

# Committee on Surgical Combat Casualty Care (CoSCCC)



**Journal Watch**

**3rd Quarter**

**FY 2024**

## Journal Watch Key Terminology Searched:

Microcirculation  
Shock  
Human subject research  
Haemorrhagic shock  
Traumatic brain injury  
Plasma  
Transfusion  
RBCs  
Stability  
Blast  
Amputation  
Traumatic Clinical outcomes  
Injury  
Coagulopathy  
Fibrinogen concentrate  
Viscoelastic haemostatic assays  
Guidelines  
Fractures  
REBOA  
Orthopaedic trauma  
Wound ballistics  
Cause of injury  
Damage Control Resuscitation  
Tension pneumothorax  
Blast Injury  
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Surgical skills  
Novel Coronavirus  
Predictions  
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Trauma Management  
Sublingual  
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Walking Blood Bank  
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Imaging  
Severe trauma  
Afghanistan  
War  
Transfusion  
Damage control Surgery  
Battlefield Trauma  
Fibrinogen  
ABO  
External fixation  
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Pre-peritoneal pelvic packing  
Long bone fractures  
Surgical site infection  
Primary repair  
Poly-trauma  
Prolonged field care  
Military Medicine  
Killed in Action  
Mortality  
Infection prevention  
Hypocalcemia  
Global Surgery  
Ukraine  
Performance Improvement  
Machine Learning

# Combat Injury Profile in Urban Warfare

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## Abstract

**Introduction:** Combat ground maneuvers consist of various platforms and have several environmental characteristics, influenced by the terrain, the operational mission, and the force's capabilities. This study assesses data on injuries sustained during urban warfare, aiming to evaluate the relationship between injury characteristics, maneuver platform, and personal protective gear on the battlefield.

**Materials and methods:** IDF soldiers injured infantry soldiers from the "Cast Lead" and the "Protective Edge" operations in the Gaza Strip (2008-2009 and 2014, respectively) were divided into four groups according to the maneuver platform and the environment: mounted infantry (armored and unarmored vehicle) and dismounted infantry (urban and open area). The primary outcome was the severity of the injury, and the secondary outcome was the injured body part.

**Results:** Overall, 588 casualties were included in the final analysis, of whom 507 were dismounted infantry soldiers (265 in open terrain and 242 in urban area) and 81 were mounted infantry soldiers (20 in unarmored and 61 were injured in armored vehicles). The Injury Severity Score was similar in all subgroups. Open terrain subgroups were found to have fewer head injuries and higher levels of lower extremity injuries, similar to the unarmored vehicle group. More facial injuries were documented in the urban area group.

**Conclusions:** The Injury Severity Score was not influenced by environmental protection. Although we found differences in the injured body parts, further studies on the exact mechanism of injury are needed to elucidate further the relationship and differences between the various platforms used and injuries seen in urban warfare, aiming for tailor-made protection.

# Cataracts after Ophthalmic and Nonophthalmic Trauma Exposure in Service Members, U.S. Armed Forces

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## Abstract

**Abstract:** IntroductionWe aimed to identify injury-related risk factors for secondary cataract incidence after eye and brain injury and polytrauma. We also examined the effect of direct and indirect eye injury management on cataract diagnosis and treatment. Prevention or mitigation strategies require knowledge of the causes and types of combat injuries, which will enable more appropriate targeting of resources toward prevention and more efficient management of such injuries.

**Materials and methods:** Data were gathered from the Military Health System using the Military Health System Management and Analysis Reporting Tool (M2) between 2017 and 2021 from inpatient and outpatient Service Members (SMs) (active duty and National Guard). The date of the first cataract diagnosis was tracked to estimate the annual incidence rate, and it was longitudinally linked to any prior diagnosis of ocular trauma (OT), traumatic brain injury (TBI), or polytrauma to calculate the relative risk. International Classification of Disease codes, 10th Revision, were used to identify those diagnosed with cataracts, TBI, and polytrauma. Defense and Veterans Eye Injury and Vision Registry data were used to examine SMs who sustained ocular injuries from 2003-2020 and who may have had cataract surgery following a cataract diagnosis.

**Results:** The relative risk of traumatic cataract formation from OT, TBI, and polytrauma are 5.71 (95% CI, 5.05-6.42), 2.32 (95% CI, 2.03-2.63), and 8.95 (95% CI, 6.23-12.38), respectively. Traumatic cataracts in SMs more commonly result from open-globe injuries (70%) than closed-globe injuries (30%). By specific sub-injury type, traumatic cataracts occur most frequently from intraocular foreign bodies (22%). More than 400 patients in the cohort suffered from TBI and traumatic cataracts, more than 300 from OT and cataracts, and more than 20 from polytrauma and cataracts. The battlefield is the riskiest environment for trauma exposure, with 62% of OT occurring in combat. There was a statistically significant difference between the mean visual acuity value before cataract surgery ( $M = 1.17$ ,  $SD = 0.72$ ) and the mean visual acuity value after cataract surgery ( $M = 0.44$ ,  $SD = 0.66$ ,  $P < .001$ ).

