Griffen DL, Francis ML. Evaluating Emergency Medicine Faculty at End-of-Shift. *Western J of Emerg Med*. 2010. 11(5):486-490.
4. Wald DA, et al. The State of the Clerkship: A Survey of Emergency Medicine Clerkship Directors. *Acad Emerg Me*d. 2007. 14(7):629-34.
5. Stehman CR, et al. Professionalism Milestones Assessments Used by Emergency Medicine Residency Programs: A Cross-sectional Survey. *Western J of Emerg Med*. 2019. 21(1):152-159.
6. Wrenn K, Zink BJ. End-of-shift Evaluations: My Take. *Acad Emerg Med*. 2014. 21(7):840-840.
7. Dehon E, et al. Use of Emergency Medicine Milestones as Items on End-of-Shift Evaluations Results in Overestimates of Residents' Proficiency Level. *J Grad Med Educ*. 2015. 7(2):192-6.
8. Sheng AY. Trials and Tribulations in Implementation of the Emergency Medicine Milestones from the Frontlines. *West J of Emerg Med*. 2019. 20(4):647-650.
9. Sorge R, et al. How Well Do Core Faculty Understand The Emergency Medicine Milestones? *West J of Emerg Med*. 2019. 21(1):160-162.
10. Warrington S, Beeson M, Bradford A. Inter-rater Agreement of End-of-shift Evaluations Based on a Single Encounter. *West J of Emerg Med*. 2017. 18(3):518-524.
11. Blankush JM, et al. What are the Associations Between the Quantity of Faculty Evaluations and Residents' Perception of Quality Feedback? *Annals of Med Surg*. 2017. 16:40-43.

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Development of the Defense Registry for Emergency Airway Management (DREAM)

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Abstract

Introduction: Airway obstruction is the second leading cause of potentially preventable death on the battlefield. Endotracheal intubation is a critical skill needed by emergency military physicians to manage these patients. Our objective is to describe the development of the Defense Registry for Emergency Airway Management (DREAM) at Brooke Army Medical Center (BAMC), a level 1 trauma center over a 7-month period.

Methods: Emergency physicians (EP) performing endotracheal intubations in the BAMC emergency department (ED) completed standardized data collection forms with information about each event. Trained study team members extracted additional data from the medical records. We cross-referenced each intubation with patient tracking systems in the department and would fill in missing variables through interview with the intubating operator and/or medical records review.

Results: The study period comprised January through July 2020. During the study period emergency physicians (EP) performed a total of 74 intubations. Reasons for intubation were related to trauma for 47 patients (64%) and medical conditions for 26 patients (36%). The median age was 51 (interquartile range 30-72) and most were male 48 (65.7%). Difficult airway characteristics encountered included blood in the airway (26%), facial trauma (23%), and airway obstruction (1%). Most intubations utilized video laryngoscopy, and the most frequently used airway devices were Macintosh-shaped (45%) and hyperangulated-shaped (41%). Overall, first-pass success rate was 93% (69) with majority of intubations performed by second-year emergency residents (61%) followed by first-year residents (28%).

Conclusions: Most DREAM intubations were related to traumatic injuries. The most frequently encountered difficult airway characteristics were blood in airway and facial trauma. Most intubations were conducted using video laryngoscopy with a high first-pass success rate similar to other published studies. Expansion of the registry to other military emergency departments would enable a data-driven solution for development of individual critical task lists.

Background

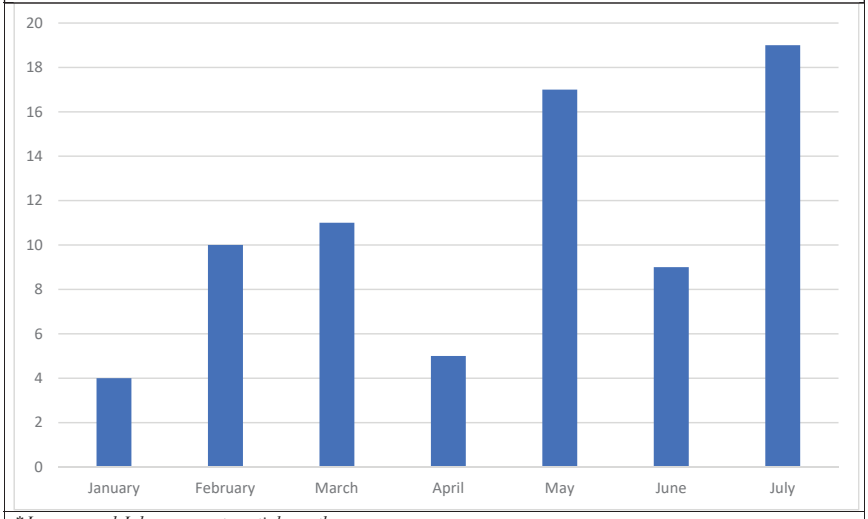
Emergency physicians (EP) require extensive training to proficiently perform critical life-saving skills. Endotracheal intubation, an important lifesaving procedure in the garrison setting and the deployed setting,[1] is paramount to successful airway management in critically injured patients. One study reports that EPs perform emergent intubations more frequently than anesthesiologists (81% versus 7%) in the emergency department (ED) setting.[2] Studies over the past two decades estimate the proportion of ED intubations performed by EPs ranges from 89% to 95%.[3-5] Ensuring military EP readiness requires proper training and hands-on experience with intubations in garrison to execute life-saving interventions in the deployed setting.[6,7]

