

Committee on Surgical Combat Casualty Care (CoSCCC)



Journal Watch

4th Quarter

FY 2024

Journal Watch Key Terminology Searched:

Microcirculation	Trauma Management	Haemorrhage
Shock	Sublingual	Ethics committees
Human subject research	IDF	Institutional review board
Haemorrhagic shock	Multiple trauma	Shock index
Traumatic brain injury	Coagulopathy	Diagnostic accuracy
Plasma	Pre-hospital	Thrombelastography (TEG)
Transfusion	Trauma	Imaging
RBCs	Resuscitation	Severe trauma
Stability	Ultrasound	Afghanistan
Blast	Facial trauma	War
Amputation	Multiple	Transfusion
Traumatic Clinical outcomes	Clinical parameters	Damage control Surgery
Injury	Pelvic fracture	Battlefield Trauma
Coagulopathy	Cryoprecipitate	Fibrinogen
Fibrinogen concentrate	Massive transfusion	ABO
Viscoelastic haemostatic assays	Angiography	External fixation
Guidelines	Internal fixation	Pelvic ring
Fractures	X-ray	Pre-peritoneal pelvic packing
REBOA	Antibiotic prophylaxis	Long bone fractures
Orthopaedic trauma	Perioperative antibiotics	Surgical site infection
Wound ballistics	Faecal diversion	Primary repair
Cause of injury	Head injuries	Poly-trauma
Damage Control Resuscitation	Battlefield Injury	Prolonged field care
Tension pneumothorax	Thoracotomy	Military Medicine
Blast Injury	Died of Wounds	Killed in Action
Combat casualty care	Medical treatment facility	Mortality
Surgical skills	Emergency surgery	Infection prevention
Novel Coronavirus	COVID-19	Hypocalcemia
Predictions	Vital Signs	Global Surgery
Limb Salvage	Temporary Shunts	Ukraine
Whole Blood	Walking Blood Bank	Performance Improvement
Simulation	Coagulopathy	Machine Learning

Internal iliac artery ligation as a damage control method in hemodynamically unstable pelvic fractures: A systematic review of the literature

Hui Li¹, Tao Ai¹, Guang-Bin Huang¹, Jun Yang¹, Gong-Bin Wei¹, Jin-Mou Gao¹, Ping He¹, Xue-Mei Cao¹, Ding-Yuan Du²

Abstract

Purpose: Internal iliac artery ligation (IIAL) has been used as a damage control procedure to treat hemodynamically unstable pelvic fracture for many years. However, there is ongoing debate regarding the effectiveness and safety of this hemostatic method. Therefore, we performed a systematic literature review to assess the efficacy and safety of IIAL for pelvic fracture hemostasis.

Methods: Three major databases, PubMed, Embase, and Google Scholar, were searched to screen eligible original studies published in English journals. Two reviewers independently read the titles, abstracts, and full texts of all literature. Articles were included if they reported the use and effects of IIAL.

Results: A total of 171 articles were initially identified, with 22 fully meeting the inclusion criteria. Among the analyzed cases, up to 66.7% of patients had associated abdominal and pelvic organ injuries, with the urethra being the most frequently injured organ, followed by the bowel. The outcomes of IIAL for achieving hemostasis in pelvic fractures were found to be satisfactory, with an effective rate of 80%. Hemorrhagic shock was the leading cause of death, followed by craniocerebral injury. Notably, no reports of ischemic complications involving the pelvic organs due to IIAL were found.

Conclusion: IIAL has a good effect in treating hemodynamically unstable pelvic fracture without the risk of pelvic organ ischemia. This procedure should be considered a priority for hemodynamically unstable pelvic fracture patients with abdominal organ injuries.

Keywords: Embolization; Internal iliac artery; Laparotomy; Ligation; Pelvic fracture.

Urologic Trauma Management for Military Providers

Shane Kronstedt¹, Eric Wahlstedt², Mason Blacker³, Gal Saffati¹, David E Hinojosa-Gonzalez¹, Hance Wilbert⁴, Thomas Fetherston⁵, Jonathan Friedman⁶, Zachary R Mucher⁷

Abstract

Introduction: Genitourinary (GU) trauma resulting from combat and the treatment of these injuries is an inadequately explored subject. While historically accounting for 2 to 5% of combat-related injuries, GU-related injuries escalated considerably during U.S. involvements in Iraq and Afghanistan due to improvised explosive devices (IEDs). Advanced body armor increased survivability while altering injury patterns, with a shift toward bladder and external genitalia injuries. Forward-deployed surgeons and military medics manage treatment, with Role 2 facilities addressing damage control resuscitation and surgery, including GU-specific procedures. The review aims to provide an overview of GU trauma and enhance medical readiness for battlefield scenarios.

Materials and methods: This review examined urologic trauma management in combat, searching PubMed, Cochrane Central, Scopus, and Web of Science databases with search terms "wounds" OR "injuries" OR "hemorrhage" AND "trauma" AND "penile" OR "genital" AND "combat." Records were then screened for inclusion of combat-related urologic trauma in conflicts after 2001 and which were English-based publications. No limits based on year of publication, study design, or additional patient-specific demographics were implemented in this review.

Results: Ultimately, 33 articles that met the inclusion criteria were included. Included texts were narrowed to focus on the management of renal injuries, ureteral trauma, bladder injuries, penile amputations, urethral injuries, testicular trauma, Central nervous system (CNS) injuries, and female GU injuries.

Conclusions: In modern conflicts, treatment of GU trauma at the point of injury should be secondary to Advanced Trauma Life Support (ATLS) care in addition to competing non-medical priorities. This review highlights the increasing severity of GU trauma due to explosive use, especially dismounted IEDs. Concealed morbidity and fertility issues underscore the importance of protection measures. Military medics play a crucial role in evaluating and managing GU injuries. Adherence to tactical guidelines and trained personnel is vital for effective management, and GU trauma's integration into broader polytrauma care is essential. Adequate preparation should address challenges for deploying health care providers, prioritizing lifesaving and quality-of-life care for casualties affected by GU injuries.