**Conclusion:** Traumatic cataracts often occur in SMs who sustain ocular injuries. New to the literature is that relationships exist between traumatic cataract formation and nonglobe trauma, specifically TBI and polytrauma. Ocular injury calls for an ophthalmic examination. A low threshold should exist for routine ocular exam consultation in the setting of TBI and polytrauma. Separately, polytrauma patients should undergo a review of systems questions, particularly questions about the ocular and visual pathways. A positive response to screening warrants further investigation of possible ocular pathology, including traumatic cataract formation. Cataract surgery is an effective treatment in improving the vision of SMs who suffer from traumatic cataracts. Constant effort must be made to limit occurrences of occupation-related traumatic cataracts.

# Incidence of Coagulopathy After Resuscitation at a Role 1 Facility: The Prehospital Trauma Registry Experience

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## Abstract

**Background:** The development of acute traumatic coagulopathy is associated with increased mortality and morbidity in patients with battlefield traumatic injuries. Currently, the incidence of acute traumatic coagulopathy in the Role 1 setting is unclear.

**Methods:** We queried the Prehospital Trauma Registry (PHTR) module of the Department of Defense Trauma Registry (DoDTR) for all encounters from inception through May 2019. The PHTR captures data on Role 1 prehospital care. Data from the PHTR was linked to the DoDTR to analyze laboratory data and patient outcomes using descriptive statistics. We defined coagulopathy as an international normalized ratio (INR) of  $\geq 1.5$  or platelet count  $\leq 150 \times 10^9/L$ .

**Results:** A total of 595 patients met the inclusion criteria; 36% (212) met our definition for coagulopathy, with 31% (185) carrying low platelet numbers, 11% (68) showing an elevated INR, and 7% (41) with both. The baseline (no coagulopathy) cohort had a mean INR of 1.10 (95% CI 1.09-1.12) versus 1.38 (95% CI 1.33-1.43) in the coagulopathic cohort. The mean platelet count was 218 (95% CI 213-223)  $\times 10^9/L$  in the baseline cohort versus 117 (95% CI 110-125)  $\times 10^9/L$  in the coagulopathic cohort.

**Conclusions:** Our findings indicate a high incidence of coagulopathy in trauma patients. Approximately one-third of wounded patients had laboratory evidence of coagulopathy upon presentation to a forward medical care facility. Advanced diagnostic facilities are therefore needed to facilitate early diagnosis of acute traumatic coagulopathy. Blood products with a long shelf life can aid in early correction.

**Keywords:** coagulation; coagulopathy; military; prehospital; trauma.

# A Narrative Review of Existing and Developing Biomarkers in Acute Traumatic Brain Injury for Potential Military Deployed Use

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## Abstract

**Introduction:** Traumatic brain injury (TBI) is a leading cause of morbidity and mortality in both adult civilian and military populations. Currently, diagnostic and prognostic methods are limited to imaging and clinical findings. Biomarker measurements offer a potential method to assess head injuries and help predict outcomes, which has a potential benefit to the military, particularly in the deployed setting where imaging modalities are limited. We determine how biomarkers such as ubiquitin C-terminal hydrolase-L1 (UCH-L1), glial fibrillary acidic protein (GFAP), S100B, neurofilament light chain (NFL), and tau proteins can offer important information to guide the diagnosis, acute management, and prognosis of TBI, specifically in military personnel.

**Materials and methods:** We performed a narrative review of peer-reviewed literature using online databases of Google Scholar and PubMed. We included articles published between 1988 and 2022.

**Results:** We screened a total of 73 sources finding a total of 39 original research studies that met inclusion for this review. We found five studies that focused on GFAP, four studies that focused on UCH-L1, eight studies that focused on tau proteins, six studies that focused on NFL, and eight studies that focused on S100B. The remainder of the studies included more than one of the biomarkers of interest.

**Conclusions:** TBI occurs frequently in the military and civilian settings with limited methods to diagnose and prognosticate outcomes. We highlighted several promising biomarkers for these purposes including S100B, UCH-L1, NFL, GFAP, and tau proteins. S100B and UCH-L1 appear to have the strongest data to date, but further research is necessary. The robust data that explain the optimal timing and, more importantly, trending of these biomarker measurements are necessary before widespread application.