The Military Health System's (MHS) largest military hospital and only level 1 trauma center is Brooke Army Medical Center (BAMC). BAMC has a large scope of medical care capabilities and responsibilities making it the ideal location to offer military emergency physicians experience with procedures. It also serves as the pre-deployment center as part of the Strategic Trauma and Readiness Center of San Antonio (STaRC).[8] Additionally, BAMC provides care to military personnel and

beneficiaries while working in collaboration with civilian hospitals in the local area to provide trauma casualty care to civilians in the community.[9] EP skills attainment and sustainment require opportunities for improving, refinement, and retention of critical life-saving skills such as airway management.[1]

In 2016, the BAMC emergency department (ED) joined a multicenter observational intubation registry through Brigham and Women's Hospital in Boston, MA, on a research-based surveillance of intubation practices as part of National Emergency Airway Registry (NEAR).[3-5,10] NEAR evaluates the method of airway obtainment, complication rates, and number of difficult airways encountered.[11] NEAR data capture ended in December 2018. However, publications associated with the NEAR demonstrated the value of collecting and analyzing military-relevant airway management data on a continuous basis. As a result, we developed a military-specific airway registry.

Figure 1. Volume of intubations during the pilot study period.



**January and July represent partial months*

Goal of this Study: We describe the pilot data collected as part of the development of the DREAM at BAMC – the Department of Defense's (DoD) only level 1 trauma center.

Methods

Ethics: The Regional Health Command—Central Institutional Review Board (IRB) reviewed and approved protocol C.2015.140. We requested and obtained a waiver of informed consent given the emergency setting and critically ill status of the patients we were seeking to enroll.

Subjects & Setting: Brooke Army Medical Center (BAMC) as a level 1 trauma center, San Antonio, TX, serves as a regional receiving center for the southwest Texas region. It is the only level 1 trauma center within the DoD. The ED has approximately 84,000 visits annually which includes active duty personnel, retired military beneficiaries, and dependents, of which, roughly 6,000 encounters are traumas. The ED has a 3-year residency training program with 16 residents in each class, 48 residents in total. It is part of the San Antonio Uniformed Services Health Education Consortium.

Our study included all patients intubated since the piloting of DREAM in January 2020. Intubating operators document on the data collection form and near real-time. Variables included demographics, indications, intubating methods, operator characteristics, intubation attempts and successes or failures. Other variables were extracted from the medical records. Missing variables were cross-referenced with nursing documents and intubating operator interviews. Data collection forms were deposited by intubating providers in secured file cabinets throughout the department by the intubating providers. Research staff cross-referenced nursing reports to ensure >95% capture of ED intubations within 30 days during non-COVID-restricted time frames where research personnel had limited physical access to the department. This adherence rate was based on the previous metrics required from inclusion into the National Emergency Airway Registry, with which we were previously associated.[12,13] Trained research personnel would extract the remaining data from the medical records and/or interviews.

Data Analysis: We performed all statistical analyses using a commercial software packages. We describe continuous study variables using means with confidence (95%) intervals for continuous variables, ordinal variables with medians and interquartile ranges, and numbers and percentages for nominal variables.