Final Lifelines: The Implications and Outcomes of Thoracic Damage Control Surgeries

Muhammad Haris Khurshid¹, Audrey Yang¹, Hamidreza Hosseinpour¹, Christina Colosimo¹, Omar Hejazi¹, Audrey L Spencer¹, Sai Krishna Bhogadi¹, Michael Ditillo¹, Louis J Magnotti¹, Bellal Joseph²

Abstract

Introduction: There is a lack of data on the outcomes of thoracic damage control surgery (TDCS). This study aimed to describe the characteristics and outcomes of patients undergoing TDCS.

Methods: This is a retrospective analysis of the American College of Surgeons-Trauma Quality Improvement Program database (2017-2021). All trauma patients who underwent emergency thoracotomy and packing with temporary closure were included. Patients were stratified based on the age groups (pediatric [<18 y], adults [$18-64$ y], and older adults [≥ 65 y]). Our primary outcome measures included 6-h, 24-h, and in-hospital mortality. Secondary outcomes were major complications.

Results: We identified 14,192 thoracotomies, out of which 213 underwent TDCS (pediatric [$n = 17$], adults [$n = 175$], and older adults [$n = 21$]). The mean (SD) age was 37 (18), and 86% were male. The mean shock index was 1.1 (0.4) on presentation with a median [IQR] Glasgow Coma Scale of 4 [3-14], and 22.1% had a prehospital cardiac arrest. The study population was profoundly injured with a median injury severity score and chest-abbreviated injury scale of 26 [17-38] and 4 [3-5], respectively, with lung (76.5%) being the most injured intrathoracic organs. Overall, the rates of 6-h, 24-h, and in-hospital mortality were 22.5%, 33%, and 53%, respectively, and 51% developed major complications. There was no significant difference in terms of in-hospital mortality ($P = 0.800$) and major complications (0.416) among pediatrics, adults, and older adults.

Conclusions: One in three patients undergoing TDCS die within the first 24 h, and more than half of them develop major complications and die in the hospital, with no difference among pediatric, adults, and older adults. Future efforts should be directed to improve the survival of these severely injured, metabolically depleted, challenging patients.

Keywords: Complications; Mortality; Thoracic damage control surgery; Thoracotomy; Trauma.

Emergency treatment of pelvic ring injuries: state of the art

Jan Erik Madsen^{1,2}, Gunnar Birkeland Flugsrud³, Niels Hammer^{4,5,6}, Paul Puchwein^{5,6,7}

Abstract

High energy pelvic injuries sustain significant mortality rates, due to acute exsanguination and severe associated injuries. Managing the hemodynamically unstable trauma patient with a bleeding pelvic fracture still forms a major challenge in acute trauma care. Various approaches have been applied through the last decades. At present the concept of Damage Control Resuscitation (DCR) is universally accepted and applied in major trauma centers internationally. DCR combines hemostatic blood transfusions to restore blood volume and physiologic stability, reduced crystalloid fluid administration, permissive hypotension, and immediate hemorrhage control by operative or angiographic means. Different detailed algorithms and orders of hemostatic procedures exist, without clear consensus or guidelines, depending on local traditions and institutional setups. Fracture reduction and immediate stabilization with a binder constitute the basis for angiography and embolization (AE) or pelvic packing (PP) in the hemodynamically unstable patient. AE is time consuming and may not be available 24/7, whereas PP offers a quick and technically easy procedure well suited for the patient in extremis. Resuscitative endovascular balloon occlusion of the aorta (REBOA) has also been described as a valuable adjunct in hemostatic non-responders, but merely constitute a bridge to surgical or angiographic hemostasis and its definitive role in DCR is not yet clearly established. A swift algorithmic approach to the hemodynamically unstable pelvic injury patient is required to achieve optimum results. The present paper summarizes the available literature on the acute management of the bleeding pelvic trauma patient, with emphasis on initial assessment and damage control resuscitation including surgical and angiographic hemostatic procedures. Furthermore, initial treatment of open fractures and associated injuries to the nervous and genitourinary system is outlined.

Keywords: Damage control resuscitation; Hemorrhage; Initial treatment; Pelvic fracture.

A safety and feasibility analysis on the use of cold-stored platelets in combat trauma

Andrew D Fisher¹, Jonathan D Stallings, Steven G Schauer, Brock A Graham, Caryn A Stern, Andrew P Cap, Jennifer M Gurney, Stacy A Shackelford

Abstract

Background: Damage-control resuscitation has come full circle, with the use of whole blood and balanced components. Lack of platelet availability may limit effective damage-control resuscitation. Platelets are typically stored and transfused at room temperature and have a short shelf-life, while cold-stored platelets (CSPs) have the advantage of a longer shelf-life. The US military introduced CSPs into the battlefield surgical environment in 2016. This study is a safety analysis for the use of CSPs in battlefield trauma.

Methods: The Department of Defense Trauma Registry and Armed Services Blood Program databases were queried to identify casualties who received room-temperature-stored platelets (RSPs) or both RSPs and CSPs between January 1, 2016, and February 29, 2020. Characteristics of recipients of RSPs and RSPs-CSPs were compared and analyzed.

Results: A total of 274 patients were identified; 131 (47.8%) received RSPs and 143 (52.2%) received RSPs-CSPs. The casualties were mostly male (97.1%), similar in age (31.7 years), with a median Injury Severity Score of 22. There was no difference in survival for recipients of RSPs (88.5%) versus RSPs-CSPs (86.7%; $p = 0.645$). Adverse events were similar between the two cohorts. Blood products received were higher in the RSPs-CSPs cohort compared with the RSPs cohort. The RSPs-CSPs cohort had more massive transfusion (53.5% vs. 33.5%, $p = 0.001$). A logistic regression model demonstrated that use of RSPs-CSPs was not associated with mortality, with an adjusted odds ratio of 0.96 ($p > 0.9$; 95% confidence interval, 0.41-2.25).

Conclusion: In this safety analysis of RSPs-CSPs compared with RSPs in a combat setting, survival was similar between the two groups. Given the safety and logistical feasibility, the results support continued use of CSPs in military environments and further research into how to optimize resuscitation strategies.