# The employment of resuscitative endovascular balloon occlusion of the aorta in deployed settings

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## Abstract

**Background:** Resuscitative endovascular balloon occlusion of the aorta (REBOA) has been often used in place of open aortic occlusion for management of hemorrhagic shock in trauma. There is a paucity of data evaluating REBOA usage in military settings.

**Study design and methods:** We queried the Department of Defense Trauma Registry (DODTR) for all cases with at least one intervention or assessment available within the first 72 h after injury between 2007 and 2023. We used relevant procedural codes to identify the use of REBOA within the DODTR, and we used descriptive statistics to characterize its use.

**Results:** We identified 17 cases of REBOA placed in combat settings from 2017 to 2019. The majority of these were placed in the operating room (76%) and in civilian patients (70%). A penetrating mechanism caused the injury in 94% of cases with predominantly the abdomen and extremities having serious injuries. All patients subsequently underwent an exploratory laparotomy after REBOA placement, with moderate numbers of patients having spleen, liver, and small bowel injuries. The majority (82%) of included patients survived to hospital discharge.

**Discussion:** We describe 17 cases of REBOA within the DODTR from 2007 to 2023, adding to the limited documentation of patients undergoing REBOA in military settings. We identified patterns of injury in line with previous studies of patients undergoing REBOA in military settings. In this small sample of military casualties, we observed a high survival rate.

**Keywords:** REBOA; balloon; combat; endovascular; military; resuscitation; trauma.

# Frequency of deployed emergency donor panel use prior to implementation of the low titre group O whole blood program

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## Abstract

**Introduction:** The US military has frequently used a 'walking blood bank', formally known as an 'emergency donor panel' (EDP) to obtain warm fresh whole blood (WFWB) which is then immediately transfused into the casualty. We describe the frequency of EDP activation by the US military.

**Methods:** We analysed data from 2007 to 2015 within the Department of Defense Trauma Registry for US, Coalition and US contractor casualties that received at least 1 unit of blood product within the first 24 hours and described the frequency of WFWB use.

**Results:** There were 3474 casualties that met inclusion, of which, 290 casualties (8%) required activation of the EDP. The highest proportion of EDP events was in 2014, whereas the highest number of EDP events was in 2011. Median injury severity scores were higher in the recipients, compared with non-EDP recipients (29 vs 20), as were proportions with serious injuries to the abdomen (43% vs 19%) and extremities (77% vs 65%). The median number of units of all blood products, except for packed red blood cells, was higher for WFWB recipients. Of the WFWB recipients, the median was 5 units (IQR 2-10) with a maximum documented 144 units. There were four documented cases of EDP recipients receiving >100 units of WFWB with only one surviving to hospital discharge. During the study period, there were a total of 3102 (3%) units of WFWB transfused among a total of 104 288 total units.

**Conclusions:** We found nearly 1 in 11 casualties who received blood required activation of the EDP. Blood from the EDP accounted for 3% of all units transfused. These findings will enable future mission planning and medical training, especially for units with smaller, limited blood supplies. The lessons learned here can also enable mass casualty planning in civilian settings.

**Keywords:** ACCIDENT & EMERGENCY MEDICINE; Adult intensive & critical care; ORTHOPAEDIC & TRAUMA SURGERY; Trauma management.



# Pack the chest: Damage control strategy for management in thoracic trauma

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## Abstract

**Background:** Damage control surgery aims to control hemorrhage and contamination in the operating room (OR) with definitive management of injuries delayed until normal physiology is restored in the intensive care unit (ICU). There are limited studies evaluating the use of damage control thoracotomy (DCT) in trauma, and the best method of temporary closure is unclear.

**Methods:** A retrospective review of trauma patients at two level I trauma centers who underwent a thoracotomy operation was performed. Subjects who underwent a thoracotomy after 24 h, age less than 16, expired in the trauma bay, or in the OR prior to ICU admission were excluded. One-way ANOVA and Kruskal-Wallis test were used to compare continuous and categorical variables between DCT and definitive thoracotomy (DT) patients.

**Results:** 207 trauma patients underwent thoracotomy, 76 met our inclusion criteria. DCT was performed in 30 patients (39%), 46 (61 %) underwent DT operation. Techniques for temporizing the chest varied from skin closure with suture (8), adhesive dressing (5), towel clamps (2), or negative pressure devices (12). Compared to definitive closure, DCT had more derangements in HR, pH, (110 vs. 95,  $p = 0.04$ ; 7.05 vs 7.24,  $p < 0.001$ ), and injury severity score (41 vs 25,  $p < 0.001$ ), and required more blood transfusions (40 vs 6,  $p < 0.001$ ). Eleven (36.7 %) DCT patients survived to discharge compared to 38 patients (95.0 %) in the DT group. DCT showed significantly higher differences in cardiac arrest and unplanned returns to the OR rates. No differences were observed in ventilator days, or ICU length of stay.