Results

The study period comprised January through July 2020. During the study period emergency physicians (EP) performed a total of 74 intubations. (Figure 1) The indication for intubation consisted of 47 (64%) traumatic

and 26 (36%) medical. The median age was 51 (interquartile range 30-72) and most were male 48 (65.7%) (Table 1). Complications encountered included blood in the airway (26%), facial trauma (23%), and airway obstruction (1%). Emergency physicians performed most intubations using video laryngoscopy (VL), the most frequently used airway devices were Macintosh-shaped (45%) and the hyperangulated-shaped (41%). Overall, first-pass success rate is 93% (69) with majority of intubations being performed by second year emergency residents (61%) followed by year one residents (28%). Our direct laryngoscopy (DL) versus VL first-pass success rates were similar (90%, n=9/10 versus 93%, n=60/64, p=0.526).

Table 1. Demographics and intubation information.

		N=74
Demographics	Age	51 (30-72)
	Male	65.7% (48)
	Estimated weight	78.7 (73.0-84.4)
Indication	Medical	26
	Trauma	47
Complications	Airway obstruction	1% (1)
	Facial trauma	22.9% (17)
	Airway blood	25.6% (19)
Airway Device	Direct (Miller)	1% (1)
	Direct (Macintosh)	12.1% (9)
	Macintosh-shaped video laryngoscopy	45% (33)
	Hyperangulated-shaped video laryngoscopy	41% (30)
	Bougie used	1% (1)
Training level	PGY1	28% (21)
	PGY2	61% (45)
	PGY3	9% (7)
	First-pass success	93% (69)

Discussion

Airway management is a critical skill needed by military healthcare providers.[13] We found that EPs used video laryngoscopy most frequently with a high first-pass success rate. A majority of the total number of intubations performed by EPs (64%) involved trauma patients, highlighting the importance of a public trauma mission to maintain military medical readiness.[1] A previous study in the deployed setting noted that more than 1 in 10 casualties presenting to deployed emergency departments underwent intubation. Our study demonstrates that emergency physicians at BAMC receive robust airway management experience that will prepare them for future deployed missions. We must also note that the preponderance of intubations appeared to happen via VL rather than DL (64 versus 10). Our finding of similar first pass success between VL and DL is different than repeated findings in the literature that VL optimizes first pass success and is likely a reflection of low sample size and patient selection for DL.[13,14]

The military health system (MHS) and its treatment facilities exist to support the training and readiness missions. Memorandums disseminated by nearly every US Army Surgeon General over the past two decades during which we have been at war highlight the need for medical personnel to use the medical treatment facilities (MTFs) for skill sustainment.[15] We must also highlight the importance of providing this procedural opportunities to resident physicians in training. The Accreditation Council for Graduate Medical Education (ACGME) requires that emergency medicine residents have at least 35 intubations to obtain procedural competency.[16] For the BAMC residency, we depend upon a civilian anesthesia rotation to obtain basic intubation skills on non-emergent patient presentations and utilize the BAMC platform to augment intubation skills that more closely align with those seen in operational settings. Relative to the operational setting, EM physicians are expected to deploy to far forward areas and manage airway emergencies.[7,17-20] As such, we must ensure they are adequately trained in airway management given the volume of casualties requiring an airway.[7,19]

To provide more generalizable data for military medicine, we have started to expand the DREAM registry. As of July 2020, we have added the Madigan Army Medical Center (MAMC) to our study protocol, and we are preparing to launch our data collection. Adding additional MTFs to the DREAM registry will allow for more robust data collection. Trends and lessons learned from the registry could be useful for inclusion into the deployed clinical practice guidelines such as those promulgated by the Joint Trauma System.

This study has several limitations. Due to COVID19 research restrictions the research team had limited physical access to the department during the early phases of the pandemic. As such, we do not have data assessing the number of missing intubation forms that were not properly documented on department tracking documents or in the electronic medical records (EMR) system. To this end, we must acknowledge that we may be missing samples during the early pandemic period, and we cannot assess how long the time from intubation to form completion occurred. Some recall and sampling bias may be present. Given our small sample size and limited period, we were unable to complete cross-group comparisons. Moreover, we are unable to identify any trends currently that allow for performance

improvement feedback. Larger data sets are necessary to identify trends and study the effects of practice patterns on outcomes.

Conclusion

Most DREAM intubations were related to traumatic injuries. The most frequently encountered difficult airway characteristics were blood in airway and facial trauma. Most intubations were conducted using video laryngoscopy with a high first-pass success rate similar to other published studies. Expansion of the registry to other military emergency departments would enable a data-driven solution for development of individual critical task lists.