Level of evidence: Therapeutic/Care Management; Level IV.

In-Hospital Risk Factors for Reintervention and Amputation in Brachial Arterial Trauma

Justin M Robbins¹, Corinna Crayton², Isaac Koloditch², Casey Walk², Limayre Gramajo³, Samantha Shugar², Peter Ekeh², Joseph DuBose⁴, Yee Wong², Cathline Layba²; AAST PROOVIT Study Group

Abstract

Introduction: Brachial artery trauma is a rare but potentially devastating injury. There is little data regarding risk factors for reintervention and amputation prevention in this population, as well as anticoagulant (AC) and antiplatelet (AP) regimens and outcomes after discharge in trauma patients with vascular injuries requiring repair. This study aims to identify in-hospital risk factors for reintervention and amputation and stratify outcomes of follow-up by discharge AC or AP regimen.

Methods: The AAST Prospective Observational Vascular Injury Trial database was queried for all patients who underwent traumatic brachial arterial repair from 2013 to 2022. Patients were evaluated by need for reintervention, amputation, and outcomes at follow-up by AC or AP regimen.

Results: Three hundred and eleven patients required brachial repair, 28 (9%) required reoperation, and 8 (2.6%) required amputation. High injury severity score and an increased number of packed red blood cells and platelets showed a significant increase for reoperation and amputation. Damage control and shunt use were significant for the need to reoperate. Seventy-four percent (221/298) of patients were discharged with postoperative AC or AP regimens. There was no significant difference of short-term follow-up by type of AC or AP regimen.

Conclusions: Damage control and temporary shunt may lead to additional operations but not an increase in amputations. However, anticoagulation intraoperatively and postoperatively does not appear to play a significant role in reducing reintervention. It also suggests that there is no increase in short-term follow-up complications with or without AC or AP therapy.

Keywords: Amputation; Brachial artery; PROspective Observational Vascular Injury Trial; Reintervention; Trauma.

A Descriptive Analysis of Blood Products Utilized by a Forward Deployed Surgical Team in Syria

Bailey M Grimsley¹, Elizabeth Mann-Salinas², Tyson Becker³

Abstract

Introduction: Traumatically injured combat casualties urgently need both blood and surgery. Forward Surgical Teams (FSTs) or Role 2 (R2) surgical teams were created to minimize the time-space distance from point of injury to damage control surgery. Our goal is to describe the use of blood products from a Split FST deployed to Green Village from July 2018 to April 2019.

Materials and methods: A retrospective review of a collection of patients treated by a single R2 was conducted following institutional regulatory approval. De-identified data were input into the study database and were then retrospectively reviewed for patients who presented to and received treatment at the R2 facility.

Results: Of the 470 total patients treated in 10 months: 226 (48%) received blood products and 132 (28%) underwent operative procedures. The patients were 98% male; 74% Host Nationals (HN), 24% North American Treaty Organization members. Mechanism of injury was 75% explosive and 98% penetrating. Documented Injury Severity Scores (n = 214) were: <9 (n = 57/27%), 9 to 15 (n = 34/16%), 16 to 25 (n = 64/30%), and >25 (n = 59/28%). In total 1,052 units of blood products were administered: whole blood (n = 495), red blood cells (n = 200), fresh frozen plasma (n = 109), and liquid plasma (n = 248). HN whole blood used was 337/495 (68%) units for 78 patients; walking blood bank was mobilized six times for HN patients. Of the patients seen, >99% who arrived with a pulse survived to be discharged to a higher level of care.

Conclusions: This analysis describes blood usage associated with one high volume forward deployed operative team and demonstrates the vital importance of the R2 split FST to provide coalition forces with surgical care in proximity to the point of injury. Over time, the supply chain has improved with more component therapy available at R2s; however, the need for walking blood bank and innovative solutions to care for all casualties must be part of small team capabilities. Liquid plasma use should be expanded as soon as it is feasible.

Blood far forward: A cross-sectional analysis of prehospital transfusion practices in the Canadian Armed Forces

Pierre-Marc Dion¹, Brodie Nolan², Christopher Funk³, Colin Laverty³, Jeffrey Scott³, Damien Miller³, Andrew Beckett⁴

Abstract

Background: Canadian Armed Forces (CAF) operate in environments that challenge patient care, especially trauma. Military personnel often find themselves in remote settings without conventional healthcare facilities. Treating traumatic injuries, particularly hemorrhagic shock, often necessitates prehospital blood transfusion. This study aims to present an overview of the current CAF prehospital transfusion practices. Furthermore, the study compared current and developing protocols against expert-recommended guidelines.

Methods: A cross-sectional survey design was employed to describe and compare CAF prehospital blood transfusion practices and protocols against expert recommendations. Topics included protocols, equipment, and procedures. An online survey targeted medical leadership and providers within CAF, with data collected from August 15 to December 15, 2023. Results were summarized descriptively. This study received approval from the Unity Health Toronto Research Ethics Board (REB 23-087).

Results: Units and teams with prehospital blood transfusion capabilities were contacted, achieving a 100 % response rate. Within CAF, Canadian Special Operations Forces Command (CANSOFCOM), Mobile Surgical Resuscitation Team (MSRT), and Canadian Medical Emergency Response Team (CMERT) possess these capabilities, established between 2013 and 2018. These programs are crucial for military operations. CAF has access to standard blood components, cold Leuko-Reduced Whole Blood (LrWB), and factor concentrates from Canadian Blood Services (CBS), available for both domestic and international missions given adequate planning and favorable conditions. Key findings indicate high adherence to recommended practices, some variability in the transfusion process, and potential benefits of standardizing prehospital transfusion practices.

Conclusions: This study provided insights into CAF's implementation of prehospital transfusion practices, highlighting high adherence to national expert recommendations and the importance of structured protocols in military prehospital trauma management.

Implications of key findings: CAF's approach and adoption of prehospital transfusion protocols lay a strong foundation for managing trauma patients in remote settings and for expanding prehospital transfusion capabilities across CFHS deployed assets. Further research is needed to advance military trauma care by adapting prehospital blood transfusion to dynamic tactical landscapes and evolving technologies.

