Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rhee, MD, FACS, Jay Johannigman, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Sumeru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, Greg J. Beilman, MD, FACS, Martin Schreiber, MD, FACS, Stephen F. Flaherty, MD, FACS, Kurt W. Grathwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beekley, MD, FACS, Neil R. McMullin, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dubick, PhD, C. William Schwab, MD, FACS, Fred A. Moore, MD, FACS, Howard R. Champion, FRCS, FRCA, RAMC, Sumeru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, FACS, and John R. Hess, MD, MPH, FACP

Rapid progress in trauma care occurs when the results of translational research are promptly integrated into clinical practice. Experience with a high volume of severely injured casualties expedites the process.1 Historically, these conditions have converged during times of conflict, improving the care of combat casualties and subsequently that of civilian trauma patients.1,2

In the most severely injured casualties, we know that when the lethal triad of hypothermia, acidosis, and coagulopathy are present, death is imminent.3 Current teaching is to avoid reaching these conditions by using “damage control surgery.”4–6 However, conventional resuscitation practice for damage control focuses on rapid reversal of acidosis and prevention of hypothermia, and surgical techniques focus on controlling hemorrhage and contamination. Direct treatment of coagulopathy has been relatively neglected, viewed as a byproduct of resuscitation, hemodilution, and hypothermia, and delayed by blood banking logistics. Damage control resuscitation addresses the entire lethal triad immediately upon admission to a combat hospital.7,8

By demonstrating that in the severely injured the coagulopathy of trauma is present at admission, recent studies have brought back to light the importance of treating this disorder at an earlier stage.9–12 Reports of lactated Ringer’s solution and normal saline increasing reperfusion injury and leukocyte adhesion lead one to conclude that the standard crystalloid-based resuscitation guidelines in prehospital trauma life support (PHTLS) and advanced trauma life support (ATLS) may worsen the presenting acidosis and coagulopathy in severely injured trauma patients, and possibly increase ARDS, SIRS, and MOF.13–17 The safety of withholding PRBCs in hemodynamically stable patients has been demonstrated,18 and the risks associated with blood transfusion are well described.19,20 Further, massive transfusion in military and civilian casualties has been associated with an increased risk of death.21–23 Taken together, these observations suggest that the most severely injured may need a resuscitative approach tailored specifically to their needs. However, even in the largest civilian academic trauma centers, patients with injuries at the outer limits of survivability, such as those massively transfused with more than 10 units of RBCs in the first 24 hours, are uncommon and constitute only 1% to 2% of the patient population, making it difficult to develop and test new resuscitation concepts.21 Because 7% of combat casualties require massive transfusion, we have had just such an opportunity to observe the effects of new resuscitation strategies in the combat hospitals of Iraq and Afghanistan.

The military munitions used in Southwest Asia can inflict severe multisystem injuries on both combatants and civilians. These patients frequently present to American military medical personnel shortly after being wounded. Unlike civilian systems, where treatment of coagulopathy is often limited by standard blood bank logistics, in Iraq we frequently have immediate access to PRBCs and thawed AB or A plasma, and rapid access to apheresis platelets, prepooled cryoprecipitate, fresh whole blood, and rFVIIa, as indicated.24–29 Thus, the opportunity to formally evaluate the immediate and direct treatment of the coagulopathy of trauma is available.