References

1. Carius BM, April MD, Schauer SG. Procedural Volume Within Military Treatment Facilities-Implications for a Ready Medical Force. *Mil Med*. 2020;185(7-8):e977-e981.
2. Chiaghana C, Giordano C, Cobb D, Vasilopoulos T, Tighe PJ, Sappenfield JW. Emergency Department Airway Management Responsibilities in the United States. *Anesth Analg*. 2019;128(2):296-301.
3. Brown CA, Bair AE, Pallin DJ, Walls RM. Investigators NI. Techniques, success, and adverse events of emergency department adult intubations. *Ann Emerg Med*. 2015;65(4):363-370 e361.
4. Sagarin MJ, Barton ED, Chng YM, Walls RM. Airway management by US and Canadian emergency medicine residents: a multicenter analysis of more than 6,000 endotracheal intubation attempts. *Ann Emerg Med*. 2005;46(4):328-336.
5. Sakles JC, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Ann Emerg Med*. 1998;31(3):325-332.
6. Schauer SG, Hill GJ, Naylor JF, April MD, Borgman M, Bebarta VS. Emergency department resuscitation of pediatric trauma patients in Iraq and Afghanistan. *Am J Emerg Med*. 2018;36(9):1540-1544.
7. Schauer SG, Naylor JF, Oliver JJ, Maddry JK, April MD. An analysis of casualties presenting to military emergency departments in Iraq and Afghanistan. *Am J Emerg Med*. 2019;37(1):94-99.
8. Newman L. New trauma training program prepares surgical team for deployment. https://health.mil/News/Articles/2020/06/08/New-trauma-training-program-prepares-surgical-team-for-deployment. Published 2020. Accessed.
9. Savell SC, Blessing A, Shults NM, et al. Level 1 Trauma Centers and OEF/OIF Emergency Departments: Comparison of Trauma Patient Populations. *Mil Med*. 2020;185(9-10):e1569-e1575.
10. Walls RM, Brown CA, Bair AE, Pallin DJ. Emergency airway management: a multi-center report of 8937 emergency department intubations. *J Emerg Med*. 2011;41(4):347-354.
11. Phelan MP, Glauser J, Yuen HW, Sturges-Smith E, Schrump SE. Airway registry: a performance improvement surveillance project of emergency department airway management. *Am J Med Qual*. 2010;25(5):346-350.
12. April MD, Arana A, Pallin DJ, et al. Emergency Department Intubation Success With Succinylcholine Versus Rocuronium: A National Emergency Airway Registry Study. *Ann Emerg Med*. 2018;72(6):645-653.
13. April MD, Schauer SG, Brown CA, et al. A 12-month descriptive analysis of emergency intubations at Brooke Army Medical Center: a National Emergency Airway Registry study. *US Army Med Dep J*. 2017(3-17):98-104.
14. Brown CA, 3rd, Kaji AH, Fantegrossi A, et al. Video Laryngoscopy Compared to Augmented Direct Laryngoscopy in Adult Emergency Department Tracheal Intubations: A National Emergency Airway Registry (NEAR) Study. *Acad Emerg Med*. 2020;27(2):100-108.
15. Schauer SG, Cunningham CW, Fisher AD, DeLorenzo RA. A Pilot Project Demonstrating that Combat Medics Can Safely Administer Parenteral Medications in the Emergency Department. *Prehosp Disaster Med*. 2017;32(6):679-681.
16. Bucher JT, Bryczkowski C, Wei G, et al. Procedure rates performed by emergency medicine residents: a retrospective review. *Int J Emerg Med*. 2018;11(1):7.
17. Schauer SG, Naylor JF, Chow AL, et al. Survival of Casualties Undergoing Prehospital Supraglottic Airway Placement Versus Cricothyrotomy. *J Spec Oper Med*. 2019;19(2):91-94.
18. Schauer SG, Naylor JF, Hill GJ, Arana AA, Roper JL, April MD. Association of prehospital intubation with decreased survival among pediatric trauma patients in Iraq and Afghanistan. *Am J Emerg Med*. 2018;36(4):657-659.
19. Schauer SG, Naylor JF, Maddry JK, et al. Prehospital Airway Management in Iraq and Afghanistan: A Descriptive Analysis. *South Med J*. 2018;111(12):707-713.
20. Fisher AD, Naylor JF, April MD, Thompson D, Kotwal RS, Schauer SG. An Analysis and Comparison of Prehospital Trauma Care Provided by Medical Officers and Medics on the Battlefield. *J Spec Oper Med*. 2020;20(4):53-59.

