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Critical Care Update

Toward Zero Preventable Deaths

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Recent military conflicts have led to enhanced civilian trauma care through lessons learned. Because of concerns regarding the maintenance of civilian and military trauma care preparedness, a recent conference proposed reinvigorated collaboration between the civilian and military trauma systems. A synopsis of these comments is provided in this article.

The release of the statement favoring collaboration between military and civilian trauma programs coincides with multiple published summaries of recent military trauma research. Articles selected from this collection, published in *Shock*, are summarized here.

Berwick DM, Downey AS, Cornett EA. A national trauma care system to achieve zero preventable deaths after injury, recommendations from a National Academies of Sciences, Engineering, and Medicine report. *JAMA*. 2016;316:927-928.

Stewart RM, Jenkins DH, Winchell RJ, Rotondo MF. ACS Committee on Trauma pledges to make zero preventable deaths a reality. *Bulletin of the American College of Surgeons*. 2016;101:23-28.

The National Academies of Sciences, Engineering, Medicine. *A National Trauma System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury.* Washington, DC: The National Academies Press; 2016.

In the United States, trauma is the third leading cause of death and accounts for more years of life lost than any other cause. During the most recent military conflicts in Afghanistan and Iraq, the percentage of wounded service members who died of their injuries reached an all-time low of 9.3% compared with 23% during the Vietnam War. This improvement has been attributed to advances in hemorrhage control, improved resuscitation techniques, and aggressive neurocritical care interventions. Many of these advances were made via continuous performance improvement and *focused empiricism*. Questions have arisen regarding the use of knowledge gained in the military during combat by the civilian sector and how to maintain military trauma readiness for future combat operations. The National Academies of Science, Engineering, and Medicine Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector released a report this spring calling for the development of a national trauma system with the aim of achieving zero preventable deaths after injury and minimizing trauma-related disability. The complete document, cited earlier, calls for coordination between trauma provider organizations, the Secretary of Defense, the Defense Health Agency, and the US Department of Health and Human Services to establish stable, long-term support of a national trauma system from point of injury to rehabilitation and post-acute care.

Elements needed for an effective learning trauma care system include 1) leadership and a culture of learning via the integration of military and civilian trauma care, 2) examination of the entire patient experience from prehospital resuscitation to long-term outcomes, 3) coordinated performance improvement and research to generate best trauma care practices, 4) timely dissemination of trauma knowledge with real-time access to high-quality information, 5) transparency and incentives for quality trauma care with provider access to performance data, and 6) systems for ensuring an expert trauma care workforce by integrating military and civilian trauma centers as a platform to train and sustain the trauma care provider community.

As Donald Berwick, MD, Chair of the National Academies of Science, Engineering, and Medicine Committee on Military Trauma Care's Learning Health System and Its Translation to the Civilian Sector stated,

> "Both the military and civilian sectors have made impressive progress and important innovations in trauma care, but there are serious limitations in the diffusion of these gains from location to location…the successes have saved many lives; the disparities have cost many lives. With the decrease in combat and the need to maintain readiness for trauma care between wars, a window of opportunity now exists to integrate military and civilian trauma systems and view them not separately, but as one."

Recently, *Shock* published a supplement containing military trauma research. Studies include a range of basic science and clinical research. Some of that work is highlighted here, focusing on improved parameters for the early recognition of hemorrhage and initial treatment with junctional tourniquets and hemostatic agents. The optimal use of blood products also continues to be of widespread interest to civilian and military investigators.

Joseph B, Haider A, Ibraheem K, et al. Revitalizing vital signs: the role of the delta shock index. *Shock*. 2016;46(suppl 1):50-54.

The trimodal distribution of trauma deaths has been well described, with the majority of preventable early trauma deaths attributed to hemorrhage. Early identification of hemorrhagic shock is essential for survival; however, standard vital sign monitoring with heart rate (HR) and systolic blood pressure (SBP) may be

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falsely reassuring in a compensating patient. The shock index (SI), a ratio of HR and SBP, has been proposed as a better predictor of hemorrhagic shock than HR or SBP alone. A normal SI value is less than 0.7, with an SI greater than 1 considered a predictor of hemodynamic instability. However, there are subsets of patients in whom hypovolemia may not elevate the SI, namely, those with pseudohypertension and those who present with relative bradycardia. In these patients, a change from the field SI to the emergency department (ED) SI may better identify hemorrhage. It was hypothesized that a rise in the SI or a positive delta SI would predict a higher mortality than an unchanged or negative (decreasing) delta SI.

The authors performed a 2-year review (2011-2012) of the National Trauma Data Bank. Trauma patients aged 18 to 85 years with an Injury Severity Score (ISS) of 16 or above were included. Field and ED SI values were calculated based on documented emergency medical services and ED measurements of HR and SBP. The delta SI was calculated by subtracting the field SI from the ED SI. A total of 95,088 patients were included with a mean age of 46.2 years and a median ISS of 22. Seventy-two percent were male. Patients with a positive delta SI were more likely to be hypotensive and tachycardic in the ED and less likely to have been tachycardic and hypotensive in the field. They were also more likely to require exploratory laparotomy. The mortality rate for all patients was 11.9%, with patients with a positive delta SI having a higher mortality than those with an unchanged or negative delta SI ($P < .001$). Patients with a delta SI greater than 0.1 had a mortality rate of 16.6% versus 9.5% in patients with a delta SI of 0.1 or less ($P < .001$). After stratifying patients based on blunt versus penetrating injury, a delta SI more than 0.1 was still associated with an increased hazard ratio of death. This association remained after stratifying patients based on age, sex, ISS, and Glasgow Coma Score.