Volume 62 • Number 2

DOI: 10.1097/TA.0b013e3180324124

**Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma**

**U.S. Army Institute of Surgical Research (USAISR), 3400 Rawley E. Chambers Avenue, Fort Sam Houston, TX, 78234-6315**

**Approved for public release; distribution unlimited**

**Same as Report (SAR)**

**Number of Pages**: 4

**Security Classification of**: Unclassified

**Abstract**

**Limitation of Abstract**

**Name of Responsible Person**
The trauma patients who are most severely injured (approximately 10%) also represent the majority of in-hospital trauma deaths. Considerable attention has been directed toward the technical details of damage control surgery and reversing the acidosis and hypothermia present at admission. Less attention has been directed toward reversing the coagulopathy related to blood loss that is present at the same time. Clinical experience in Operation Iraqi Freedom and Operation Enduring Freedom suggests that coagulopathy may be present at the time of admission before significant resuscitative fluid has been given, as a consequence of acidosis-induced coagulation factor dysfunction, coagulation factor consumption, and hypothermia-induced failure of platelet activation. Failure to recognize and immediately address the coagulopathy found in severely injured patients can be linked to several factors. Most studies of trauma-induced coagulopathy have measured the laboratory changes that happen in the OR or ICU after dilution with crystalloid and PRBCs, and have concluded that the coagulopathy could be fully explained by the resuscitation and/or hypothermia.50

The goal of shock resuscitation efforts in the past has been largely to support blood pressure and urine output and to reverse the metabolic derangements associated with the ischemia associated with acute blood loss.31,32 Although these goals are obviously important, the studies supporting this concept were based on controlled animal hemorrhage studies, and the results were not evaluated in randomized human trials.33–35 Additionally, the potential benefits of mitigating ischemia-induced reperfusion injury after standard crystalloid resuscitation were not fully recognized.14,36 Furthermore, recent resuscitation studies have overlooked the importance of an integrated and coherent prehospital, ED, OR, and ICU shock resuscitation plan that incorporates intravascular treatment of coagulopathy.32,37 Finally, the current generation of clinicians has been taught to not use plasma as a resuscitation fluid.38 We agree that current standard resuscitation methods are appropriate policy for the approximately 90% of trauma patients who are not in shock and are hypercoagulable after injury.39–42 However, for the approximately 10% of casualties who constitute the most seriously injured, are in shock and coagulopathic, and represent the potentially preventable hemorrhagic deaths, liquid plasma may be the optimal resuscitation fluid currently available.43–50

Based on (1) previous civilian clinical studies, (2) the recommendations of an international consensus conference on early massive transfusion for trauma,45 and (3) considerable experience in the current war, we think patients at high risk for coagulopathy can be readily identified at admission and prompt simultaneous treatment of hypothermia, acidosis, and coagulopathy initiated. Hypothermia, an independent factor for increased mortality in trauma patients, was an earlier focus for active prevention and treatment,52–54 but application of training and equipment recommendations of the Committee on Tactical Combat Casualty Care and the Joint Theater Trauma System has made it an uncommon finding.55 Acidos-
observations cause us to question further the use of excessive crystalloid resuscitation and to begin to formulate hypotheses that can be tested to demonstrate beneficial effects of preemptive control of coagulopathy.1,2

For the first time in US warfare, data for all admitted trauma casualties in the current conflict in Southwest Asia are entered into a joint theater trauma registry (JTTR).64 A deployed combat research team is being sent into theater for the first time since Vietnam, operating under the same standards of IRB approval as practiced in the United States. Data collected by this team, along with outcome data from the JTTR, will allow an analysis of the effects of resuscitation with thawed plasma, fresh whole blood, administration of rFVIIa, and limited crystalloid. Additionally, focused effort will be required to describe the mechanisms causing the early coagulopathy of trauma present at admission. The clinical effects and consequences of damage control resuscitation will be measurable in patient outcomes. We will know if we are saving more severely injured soldiers, if reducing coagulopathy and edema leads to better outcomes, and, ultimately, whether we are creating more blood exposure or less. We will soon have sufficient data to assess the full benefits of damage control resuscitation in the population of critically injured for whom it matters most. As in the past, perceptive observation, thoughtful discussion, and insightful analysis concerning medical care during war from experienced military medics, surgeons, and scientists, in concert with our civilian colleagues, will generate recommendations for new and improved medical practice, with continuous modification as further experience, research, and development produce new and relevant information.1,2

REFERENCES