**Conclusions:** DCT is a viable option for management of patients in extremis following thoracic trauma. DCT was associated with higher mortality rates, likely due to differences in injury and physiologic derangement. Despite this, DCT was associated with similar rates of complications, ICU stay, and ventilator days.

**Keywords:** Damage-control; Level II; Level of Evidence; Retrospective cohort; Thoracic; Thoracotomy; Trauma.

# Performance Improvement Program Review of Institutional Massive Transfusion Protocol Adherence: An Opportunity for Improvement

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## Abstract

**Background:** Given the acuity of patients who receive MTPs and the resources they require, MTPs are a compelling target for performance improvement. This study evaluated adherence with our MTP's plasma:red blood cell ratio (FFPR) of 1:2 and platelet:red blood cell ratio (PLTR) of 1:12, to test the hypothesis that ratio adherence is associated with lower inpatient mortality.

**Materials and methods:** The registry of an urban level I trauma center was queried for adult patients who received at least 6 units of packed red blood cells within 4 hours of presentation. Patients were excluded for interfacility transfer, cardiac arrest during the prehospital phase or within one hour of arrival, or for head AIS  $\geq 5$ . Univariate analysis and multiple logistic regressions were performed to identify variables associated with early transfusion protocol noncompliance and the effect on inpatient mortality.

**Results:** Three hundred and eighty-three patients were included, with mean ISS of  $25.9 \pm 13.3$  and inpatient mortality of 28.5%. Increasing age, ISS, INR, and total units of blood product transfused were associated with increased odds of mortality, while an increase in revised trauma score was associated with a decreased odds ratio of mortality. Achieving our goal ratios were protective against mortality, with OR of .451 ( $P = .013$ ) and .402 ( $P = .003$ ), respectively.

**Discussion:** Large proportions of critically injured patients were transfused fewer units of plasma and platelets than our MTP dictated; failure to achieve intended ratios at 4 hours was strongly associated with inpatient mortality. MTP processes and outcomes should be critically assessed on a regular basis as part of a mature performance improvement program to ensure protocol adherence and optimal patient outcome.

**Keywords:** damage control resuscitation; massive transfusion protocol; performance improvement; protocol adherence; transfusion ratios.

# A 20-year retrospective analysis of deep venous thrombosis and pulmonary embolism among combat casualties requiring damage control laparotomy at US Military Role 2 surgical units

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## Abstract

**Background:** Combat casualties receiving damage control laparotomy at forward deployed, resource-constrained US Military Role 2 surgical units (R2) require multiple evacuations, but the added risk of venous thromboembolism (VTE) in this population has not been defined. To fill this gap, we retrospectively analyzed 20 years of Department of Defense Trauma Registry (DoDTR) data to define the VTE rate in this population.

**Methods:** DoDTR from 2002 to 2023 was queried for US Military combat casualties requiring damage control laparotomy at R2. All deaths were excluded in subsequent analysis. Rates of VTE were assessed, and subgroup analysis was performed on patients requiring massive transfusion.

**Results:** DoDTR (n = 288) patients were young (mean age 25 years), predominantly male (98%) with severe (mean ISS 26), mostly penetrating injury (76%), and high mortality. VTE rate was high: 15.8% (DVT: 10.3% and PE 7.1%). In the massively transfused population, the VTE rate was even higher (26.7% vs 10.2%,  $p < 0.001$ ).

**Conclusions:** This is the first report that combat casualties requiring damage control laparotomy at R2 have such high VTE rates. Therefore, for military casualties, we propose screening ultrasound upon arrival to each subsequent capable echelon of care and low threshold for initiating thromboprophylaxis.

# Is Barbed Better? Evaluation of Triclosan-Coated Barbed Suture on Wound Complications Following Emergency Laparotomy

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## Abstract

**Introduction:** Emergent laparotomy is associated with significant wound complications including surgical site infections (SSI) and fascial dehiscence (FD). Triclosan-coated barbed suture (TCB) for fascial closure has been shown to reduce local complications but primarily in elective settings. We sought to evaluate the effect of TCB emergency laparotomy fascial closure on major wound complications.

**Methods:** Adult patients undergoing emergency laparotomy were prospectively evaluated over 1-year. Patients were grouped into TCB vs polydioxanone (PDS) for fascial closure. Subanalysis was performed on patients undergoing single-stage laparotomy. Primary outcomes were SSI and FD. Multivariate analysis identified independent factors associated with SSI and FD.