Keywords: Blood Transfusion; Canadian Armed Forces; Hemorrhagic Shock; Prehospital; Remote Damage Control Resuscitation; Tactical Combat Casualty Care; Trauma Care.

Telemedicine Improves Performance of a Two-Incision Lower Leg Fasciotomy by Combat Medics: A Randomized Controlled Trial

Pieter W Stark^{1,2}, Boudewijn L S Borger van der Burg², Thijs T C F van Dongen^{2,3}, Marnalg Casper³, Wouter³, Rigo Hoencamp^{1,2,3,4}

Abstract

Introduction: The primary aim of this randomized controlled trial was to assess if a head-mounted display (HMD) providing telemedicine support improves performance of a two-incision lower leg fasciotomy by a NATO special operations combat medic (combat medic).

Materials and methods: Thirty-six combat medics were randomized into two groups: One group performed a two-incision lower leg fasciotomy with the assistance of an HMD, while the control group completed the procedure without guidance. A Mann-Whitney U test was used to determine the possible differences in release of compartments and performance scores, as assessed by a supervising medical specialist. A Fisher's exact test was used to compare the proportions of collateral damage between groups. An independent-samples t-test was used to interpret total procedure times. The usability and technical factors involving HMD utilization were also assessed.

Results: Combat medics in the HMD group released the anterior compartment ($P \leq .001$) and deep posterior compartment ($P = .008$) significantly better. There was significantly more iatrogenic muscle ($P \leq .001$) and venous damage ($P \leq .001$) in the control group. The overall performance of combat medics in the HMD group was significantly better than that of the control group ($P < .001$). Combat medics in the control group were significantly faster ($P = .012$). The combat medics were very satisfied with the HMD. The HMD showed no major technical errors.

Conclusions: This randomized controlled trial shows that a HMD providing telemedicine support leads to significantly better performance of a two-incision lower leg fasciotomy by a combat medic with less iatrogenic muscle and venous damage.

Reassessing reverse triage in future conflict

Daniel J Hurst¹, T L Ray²

Abstract

Future warfare will likely involve near-peer or peer-peer conflict in which there is a great risk of mass casualty scenarios. Because of anti-access and area denial, air superiority will not be guaranteed, which will hamper rapid evacuation of casualties as well as resupply. Under such circumstances, military medical personnel may be forced, due to the constraints of the battlefield and tactical necessity to return servicemembers to duty, to implement reverse triage in which servicemembers with less severe injuries are treated first. However, reverse triage is potentially incongruent with international humanitarian law. Furthermore, should reverse triage need to be implemented, from the extant military doctrine it is not certain when this would be appropriate or the steps that might be followed, which highlight the gaps that exist before reverse triage should be considered as military doctrine on the battlefield. Lastly, we question the psychological impact that reverse triage could portend on military medical personnel, unit morale and unit cohesion. While there have been recent recommendations that reverse triage might need to be implemented in a near-term future conflict, these issues linger. It is time for Western militaries to assess the merits of reverse triage and the potential drawbacks.

Keywords: ACCIDENT & EMERGENCY MEDICINE; MEDICAL ETHICS; TRAUMA MANAGEMENT.

Venous thromboembolic events associated with blood product administration in an era of whole blood use

Steven G Schauer¹, Michael D April², Andrew D Fisher³, Franklin L Wright⁴, Mitchell J Cohen⁴, Todd M Getz⁵, Julie A Rizzo⁶, Julie M Winkle⁷, Maxwell A Braverman⁸

Abstract

Background: The risks associated with blood product administration and venous thromboembolic events remains unclear. We sought to determine which blood products were associated with the development of deep vein thrombosis (DVT) and pulmonary embolism (PE).

Methods: We analyzed data from patients ≥ 18 years of age in the Trauma Quality Improvement Program (TQIP) database that received ≥ 1 blood product and survived ≥ 24 h.

Results: There were 42,399 that met inclusion, of whom, 2086 had at least one VTE event. In our multivariable logistic regression model, we found that WB had a unit odds ratio (uOR) of 1.05 (95 % CI 1.02-1.08) for DVT and 1.08 (1.05-1.12) for PE. Compared to WB, platelets had a higher uOR for DVT of 1.09 (1.04-1.13) but similar uOR for PE of 1.08 (1.03-1.14).

Conclusions: We found an association of both DVT and PE with early whole blood and platelets.

Keywords: Blood; Deep vein thrombosis; Hemorrhage; Pulmonary embolism; Trauma; Whole.

A Scoping Review of Military Combat Casualty Data on Submassive, Massive, and Supermassive Transfusions

Rohan C Banerjee¹, Jasmine A Castillejos¹, Sean P Krewson¹, Karen R Mina¹, Andrew D Fisher^{2,3}, Michael D April⁴, Steven G Schauer^{4,5,6,7}

Abstract

Introduction: Blood transfusions are common during combat casualty care, aiming to address the loss of blood volume that often accompanies severe battlefield injuries. This scoping review delves into the existing military combat casualty data to analyze the efficacy, challenges, and advances in the use of massive and super-massive transfusions in the management of critically injured warfighters.

Materials and methods: We performed a scoping review of combat-related literature published between 2006 and 2023 pertaining to massive transfusions used during combat deployments. We utilized PubMed to identify relevant studies and utilized the PRISMA-ScR Checklist to conduct the review.

Results: We identified 53 studies that met the inclusion criteria with the majority being retrospective studies from registries used by the United States, British, French, and Dutch Militaries. Most of the studies focused on transfusion ratios, the movement of blood transfusions to more forward locations, implementation of massive transfusions with different fibrinogen-to-red blood cell ratios, the addition of recombinant factor VII, and the use of predictive models for transfusion. Lastly, we identified reports of improved survival for casualties with the rapid implementation of various blood products (warm fresh whole blood, cold-stored low titer group O blood, freeze-dried plasma, and component therapy) and literature relating to pediatric casualties and submassive transfusions. Notable findings include the establishment of hemodynamic and cell blood count parameters as predictors of the requirement for massive transfusions and the association of higher fibrinogen-to-red blood cell ratios with decreased mortality.