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A Case Report Utilizing Ultrasound for the Identification of Traumatic Pulmonary Contusion

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MAJ Melissa Myers, MD

Abstract

Pulmonary contusions are a common injury in both military and civilian trauma patients. In austere and resource-limited settings common to deployment, military physicians may be limited on their ability diagnose or differentiate this entity from other traumatic injuries. We describe the use of ultrasound for the identification of pulmonary contusion in a patient with a gunshot wound while performing an extended Focused Assessment with Sonography (eFAST). The utility of ultrasound in polytraumatic patients stretches far beyond the initial FAST exam and can drastically inform clinical decision making and treatment.

Introduction

Pulmonary contusion is a common finding in patients presenting after blunt chest trauma. Pulmonary contusions were present in 52% of patients with combat related thoracic trauma in Operations Iraqi Freedom and Enduring Freedom.[1,2] Pulmonary contusion has been independently associated with severe complications in polytrauma patients including hypoxemia, hypercarbia, coagulopathy, pneumonia, intubation, acute respiratory distress syndrome (ARDS), and mortality secondary to respiratory compromise.[3,4] Ultrasound has been previously described as an effective screening for pulmonary contusion and is increasingly available to military medical providers.[2,5-7] We describe the use of ultrasound in the assessment of a patient presenting with penetrating trauma.

Case Presentation: A 20-year-old male was brought to a level 1 trauma center with a gunshot wound to the chest. Initial vital signs were significant only for a mild tachycardia of 103. A single penetrating injury over the lower third of the sternum was noted with tenderness to palpation, tenderness, and crepitus over the right lateral chest wall with a palpable mass. There were no other visible traumatic injuries on exam.

An eFAST was performed and was negative for intra-abdominal free fluid, pneumothorax or pericardial effusion. The eFAST demonstrated focal B-lines and pulmonary parenchymal changes consistent with possible right lower pulmonary contusion approximately 4cm to the right of the sternum. Additionally, ultrasound identified a discrete hyperechoic object within the right lateral chest wall at the anterior midaxillary line (Figures 1 & 2). A subsequent chest radiograph and aortic computed tomography (CT) with contrast identified a pulmonary contusion with 5th and 6th rib fractures while confirming no intrathoracic or intraperitoneal injury or hemorrhage (Figure 3). Laboratory evaluation was notable for a detectable troponin at 0.04 ng/mL. The patient was admitted for pulmonary support and cardiac monitoring and discharged the next day after normalization of his cardiac enzymes and with incentive spirometry.

Discussion

Several studies have evaluated the use of ultrasound to screen and evaluate pneumothorax, hemothorax, pneumonia, pleural effusion, and pulmonary contusions.[5,6,8] Pulmonary contusion is suggested on ultrasound by the presence of B-lines or a peripheral parenchymal lesion (PPL), with increased sensitivity utilizing a cutoff of 6 or greater to diagnose a positive study.[6] Vaefi et al. found that within trauma patients, ultrasound had greater sensitivity for the detection of pulmonary contusion and pneumothoracies among patients with chest trauma than chest x-ray.[8] Additionally, a recent meta-analysis compared the sensitivity, specificity, and negative likelihood ratios of ultrasound and chest x-ray in regards to pulmonary contusion, which suggested that ultrasound would be a superior screening tool for pulmonary contusion

Figure 1. Upright chest x-ray demonstrating right pulmonary contusion and retained foreign body.

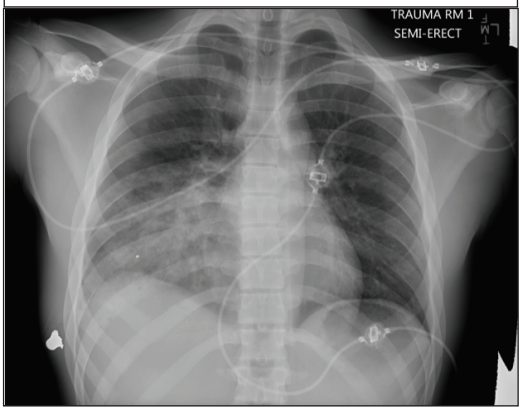
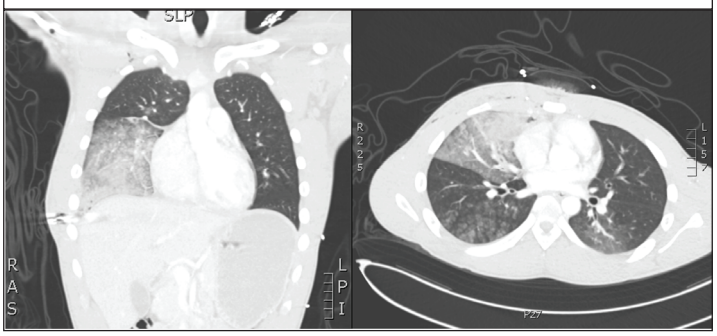