**Results:** Of the 206 laparotomies, 73 (35%) were closed with TCB and 133 (65%) were closed with PDS. Trauma was the reason for laparotomy in 73% of cases; damage control laparotomy (DCL) was performed in 27% of cases. The overall rate of SSI and FD was 18% and 10%, respectively. Operative strategy was similar between groups, including DCL, wound vac use, skin closure, and blood products. SSI events trended lower with TCB vs PDS closure (11% vs. 21%;  $p = .07$ ), and FD was significantly lower with TCB versus PDS (4% vs. 14%;  $p < .05$ , Fig 1). Subanalysis of trauma and non-trauma cases showed no difference in SSI or FD. Multivariable analysis found that TCB decreased the likelihood of FD (OR .07;  $p < .05$ , Fig 2) following emergency laparotomy. Increased odds of FD were seen in DCL (OR 3.1;  $p < 0.05$ ).

**Conclusions:** Emergency laparotomy fascial closure with TCB showed significantly decreased rates of FD compared to closure with PDS, and a strong trend toward lower SSI events. TCB was independently associated with decreased FD rates after emergency laparotomy.

# Lactic acid levels are associated with morbidity, length of stay, and total treatment costs in urban trauma patients with lower extremity long bone fractures

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## Abstract

**Introduction:** Lactic acid is well studied in the trauma population and is frequently used as a laboratory indicator that correlates with resuscitation status and has thus been associated with patient outcomes. There is limited literature that assesses the association of initial lactic acid with post-operative morbidity and hospitalization costs in the orthopedic literature. The purpose of this study was to assess the association of lactic acid levels and alcohol levels post-operative morbidity, length of stay and admission costs in a cohort of operative lower extremity long bone fractures, and to compare these effects in the ballistic and blunt trauma sub-population.

**Methods:** Patients presenting as trauma activations who underwent tibial and/or femoral fixation at a single institution from May 2018 to August 2020 were divided based on initial lactate level into normal, (< 2.5) intermediate (2.5-4.0), and high (> 4.0). Mechanism of trauma (blunt vs. ballistic) was also stratified for analysis. Data on other injuries, surgical timing, level of care, direct hospitalization costs, length of stay, and discharge disposition were collected from the electronic medical record. The primary outcome assessed was post-operative morbidity defined as in-hospital mortality or unanticipated escalation of care. Secondary outcomes included hospital costs, lengths of stay, and discharge disposition. Data were analyzed using ANOVA and multivariate regression.

**Results:** A total of 401 patients met inclusions criteria. Average age was  $34.1 \pm 13.0$  years old, with patients remaining hospitalized for  $8.8 \pm 9.5$  days, and 35.2% requiring ICU care during their hospitalization. Patients in the ballistic cohort were younger, had fewer other injuries and had higher lactate levels ( $4.0 \pm 2.4$ ) than in the blunt trauma cohort ( $3.4 \pm 1.9$ ) ( $p = 0.004$ ). On multivariate regression, higher lactate was associated with post-operative morbidity ( $p = 0.015$ ), as was age ( $p < 0.001$ ) and BMI ( $p = 0.033$ ). ISS, ballistic versus blunt injury mechanism, and other included laboratory markers were not. Lactate was also associated with longer lengths of stay, and higher associated direct hospitalization cost ( $p < 0.001$ ) and lower rates of home disposition ( $p = 0.008$ ).

**Conclusion:** High initial lactate levels are independently associated with post-operative morbidity as well as higher direct hospitalization costs and longer lengths of stay in orthopedic trauma patients who underwent fixation for fractures of the lower extremity long bones. Ballistic trauma patients had significantly higher lactate levels compared to the blunt cohort, and lactate was not independently associated with increased rates of post-operative morbidity in the ballistic cohort alone.

# Beyond Trauma: High-Volume Critical Care Medicine in a Military Medical Center-Based Military-Civilian Partnership

[Jeremy P Kilburn<sup>1</sup>](#), [Stephanie M Streit<sup>1</sup>](#), [W Patrick Luan<sup>2</sup>](#), [Jamie Lindly<sup>2</sup>](#), [Angelica Honsberg<sup>3</sup>](#), [Buddhadeb Dawn<sup>3</sup>](#), [Ryan G K Mihata<sup>1</sup>](#), [Jonas J Carmichael<sup>4</sup>](#), [Renee I Matos<sup>5</sup>](#), [Terence P Lonergan<sup>5</sup>](#), [Robert J Walter<sup>5</sup>](#), [Bryan D Szalwinski<sup>6</sup>](#), [Sean N Dooley<sup>7</sup>](#), [Edward T McCann<sup>5</sup>](#), [James B Sampson<sup>8</sup>](#), [Steven P Praske<sup>9</sup>](#), [Jennifer M Gurney<sup>10</sup>](#), [Cristin A Mount<sup>11</sup>](#) **Abstract**

**Introduction:** Critical Care Internal Medicine (CCIM) is vital to the U.S. Military as evidenced by the role CCIM played in the COVID-19 pandemic response and wartime operations. Although the proficiency needs of military surgeons have been well studied, this has not been the case for CCIM. The objective of this study was to compare the patient volume and acuity of military CCIM physicians working solely at Military Treatment Facilities (MTFs) with those at MTFs also working part-time in a military-civilian partnership (MCP) at the University Medical Center of Southern Nevada (UMC).