Conclusions: We identified 53 studies focused on blood transfusions from the Global War on Terrorism conflicts. The majority were related to transfusion ratios and the movement of blood transfusions to more forward locations. We highlight key lessons learned on the battlefield that have been translated into scientific developments and changes in civilian trauma methods.

An assessment of nationwide trends in emergency department (ED) resuscitative endovascular balloon occlusion of the aorta (REBOA) use - A trauma quality improvement program registry analysis

Hamza Hanif¹, Andrew D Fisher², Michael D April³, Julie A Rizzo⁴, Richard Miskimins⁵, Joseph D Dubose⁶, Michael W Cripps⁷, Steven G Schauer⁸

Abstract

Background: Use of resuscitative endovascular balloon occlusion of the aorta (REBOA) for temporary hemorrhage control in severe non-compressible torso trauma remains controversial, with limited data on patient selection and outcomes. This study aims to analyze the nationwide trends of its use in the emergency department (EDs).

Methods: A retrospective analysis of the American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP) from 2017 to 2022 was performed, focusing on REBOA placements in EDs.

Results: The analysis included 3398 REBOA procedures. Majority patients were male (76 %) with a median age of 40 years (27-58) and injury severity score of 20 (20-41). The most common mechanism was collision (64 %), with emergency surgeries most frequently performed for pelvic trauma (14 %). Level 1 trauma centers performed 82 % of these procedures, with consistent low annual utilization (<200 facilities). Survival rates were 85 % at 1-h post-placement, decreasing significantly to 42 % by discharge.

Conclusions: REBOA usage in remains limited but steady, primarily occurring at level 1 trauma center EDs. While short-term survival rates are favorable, they drop significantly by the time of discharge.

Keywords: Aortic occlusion; Endovascular; Hemorrhage; REBOA; Trauma.

The thin red line: Blood planning factors and the enduring need for a robust military blood system to support combat operations

Jennifer M Gurney¹, Andrew P Cap, John B Holcomb, Amanda M Staudt, Matthew D Tadlock, Travis M Polk, Crystal Davis, Jason B Corley, Martin A Schreiber, Andrew Beckett, Mary Ann Spott, Stacy A Shackelford, Jan-Michael Van Gent, Jonathan D Stallings, Matthew J Martin, Leslie E Riggs

Abstract

Battlefield lessons learned are forgotten; the current name for this is the Walker Dip. Blood transfusion and the need for a Department of Defense Blood Program are lessons that have cycled through being learned during wartime, forgotten, and then relearned during the next war. The military will always need a blood program to support combat and contingency operations. Also, blood supply to the battlefield has planning factors that have been consistent over a century. In 2024, it is imperative that we codify these lessons learned. The linchpins of modern combat casualty care are optimal prehospital care, early whole blood transfusion, and forward surgical care. This current opinion comprised of authors from all three military Services, the Joint Trauma System, the Armed Services Blood Program, blood SMEs and the CCC Research Program discuss two vital necessities for a successful military trauma system: (1) the need for an Armed Services Blood Program and (2) Planning factors for current and future deployed military are is no effective care for wounded soldiers, and by extension there is no effective military medicine.

Designing the Prolonged Field Care Kit (PFAK) to Address the Logistical Challenges of Future Combat Casualty Care

Zaiba Shafik Dawood¹, Toby P Keeney-Bonthrone^{1,2}, Rachel M Russo³, Jessie W Ho¹, Marjorie R Liggett¹, Jennifer Gurney⁴, Allyson Greenberg^{2,5}, Joshua M Tobin⁶, Walter Clark⁷, Aleezeh Shaikh¹, Hasan B Alam¹

Abstract

Introduction: Prolonged Casualty Care (PCC) is a military adaptation aimed at providing pre-hospital care in austere settings when evacuation is delayed or even impossible. Current lack of standardized medical equipment and size/weight restrictions of military packs during dismounted operations hinder effective PCC. We sought to design a standardized, practical, and effective prolonged field care kit (PFAK) to enable widespread implementation of PCC.

Materials and methods: We reviewed Joint Trauma System Clinical Practice Guidelines to generate a list of potential contents of the PFAK. We obtained Institutional Review Board (IRB) exemption and then conducted stakeholder surveys of combat casualty care experts across the Joint Trauma System using a modified Delphi survey approach. We established a civil-military working group that provided in-depth qualitative feedback on the PFAK contents and provided an initial design of a long-range medical rucksack (LMR) to house it. Responses were analyzed using mean rank scores to help determine initial components of the PFAK. Tactical subject-matter experts tested and evaluated the PFAK and LMR prototype in austere conditions to refine the design.

Results: Review of the PCC Clinical Practice Guidelines generated 49 medications and 301 potential supplies as potential PFAK contents. The first Delphi survey was sent to 100 stakeholders (overall response rate of 60%). After the first survey, contents were narrowed to a list of the most essential 27 medications and 105 other components. Iterative prototypes of the PFAK and LMR were tested to determine ergonomics, portability, flexibility, and equipment compartmentalization to facilitate use in emergencies. The prototype was optimized to address the clinical, logistical, and tactical requirements of PCC across a variety of platforms and environmental conditions.

Conclusions: Given the changing battlefield environment, efficient and effective PCC will play an increasingly important role in the management of combat trauma. The PFAK can meet this need by providing a practical and standardized resuscitation kit generated by expert military and trauma personnel consensus, carried conveniently in the LMR.

An Assessment of Clinical Accuracy of Vital Sign-based Triage Tools Among U.S. and Coalition Forces

Tate E Vernon¹, Michael D April^{2,3}, Andrew D Fisher⁴, Julie A Rizzo^{1,3}, Brit J Long^{1,3}, Steven G Schauer^{1,3,5,6,7}

Abstract

Introduction: Early appropriate allocation of resources for critically injured combat casualties is essential. This is especially important when inundated with an overwhelming number of casualties where limited resources must be efficiently allocated, such as during mass casualty events. There are multiple scoring systems utilized in the prehospital combat setting, including the shock index (SI), modified shock index (MSI), simple triage and rapid treatment (START), revised trauma score (RTS), new trauma score (NTS), Glasgow Coma Scale + age + pressure (GAP), and the mechanism + GAP (MGAP) score. The optimal score for application to the combat trauma population remains unclear.