Figure 2. Coronal (left) and transverse (right) commuted tomography of the chest demonstrating right anterior pulmonary contusion and soft tissue foreign body without evidence of pneumothorax.



should time and circumstance allow.[5] This information could prove invaluable in an austere environment, identifying an otherwise stable appearing patient at high risk of clinical decompensation requiring transport or evacuation.

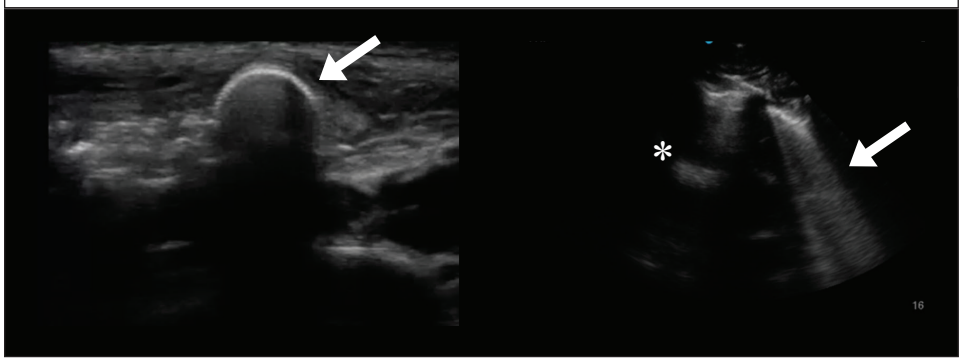
Conclusion

As the military continues unconventional warfare with small, mobile units without access to x-ray, CT scans, or large, static hospitals, the use of ultrasound will continue to be increasingly important. Our case highlights how ultrasound can be used by emergency physicians in trauma patients to evaluate for thoracic injury and pulmonary contusion for diagnosis and management.

References

1. Col L, Lichtenberger JP, Kim CAM, et al. Imaging of Combat-Related Thoracic Trauma–Blunt Trauma and Blast Lung Injury. *Mil Med*. 2018;183(April):89-96. doi:10.1093/milmed/usx033.
2. Graham R. Battlefield Radiology. *Br J Radiol*. 2012;85(1020):1556-1565. doi:10.1259/bjr/33335273.
3. Cohn SM, Dubose JJ. Pulmonary Contusion : An Update on Recent Advances in Clinical Management. *World J Surg*. 2010;34:1959-1970. doi:10.1007/s00268-010-0599-9.
4. Wright A, Charles W, Camp E, et al. Pulmonary Contusion On Admission Chest X-Ray Is Associated With Coagulopathy And Mortality In Trauma Patients. *J Emerg Med Trauma Surg Care*. 2015.
5. Hosseini M, Ghelichkhani P, Baikpour M, et al. Diagnostic Accuracy of Ultrasonography and Radiography in Detection of Pulmonary Contusion; a Systematic Review and Meta-Analysis. *Emergency*. 2015;3(4):127-136.
6. Abbasi S, Shaker H, Zareiee F, Farsi D, Hafezimoghadam P, Rezai M. Screening Performance of Ultrasonographic B-lines in De- tection of Lung Contusion following Blunt Trauma ; a Diagnostic Accuracy Study. *Emergency*. 2018;6(1):1-7.
7. Qi X, Tian J, Sun R, et al. Focused Assessment with Sonography in Trauma for Assessment of Injury in Military Settings : A Meta-analysis. *Balkan Med J*. 2020;37(October 2019):3-8. doi:10.4274/balkanmedj.galenos.2019.2019.8.79.

Figure 3. Left—Ultrasound identification of soft tissue retained foreign body along the right anterior mid-axillary line. Right—Pulmonary ultrasound demonstrating multiple B-lines (white arrow) and a peripheral parenchymal lesion (*) as demonstrated by the hyperechoic, transverse consolidation.



8. Vafaei A, Hatamabadi HR, Heidary K, Alimohammadi H, Tarbiyat M. Diagnostic Accuracy of Ultrasonography and Radiography in Initial Evaluation of Chest Trauma Patients. *Emergency*. 2016;4(Winter):29-33.

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