**Materials and methods:** We analyzed FY2019 critical care coding data from the Military Health System and UMC comparing the number of critical care encounters, the number of high-acuity critical care encounters, and the Abilities/Activity component of the Knowledge, Skills, and Abilities/Clinical Activity (KSA) score. This analysis was restricted to critical care encounters defined by Current Procedural Terminology codes for critical care (99291 and 99292). A critical care encounter was considered high acuity if the patient had ICD-10 codes for shock, respiratory failure, or cardiac arrest or had at least three codes for critical care in the same episode.

**Results:** The five AF CCIM physicians in the MCP group performed 2,019 critical care encounters in 206 days, with 63.1% (1,273) being defined as high acuity. The total number of MTF critical care encounters was 16,855 across all providers and services, with 28.9% (4,864) of encounters defined as high acuity. When limited to CCIM encounters, MTFs had 6,785 critical care encounters, with 32.0% being high acuity (2,171). Thus, the five AF CCIM physicians, while working 206 days at the UMC, equated to 12.0% (2,019/16,855) of the total critical care MTF encounters, 27.2% (1,273/4,684) of the total high-acuity MTF critical care encounters, and 29.8% (2,019/6,785) of the MTF CCIM encounters, with 58.6% (1,273/2,171) of the MTF CCIM high-acuity encounters. The USAF CCIM physicians in the MCP group performed 454,395 KSAs in 206 days, with a KSA density per day of 2,206. In the MTF group, CCIM providers generated 2,344,791 total KSAs over 10,287 days, with a KSA density per day of 227.9. Thus, the five CCIM physicians at the UMC accounted for 19.38% of the MTF CCIM KSAs, with a KSA density over 10 times higher (2,206 vs. 227.9).

**Conclusions:** The volume and acuity of critical care at MTFs may be insufficient to maintain CCIM proficiency under the current system. Military-civilian partnerships are invaluable in maintaining clinical proficiency for military CCIM physicians and can be done on a part-time basis while maintaining beneficiary care at an MTF. Future CCIM expeditionary success is contingent on CCIM physicians and team members having the required CCIM exposure to grow and maintain clinical proficiency. Limitations of this study include the absence of off-duty employment (moonlighting) data and difficulty filtering military data down to just CCIM physicians, which likely caused the MTF CCIM data to be overestimated.

# Predicting Progression of Intracranial Hemorrhage in the Prehospital TXA for TBI Trial

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## Abstract

Progression of intracranial hemorrhage is a common, potentially devastating complication after moderate/severe traumatic brain injury (TBI). Clinicians have few tools to predict which patients with traumatic intracranial hemorrhage on their initial head computed tomography (hCT) scan will progress. The objective of this investigation was to identify clinical, imaging, and/or protein biomarkers associated with progression of intracranial hemorrhage (PICH) after moderate/severe TBI and to create an accurate predictive model of PICH based on clinical features available at presentation. We analyzed a subset of subjects from the phase II double-blind, multi-center, randomized "Prehospital Tranexamic Acid Use for TBI" trial. This subset was limited to the placebo arm of the parent trial with evidence of hemorrhage on the initial hCT and a follow-up hCT 6 h after. PICH was defined as an increase in hemorrhage size by 30% or more, or the development of new hemorrhage in the intra- and extra-axial intracranial vault between the initial and the follow-up hCT. Two independent radiologists evaluated each hCT, and conflicts were adjudicated by a third. Clinical and radiographic characteristics were collected, along with plasma protein biomarkers at admission. Principal component analysis (PCA) was performed, and each principal component (PC) was interrogated for its association with PICH. Finally, expert opinion and recursive feature extraction (RFE) were used to select input features for the construction of several supervised classification models. Their ability to predict PICH was quantified and compared. In this subset of subjects ( $n = 104$ ), 46% ( $n = 48$ ) demonstrated PICH. Univariate analyses showed no association between PICH and age, sex, admission Glasgow Coma Scale (GCS), GCS motor subscore, presence of midline shift, admission platelet count or admission INR. Radiographic severity scores (Marshall score [ $p = 0.007$ ], Rotterdam score [ $p = 0.004$ ]), and initial hematoma volume [ $p = 0.005$ ] were associated with PICH. Higher levels of admission glial fibrillary acidic protein ( $p < 0.001$ ) and MAP ( $p = 0.011$ ) were also associated with PICH. Of the PCs, PC1 was significantly associated with PICH ( $p = 0.0125$ ). Using multimodal data input, machine learning classifiers successfully discriminated patients with or without PICH. Models composed of machine-selected features performed better than models composed of expert-selected variables (reaching an average of 77% accuracy, AUC = 0.78 versus AUC = 0.68 for the expert-selected variables). Predictive models utilizing variables measured at admission can accurately predict PICH, confirmed by the 6-hour follow-up hCT. Our best-performing models must now be externally validated in a separate cohort of TBI patients with low GCS and initial hCT positive for hemorrhage.