Materials and methods: This is a secondary analysis of a previously described dataset from the Department of Defense Trauma Registry from January 1, 2007 through March 17, 2020. We constructed univariable analyses to determine the area under the receiving operator characteristic (AUROC) for the scoring systems of interest. Our primary outcomes were early death (within 24 hours) or early massive transfusion, as defined by ≥ 3 units.

Results: There were 12,268 casualties that met inclusion criteria. There were 168 (1%) who died within the first 24 hours and 2082 (17%) that underwent significant transfusion within the first 24 hours. When assessing the predictive capabilities for death within 24 hours, the AUROCs were 0.72 (SI), 0.69 (MSI), 0.89 (START), 0.90 (RTS), 0.83 (NTS), 0.90 (GAP), and 0.91 (MGAP). The AUROCs for massive transfusion were 0.89 (SI), 0.89 (MSI), 0.82 (START), 0.81 (RTS), 0.83 (NTS), 0.85 (MGAP), and 0.86 (GAP).

Conclusions: This study retrospectively applied seven triage tools to a database of 12,268 cases from the Department of Defense Trauma Registry to evaluate their performance in predicting early death or massive transfusion in combat. All scoring systems performed well with an AUROC >0.8 for both outcomes. Although the SI and MSI performed best for predicting massive transfusion (both had an AUROC of 0.89), they ranked last for assessment of mortality within 24 hours, with the other tools performing well. START, RTS, NTS, MGAP and GAP reliably identified early death and need for massive transfusion, with MGAP and GAP performing the best overall. These findings highlight the importance of assessing triage tools to best manage resources and ultimately preserve lives of traumatically wounded warfighters. Further studies are needed to explain the surprising performance discrepancy of the SI and MSI in predicting early death and massive transfusion.

Lessons learned from the war in Ukraine for the anesthesiologist and intensivist: A scoping review

Audrey Jarrassier¹, Nicolas Py², Gaël de Rocquigny², Mathieu Raux³, Sigismond Lasocki⁴, Clément Dubost⁵, Emmanuel Bordier², Nicolas Libert⁶, Thomas Leclerc⁶, Éric Meaudre⁷, Pierre Pasquier⁸

Abstract

Background: The war in Ukraine provides purposefully anesthesiologists and intensivists with important data for improving the management of trauma patients. This scoping review aims to investigate the specific management of war-related trauma patients, during the war in Ukraine, through an objective and comprehensive analysis.

Methods: A comprehensive search of the Embase, Medline, and Open Grey databases from 2014 to February 2024 yielded studies focusing on anesthesia and surgery. These studies were assessed by PRISMA and STROBE criteria and needed to discuss anesthesiology and surgical procedures.

Results: Of the 519 studies identified, 21 were included, with a low overall level of evidence. The studies covered 11622 patients and 2470 surgical procedures. Most patients were Ukrainian men, 25 to 63 years old, who had sustained severe injuries from high-energy weapons, such as multiple rocket systems and combat drones. These injuries included major abdominal, facial, and extremity traumas. The surgical procedures varied from initial debridement to complex reconstructions. Anesthesia management faced significant challenges, including resource scarcity and the need for quick adaptability. Evacuations of casualties were lengthy, complex, and often involved rail transportation. Hemorrhage control with tourniquets was critical but associated with many complications. The very frequent presence of multi-resistant organisms required dedicated preventive measures and appropriated treatments. The need for qualified human resources underscored the importance of civilian-military cooperation.

Conclusion: This scoping review provides original and relevant insights on the lessons learned from the ongoing war in Ukraine, which could be useful for anesthesiologists and intensivists.

Keywords: Anesthesiology; Combat; Critical care; Trauma; Ukraine war.

Who needs a tourniquet? And who does not? Lessons learned from a review of tourniquet use in the Russo-Ukrainian war

Frank Butler¹, John B Holcomb, Warren Dorlac, Jennifer Gurney, Kenji Inaba, Lenworth Jacobs, Bob Mabry, Mike Meoli, Harold Montgomery, Mel Otten, Stacy Shackelford, Matthew D Tadlock, Justin Wilson, Kostiantyn Humeniuk, Oleksandr Linchevsky, Oleksandr Danyliuk

Abstract

Background: Extremity tourniquets have proven to be lifesaving in both civilian and military settings and should continue to be used by first responders for trauma patients with life-threatening extremity bleeding. This is especially true in combat scenarios in which both the casualty and the first responder may be confronted by the imminent threat of death from hostile fire as the extremity hemorrhage is being treated. Not every extremity wound, however, needs a tourniquet. One of the most important aspects of controlling life-threatening extremity bleeding with tourniquets is to recognize what magnitude of bleeding requires this intervention and what magnitude of bleeding does not. Multiple studies, both military and civilian, have shown that tourniquets are often applied when they are not medically indicated. Overuse of extremity tourniquets has not caused excess morbidity in either the recent conflicts in Iraq and Afghanistan or in the US urban civilian setting. In the presence of prolonged evacuation, however, applying a tourniquet when it is not medically indicated changes tourniquet application from being a lifesaving intervention to one that may cause an avoidable amputation and the development of an array of metabolic derangements and acute kidney injury collectively called prolonged tourniquet application syndrome.

Methods: The recent literature was reviewed for papers that documented the complications of tourniquet use resulting from the prolonged casualty evacuation times being seen in the current Russo-Ukrainian war. The literature was also reviewed for the incidence of tourniquet application that was found to not be medically indicated, in both the US civilian setting and from Ukraine. Finally, an in-person meeting of the US/Ukraine Tourniquet Working Group was held in Warsaw, Poland, in December of 2023.