This study shows that delta SI may be a helpful tool for the identification of subtle hemodynamic instability that may be missed using traditional vital signs. This is particularly important in patients who have apparently normal hemodynamics because of pseudohypertension or medication-induced bradycardia but are suffering from occult hypoperfusion. There are limitations of this study as a retrospective review, particularly missing data regarding prehospital treatment and the use of medications that could affect vital sign response. However, this article shows a novel and easy to calculate parameter that may be used to identify occult hypovolemic shock and those trauma patients at higher risk of death.

Stewart CL, Mulligan J, Grudic GZ, Talley ME, Jurkovich GJ, Moulton SL. The Compensatory Reserve Index following injury: results of a prospective clinical trial. *Shock*. 2016;46(suppl 1):61-67.

Photoplethysmographic waveforms have been shown to change shape in the setting of acute volume loss before changes in traditional vital sign measurements. Waveform data were collected during simulated hemorrhage models and used to create a *smart algorithm*, the Compensatory Reserve Index (CRI). The value of CRI is defined as $1 - (BLV/BLV_{HDD})$ where BLV represents current blood loss volume and BLV_{HDD} is the volume of blood loss at which a patient will experience hemodynamic decompensation (defined as systolic blood pressure < 80 mm Hg, changes in vision, or discomfort resulting in termination of a testing protocol used to generate calibration data). The CRI can be thought of as the percentage of physiologic reserve and is estimated by analyzing waveforms over a 30-beat window. The algorithm has previously been validated in healthy volunteers donating blood.

The CRI was evaluated in 47 trauma patients presenting to the Denver Health Emergency Department. Patients were categorized on arrival as actively bleeding, indeterminate bleeding, or not actively bleeding. For simplicity of comparison, the 3 patients classified as indeterminate were excluded, leaving 44 patients for analysis. The average initial CRI was calculated over the first 5 minutes and compared with prehospital HR and BP, initial HR and BP in the trauma bay, initial SI, and initial laboratory data. The initial CRI for bleeding patients was 0.17 (95% confidence interval [CI], 0.13-0.22) and on average decreased the hour after administration of each liter of crystalloid (CRI = −0.02; 95% CI, −0.05 to 0.01) or unit of blood (CRI = −0.04; 95% CI, −0.08 to −0.01). In nonbleeding patients, the initial CRI was higher (0.56; 95% CI, 0.49-0.62; $P < .001$) and increased in the hour after each liter of crystalloid (0.05; 95% CI, −0.05 to 0.14) or after each unit of blood. The average change in CRI after fluid and blood administration had a narrower range in bleeding patients compared with nonbleeding patients and did not reach significance ($P = .06$). Bleeding patients were more likely to have long bone fractures and pelvic fractures (33% vs. 0%, $P = .001$), have a positive Focused Assessment with Sonography in Trauma examination (41.7% vs. 3.1%, $P = .001$), require urgent operation (91.7% vs. 15.6%, $P < .001$), and require admission to the intensive care unit (100% vs. 15.6%, $P < .001$). Bleeding patients were more likely to receive blood transfusions within the first hour (25% vs. 3.1%, $P = .03$) and received higher volumes of crystalloid (2.3 vs. 1.3 L, $P = .007$). The early identification of bleeding patients and their magnitude of reserve to compensate for blood loss provides an opportunity to improve and expedite care in critically injured and bleeding patients.

This work with the CRI represents a long-standing interest of military researchers. The use of computational resources makes this work attractive. However, the usefulness of a data-intensive approach to patient management requires validation in remote settings and as a part of standard urban trauma care.

Gerhardt RT, Glassberg E, Holcomb JB, Mabry RL, Schreiber MB, Spinella PC. Tactical Study of Care Originating in the Prehospital Environment (TACSCOPE): acute traumatic coagulopathy on the contemporary battlefield. *Shock*. 2016;46(suppl 1):104-107.

Along with hemorrhage control, recent evidence supports the expanded use of blood products and procoagulant pharmaceuticals in prehospital combat care to prevent or delay the onset of acute traumatic coagulopathy (ATC). A retrospective cohort study was performed to analyze US combat casualties from the Department of Defense Trauma Registry to determine the incidence, epidemiologic and clinical characteristics, and the effect of ATC on survival outcomes. The data set included all casualties from October 1, 2007, to June 30, 2011. Data were collected on demographics, mechanism of injury, vital signs, ISS, complete blood count, prothrombin time, international normalized ratio (INR), serum pH, and quantities of blood transfused. ATC was defined as an INR greater than or equal to 1.5. Massive transfusion (MT) was defined as 10 or more units of packed red blood cells (PRBCs) administered in the first 24 hours after presentation. Eight thousand nine hundred twelve cases were available for analysis. Of these, 4,543 (51%) had complete data available for analysis. Of the excluded cases, 98.9% survived, the average ISS was 7, and less than 1% received MT. In the 4,543 included cases, 98.5% survived, the average ISS was 10, the average INR was 1.16, and 2.7% received MT. A total of 383 cases (8.4%) met criteria for ATC with an INR > 1.5. ATC cases had a higher ISS (15 vs. 9, $P < .01$) and were more likely to die than non-ATC cases (odds ratio = 28; 95% CI, 16-48). ATC cases were more likely to be victims of blast and penetrating injuries and