**Keywords:** machine learning; progression of hemorrhage; traumatic brain injury.

# Whole blood versus balanced resuscitation in massive hemorrhage: six of one or half dozen of the other?

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## Abstract

**Introduction:** Whole blood (WB) resuscitation is increasingly used at trauma centers. Prior studies investigating outcomes in WB versus component-only (CO) resuscitation have been limited by small cohorts, low volumes of WB resuscitation, and unbalanced CO resuscitation. This study aimed to address these limitations using data from a high-volume Level I trauma center, which adopted a WB-first resuscitation paradigm in 2018. We hypothesized that the resuscitation method, WB or balanced CO, would have no impact on patient mortality.

**Methods:** A single-center, retrospective cohort study of adults presenting as a trauma activation from July 2016 through July 2021 was performed. Receipt of 3 or more units of WB or packed red blood cells (RBC) within the first hour of resuscitation was required for inclusion. Patients were grouped into WB versus CO resuscitation and important clinical outcomes were compared. Mortality was evaluated with Kaplan-Meier analysis, log-rank testing, and multivariable Cox proportional hazards modeling.

**Results:** There were 180 patients in the WB group and 170 patients in the CO group. Of the 180 WB patients, 110 (61%) received only WB during the first 24 hours. The WB group received a median of 5.0 units (IQR 4.0-8.0) of WB and CO group received a median of 6.0 units (IQR 4.0-11.8) of RBCs during the first 24 hours of resuscitation. In the CO group, median RBC/plasma and RBC/platelet ratios approximated 1:1:1. Groups were similar in clinicopathologic characteristics including age, injury severity score, mechanism of injury, and requirement for hemorrhage control interventions (WB 55% vs CO 59%,  $p = 0.60$ ). Unadjusted survival was equivalent at 24 hours ( $p = 0.52$ ) and 30 days ( $p = 0.70$ ) between both groups on Kaplan-Meier analysis with log-rank testing. On multivariable Cox regression, WB resuscitation was not independently associated with improved survival after accounting for age, ISS, mechanism of injury, and receipt of hemorrhage control procedure (HR 0.85, 95% CI 0.61-1.19,  $p = 0.34$ ).

**Conclusions:** Balanced CO resuscitation is associated with similar mortality outcomes to that of WB based resuscitation.



# Whole Blood and Blood Component Resuscitation in Trauma: Interaction and Association with Mortality

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## Abstract

**Objective:** Evaluate the interaction between whole blood (WB) and blood component resuscitation in relation to mortality following trauma.

**Summary background data:** WB is increasingly available in civilian trauma resuscitation, and it is typically transfused concomitantly with blood components. The interaction between WB and blood component transfusions is unclear.

**Methods:** Adult trauma patients with a shock index  $>1$  who received  $\geq 4$  combined units of red blood cells (RBC) or WB within 4 hours across 501 United States trauma centers were included using the American College of Surgeons Trauma Quality Improvement Program (ACS-TQIP) database. The associations between 1)WB resuscitation and mortality, 2)WB to total transfusion volume ratio (WB:TTV) and mortality, 3)balanced blood component transfusion in the setting of combined WB and component resuscitation and mortality were evaluated with multivariable analysis.

**Results:** A total of 12,275 patients were included (WB: 2,884 vs. component-only: 9,391). WB resuscitation was associated with lower odds of 4-hour (adjusted odds ratio [aOR]: 0.81 [0.68-0.97]), 24-hour, and 30-day mortality compared to component-only. Higher WB:TTV ratios were significantly associated with lower 4-hour, 24-hour, and 30-day mortality, with a 13% decrease in odds of 4-hour mortality for each 10% increase in the WB:TTV ratio (0.87 [95%CI:0.80 - 0.94]). Balanced blood component transfusion was associated with significantly lower odds of 4-hour (aOR: 0.45 [95%CI: 0.29 - 0.68]), 24-hour, and 30-day mortality in the setting of combined WB and blood component resuscitation.