Results: Unnecessary loss of extremities and life-threatening episodes of prolonged tourniquet application syndrome are currently occurring in Ukrainian combat forces because of nonindicated tourniquet use combined with the prolonged evacuation time seen in the Russo-Ukrainian war. Specific numbers of the complications experienced as a result of tourniquet use by Ukrainian forces in the current conflict are treated as classified information and are not available, but multiple sources from the Ukrainian military medical personnel and from the US advisors providing medical assistance to Ukraine have all agreed that the problem is substantial.

Conclusion: Unnecessary tourniquet morbidity might also occur in US forces in a variety of potential future combat scenarios in which evacuation to surgical care is delayed. Prehospital trauma training programs, including but not limited to tactical combat casualty care, place insufficient emphasis on the need to avoid leaving tourniquets in place when they are not medically indicated. This aspect of training should receive emphasis in future Tactical Combat Casualty Care (TCCC) and civilian first responder curriculum development. An interim ad hoc training solution on this topic is available at the websites noted in this articles. Additional training modalities may follow in the near future.

Treating wartime injuries amidst attack: insights from a medical facility on the edge of combat

Chezy Levy^{#1}, Gili Givaty^{#1}, Yaniv S Ovadia², Mor Saban³

Abstract

Background: Providing emergency care during conflict poses unique challenges for frontline hospitals. Barzilai Medical Center (BUMCA) in Ashkelon, Israel is a Level I trauma center located close to the Gaza border. During the November 2023 escalation of conflict, BUMCA experienced surging numbers of civilian and military trauma patients while also coming under rocket fire.

Methods: We conducted a retrospective review of BUMCA operational records and 827 de-identified patient records from October 7-14, 2023. Records provided data on daily patient volumes, injury patterns, resource constraints, and impacts of rocket attacks on hospital function. Basic demographic data was obtained including age, gender, injury severity scores, and disposition.

Results: Of the 827 patients brought to BUMCA, most (n = 812, 98.2%) presented through the emergency department. Tragically, 99 individuals were pronounced dead on arrival. Injury severity assessments found nearly half (47%) had minor injuries such as lacerations, contusions and sprains, while 25% exhibited moderate injuries like deep lacerations and fractures. 15% sustained severe or critical injuries including severe head injuries. The largest age group consisted of adults aged 19-60 years. No pediatric patients were admitted despite proximity to residential neighborhoods. The majority of cases (61%) involved complex polytrauma affecting multiple body regions. BUMCA served as both the primary treatment facility and a triage hub, coordinating secondary transports to other trauma centers as needed. Patient volumes fluctuated unpredictably from 30 to an overwhelming 125 daily, straining emergency services. Resources faced shortages of beds, medical staff, supplies and disruptions to power from nearby missile impacts further challenging care delivery.

Conclusion: Despite facing surging demand, unpredictable conditions and external threats, BUMCA demonstrated resilience in maintaining emergency trauma services through an adaptive triage approach and rapid surges in capacity. Their experience provides insights for improving frontline hospital preparedness and continuity of care during conflict through advance contingency planning and surge protocols. Analysis of patient outcomes found a mortality rate of 15% given the complex, multi-region injuries sustained by many patients. This study highlights the challenges faced and strengths exhibited by medical professionals operating under hazardous conditions in minimizing loss of life.

Incidence and management of traumatic vertebral artery injuries: wartime experience in Ukraine

Andrii Sirko¹, Yuri Cherednychenko², Ehsan Dowlati^{3,4}, Vadym Perepelytsia², Rocco A Armonda³

Abstract

Objective: Modern combat-related vertebral artery (VA) injuries are increasingly being diagnosed, but the management of such injuries remains controversial. The authors report the frequency and characteristics of combat-related penetrating VA injuries and the indications for endovascular treatment, as well as analyze their treatment outcomes.

Methods: A 1-year prospective study was completed at a civilian medical center in Dnipro, Ukraine, in all patients with VA injuries sustained during the Russian invasion in the 1st year of war. The authors evaluated the location, type, and severity of the VA injuries and concomitant injuries, as well as the type of intervention and outcomes at 1 month.

Results: In total, 279 wounded patients underwent cerebral angiography and 30 (10.8%) patients had VA injuries. All patients were male. There were 28 soldiers and 2 civilians with a mean age of 37.5 years. Four (13.3%) patients had Bissl grade I injuries, 4 (13.3%) had grade II injuries, 4 (13.3%) had grade III injuries (pseudoaneurysm), and 18 (60.0%) had grade IV injuries (occlusion). Four (13.3%) patients underwent emergency open surgical intervention. Fourteen (46.7%) patients underwent endovascular intervention. There was a significant relationship between the anatomical level of the VA injury and surgical intervention ($p < 0.05$). Endovascular intervention was correlated with the severity of vascular injury to the VA, with 12.5% of the patients receiving intervention for grade I and II lesions and 59.1% receiving intervention for grade III and IV lesions ($p < 0.05$). The overall mortality in the study group was 6.7% ($n = 2$), and both died of ischemic complications.

Conclusions: In modern armed conflicts, VA injuries are much more common than reported for previous wars. With the available modern endovascular technology, cerebral angiography is warranted for suspected VA injury and allows for both the diagnosis and treatment of these injuries. Whether endovascular intervention is performed depends on the level and severity of VA injury, severity of concomitant injuries, and presence of collateral circulation.

Keywords: Ukraine; embolization; endovascular neurosurgery; gunshot wounds; penetrating trauma; pseudoaneurysm; vertebral artery; vertebral dissection; wartime trauma.

A trauma expert consensus: Capabilities are required early to improve survivability from traumatic injury

Jennifer M Gurney¹, Russ S Kotwal, John B Holcomb, Amanda M Staudt, Brian Eastridge, Max Sirkin, Shane Jensen, Stacy Shackelford, Brian J Sonka, Justin Wilson, Harold Montgomery, Kirby Gross, Wendy Warren, Edward Mazuchowski, Andrew J Rohrer

Abstract

Background: Mortality reviews examine US military fatalities resulting from traumatic injuries during combat operations. These reviews are essential to the evolution of the military trauma system to improve individual, unit, and system-level trauma care delivery and inform trauma system protocols and guidelines. This study identifies specific prehospital and hospital interventions with the potential to provide survival benefits.