**Conclusions:** WB resuscitation, higher WB:TTV ratios, and balanced blood component transfusion in conjunction with WB were associated with lower mortality in trauma patients presenting in shock requiring 4 units of RBC and/or WB transfusion within 4 hours of arrival.

# Quantifying the benefit of whole blood on mortality in trauma patients requiring emergent laparotomy

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## Abstract

**Background:** Whole blood (WB) transfusions in trauma represent an increasingly utilized resuscitation strategy in trauma patients. Previous reports suggest a probable mortality benefit with incorporating WB into massive transfusion protocols. However, questions surrounding optimal WB practices persist. We sought to assess the association between the proportion of WB transfused during the initial resuscitative period and its impact on early mortality outcomes for traumatically injured patients.

**Methods:** We performed a retrospective analysis of severely injured patients requiring emergent laparotomy and  $\geq 3$  units of red blood cell containing products (WB or packed red blood cells) within the first hour from an ACS Level 1 Trauma Center (2019-2022). Patients were evaluated based on the proportion of WB they received compared to packed red blood cells during their initial resuscitation (high ratio cohort  $\geq 50\%$  WB vs low ratio cohort  $< 50\%$  WB). Multilevel Bayesian regression analyses were performed to calculate the posterior probabilities and risk ratios (RR) associated with a WB predominant resuscitation for early mortality outcomes.

**Results:** 266 patients were analyzed (81% male, mean age of 36 years old, 61% penetrating injury, mean ISS of 30). The mortality was 11% at 4-hours and 14% at 24-hours. The high ratio cohort demonstrated a 99% (RR 0.12; 95% CrI 0.02-0.53) and 99% (RR 0.22; 95% CrI 0.08-0.65) probability of decreased mortality at 4-hours and 24-hours, respectively, compared the low ratio cohort. There was a 94% and 88% probability of at least a 50% mortality relative risk reduction associated with the WB predominate strategy at 4 hours and 24 hours, respectively.

**Conclusion:** Preferential transfusion of WB during the initial resuscitation demonstrated a 99% probability of being superior to component predominant resuscitations with regards to 4 and 24-hour mortality suggesting that WB predominant resuscitations may be superior for improving early mortality. Prospective, randomized trials should be sought.

# Does an early, balanced resuscitation strategy reduce the incidence of hypofibrinogenemia in hemorrhagic shock?

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Affiliations expand

## Abstract

**Objectives:** Some centers have recommended including concentrated fibrinogen replacement in massive transfusion protocols (MTPs). Given our center's policy of aggressive early balanced resuscitation (1:1:1), beginning prehospital, we hypothesized that our rates of hypofibrinogenemia may be lower than those previously reported.

**Methods:** In this retrospective cohort study, patients presenting to our trauma center November 2017 to April 2021 were reviewed. Patients were defined as hypofibrinogenemic (HYPOFIB) if admission fibrinogen <150 or rapid thrombelastography angle <60. Univariate and multivariable analyses assessed risk factors for HYPOFIB. Inverse probability of treatment weighting analyses assessed the relationship between cryoprecipitate administration and outcomes.

**Results:** Of 29 782 patients, 6618 level 1 activations, and 1948 patients receiving emergency release blood, <1%, 2%, and 7% were HYPOFIB. HYPOFIB patients were younger, had higher head Abbreviated Injury Scale value, and had worse coagulopathy and shock. HYPOFIB had lower survival (48% vs 82%,  $p<0.001$ ), shorter time to death (median 28 (7, 50) vs 36 (14, 140) hours,  $p=0.012$ ), and were more likely to die from head injury (72% vs 51%,  $p<0.001$ ). Risk factors for HYPOFIB included increased age (OR (95% CI) 0.98 (0.96 to 0.99),  $p=0.03$ ), head injury severity (OR 1.24 (1.06 to 1.46),  $p=0.009$ ), lower arrival pH (OR 0.01 (0.001 to 0.20),  $p=0.002$ ), and elevated prehospital red blood cell to platelet ratio (OR 1.20 (1.02 to 1.41),  $p=0.03$ ). Among HYPOFIB patients, there was no difference in survival for those that received early cryoprecipitate (within 2 hours; 40 vs 47%;  $p=0.630$ ). On inverse probability of treatment weighted analysis, early cryoprecipitate did not benefit the full cohort (OR 0.52 (0.43 to 0.65),  $p<0.001$ ), nor the HYPOFIB subgroup (0.28 (0.20 to 0.39),  $p<0.001$ ).

**Conclusions:** Low rates of hypofibrinogenemia were found in our center which treats hemorrhage with early, balanced resuscitation. Previously reported higher rates may be partially due to unbalanced resuscitation and/or delay in resuscitation initiation. Routine empiric inclusion of concentrated fibrinogen replacement in MTPs is not supported by the currently available data.