Methods: US Special Operations Command fatalities with battle injuries deemed potentially survivable (2001-2021) were extracted from previous mortality reviews. A military trauma review panel consisting of trauma surgeons, forensic pathologists, and prehospital and emergency medicine specialists conducted a methodical review to identify prehospital, hospital, and resuscitation interventions (e.g., laparotomy, blood transfusion) with the potential to have provided a survival benefit.

Results: Of 388 US Special Operations Command battle-injured fatalities, 100 were deemed potentially survivable. Of these (median age, 29 years; all male), 76.0% were injured in Afghanistan, and 75% died prehospital. Gunshot wounds were in 62.0%, followed by blast injury (37%), and blunt force injury (1.0%). Most had a Maximum Abbreviated Injury Scale severity classified as 4 (severe) (55.0%) and 5 (critical) (41.0%). The panel recommended 433 interventions (prehospital, 188; hospital, 315). The most recommended prehospital intervention was blood transfusion (95%), followed by finger/tube thoracostomy (47%). The most common hospital recommendations were thoracotomy and definitive vascular repair. Whole blood transfusion was assessed for each fatality: 74% would have required ≥ 10 U of blood, 20% would have required 5 to 10 U, 1% would have required 1 to 4 U, and 5% would not have required blood products to impact survival. Five may have benefited from a prehospital laparotomy.

Conclusion: This study systematically identified capabilities needed to provide a survival benefit and examined interventions needed to inform trauma system efforts along the continuum of care. The determination was that blood transfusion and massive transfusion shortly after traumatic injury would impact survival the most.

A Review of 75th Ranger Regiment Battle-Injured Fatalities Incurred During Combat Operations From 2001 to 2021

Charles H Moore^{1,2}, Russ S Kotwal^{2,3}, Jeffrey T Howard⁴, Montane B Silverman⁵, Jennifer M Gurney^{3,6}, Andrew J Rohrer^{3,7,8}, Ryan M Knight^{2,9}

Abstract

Introduction: The 75th Ranger Regiment is an elite U.S. military special operations unit that conducted over 20 years of sustained combat operations. The Regiment has a history of providing novel and cutting-edge prehospital trauma care, advancing and translating medical initiatives, and documenting and reporting casualty care performance improvement efforts.

Materials and methods: A retrospective case fatality rate (CFR) review, mortality review, and descriptive analysis of fatalities were conducted for battle-injured personnel assigned or attached to the 75th Ranger Regiment from 2001 to 2021 during combat operations primarily in Afghanistan and Iraq. Fatalities were evaluated for population characteristics, cause of death, mechanism of death, injury severity, injury survivability, and death preventability.

Results: A total of 813 battle injury casualties, including 62 fatalities, were incurred over 20 years and 1 month of continuous combat operations. The Regiment maintained a zero rate of prehospital preventable combat death. Additionally, no fatalities had a mechanism of death because of isolated extremity hemorrhage, tension pneumothorax, or airway obstruction. When comparing the CFR of the Regiment to the U.S. military population as a whole, the Regiment had a significantly greater reduction in the cumulative CFR as measured by the difference in average annual percentage change.

Conclusions: Documentation and analysis of casualties and care, mortality and casualty reviews, and other performance improvement efforts can guide combatant commanders, medical directors, and fighting forces to reduce preventable combat deaths and the CFR. Early hemorrhage control, blood product resuscitation, and other lifesaving interventions should be established and maintained as a standard prehospital practice to mitigate fatalities with potentially survivable injuries.

Vascular complications secondary to resuscitative endovascular balloon occlusion of the aorta placement at a Level 1 Trauma Center

Amanda Tullos¹, Sanjay Wunnava¹, Daniela Medina¹, Claudie Sheahan¹, Amit Chawla¹, Bruce Torrance¹, Amadis Brooke¹, Melissa Donovan¹, Tapash Palit¹, Malachi Sheahan²

Abstract

Objective: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is designed to manage severe hemorrhagic shock. Popularized in medical care during military conflicts, the concept has emerged as a lifesaving technique that is utilized around the United States. Literature on risks of REBOA placement, especially vascular injuries, are not well-reported. Our goal was to assess the incidence of vascular injury from REBOA placement and the risk factors associated with injury and death among these patients at our institution.

Methods: We performed a retrospective cohort study of all patients who underwent REBOA placement between September 2017 and June 2022 at our Level 1 Trauma Center. The primary outcome variable was the presence of an injury related to REBOA insertion or use. Secondary outcomes studied were limb loss, the need for dialysis, and mortality. Data were analyzed using descriptive statistics, χ^2 , and t-tests as appropriate for the variable type.

Results: We identified 99 patients who underwent REBOA placement during the study period. The mean age of patients was 43.1 ± 17.2 years, and 67.7% (67/99) were males. The majority of injuries were from blunt trauma (79.8%; 79/99). Twelve of the patients (12.1%; 12/99) had a vascular injury related to REBOA placement. All but one required intervention. The complications included local vessel injury (58.3%; 7/12), distal embolization (16.7%; 2/12), excessive bleeding requiring vascular consult (8.3%; 1/12), pseudoaneurysm requiring intervention (8.3%; 1/12), and one incident of inability to remove the REBOA device (8.3%; 1/12). The repairs were performed by vascular surgery (75%; 9/12), interventional radiology (16.7%; 2/12), and trauma surgery (8.3%; 1/12). There was no association of age, gender, race, and blunt vs penetrating injury to REBOA-related complications. Mortality in this patient population was high (40.4%), but there was no association with REBOA-related complications. Ipsilateral limb loss occurred in two patients with REBOA-related injuries, but both were due to their injuries and not to REBOA-related ischemia.

Conclusions: Although vascular complications are not unusual in REBOA placement, there does not appear to be an association with limb loss, dialysis, or mortality if they are addressed promptly. Close coordination between vascular surgeons and trauma surgeons is essential in patients undergoing REBOA placement.

Keywords: REBOA; Vascular injury; Vascular trauma.