

Damage Control Resuscitation

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J Trauma. 2007;62:S36–S37.

While the vast majority of bleeding trauma patients who arrive in emergency departments are either hypercoagulable or only slightly injured with normal coagulation parameters, a small segment of trauma patients (~10%) are hypocoagulable. This small segment of severely injured patients comprises the majority of in-hospital trauma deaths. They are frequently hypothermic with acidosis and hypothermia-induced coagulation factor and platelet dysfunction, combined with coagulation factor consumption, and culminating in a profound coagulopathy. The most severely injured are more coagulopathic. Though it has long been recognized that the lethal triad of hypothermia, acidosis and coagulopathy is associated with a significant increase in mortality,¹ coagulopathy has been viewed as a byproduct of resuscitation, hemodilution and hypothermia. We know now that coagulopathy is in fact present on admission.

Current resuscitation practice focuses primarily on rapid reversal of acidosis and prevention of hypothermia while concurrent surgical interventions focus on controlling hemorrhage and contamination. Thus, early treatment of coagulopathy has been relatively ignored. Standard resuscitation methods are an appropriate policy for the ~90% of trauma patients who are not in shock and are hypercoagulable after injury.^{2,3} However, for the 10% of patients who constitute the most seriously injured, are in shock, and coagulopathic, *liquid plasma* has been identified as the best resuscitation fluid.^{4–8} Unfortunately, clinicians are still being taught to never use plasma as a resuscitation fluid.⁹

Recent studies have shown that 1) the coagulopathy of trauma is present at a very early stage after injury,^{5,6,10–12} 2) Ringer's lactate and normal saline increase reperfusion injury and leukocyte adhesion,^{13–17} 3) increased transfusion is associated with increased risks,^{18–20} and 4) massive transfusion in military and civilian casualties are associated with an increased risk of death.^{21–23} Taken together, these observations suggest that the most severely injured patients will likely benefit from a new resuscitation strategy focused on optimal timing and modulation of the metabolic, inflammation and coagulation pathways.

Over the last 4 years I have served as a consultant and surgeon in military surgical facilities in Iraq. Based on 1) previous civilian clinical studies, 2) the recommendations of an international consensus conference on early massive transfusion for trauma,²⁴ and 3) the cumulative experience of medical experts in the current war, we now believe it is possible to rapidly identify patients at high risk for coagulopathy at admission and promptly, aggressively and simultaneously treat hypothermia, acidosis and coagulopathy. The technique to achieve this, developed by clinicians in theater and known as “damage control resuscitation,” addresses the entire lethal triad immediately upon admission in concert with aggressive hemostatic interventions. Damage control resuscitation as a structured intervention currently begins immediately after rapid initial assessment in the emergency department and progresses through the OR into the ICU. By repeated point of care testing, commercial warming devices and the use of multiple blood products and FDA-approved drugs readily available in theater, (albeit in new ratios and amounts), all efforts are directed toward normalizing the INR, base deficit and temperature. Compared with civilian damage control surgery patients, resuscitation efforts are largely completed in the OR, with little resuscitation required in the ICU. Achieving this goal quickly in the OR may ultimately allow a shift from limited damage control surgery to earlier aggressive surgical interventions, including sophisticated limb salvage techniques and improved outcomes.

Damage control resuscitation consists of two parts and is initiated within minutes of arrival in the emergency department. First, resuscitation is limited to keep blood pressure at ~90 mm Hg, preventing renewed bleeding from recently clotted vessels.^{16,17,25–31} Second, intravascular volume restoration is accomplished by using thawed plasma as a primary resuscitation fluid in at least a 1:1 ratio with PRBCs.^{32–34} Recombinant FVIIa is used along with the very first units of red cells and plasma and as required throughout the resuscitation.³⁵ For casualties who will require continued resuscitation, the blood bank is notified to activate the massive transfusion protocol. This protocol results in the delivery of 6 units of plasma, 6 units of PRBCs, 6 packs of platelets and 10 units of cryoprecipitate stored in individual coolers.³³ Finally, for the most severely injured, fresh warm whole blood from the walking blood bank is used as a primary resuscitative fluid.^{36,37} Crystalloid use is significantly limited and serves mainly as a carrier to keep lines open between the units of blood products.³⁸

Progress in trauma care requires continuous improvement in everyday patient management, based on good clinical studies. Many of our most basic trauma care principles (the ABCs) are

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This article was written for the proceedings from a conference entitled *12th Annual San Antonio Trauma Symposium* in San Antonio, Texas. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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DOI: 10.1097/TA.0b013e3180654134

founded on tradition rather than evidenced-based best practice, leading us to frequently question the status quo. Current resuscitation practices of severely injured patients fall into this category. As in past wars, observation, discussion, analysis and recommendations from experienced military medics, nurses, physicians and scientists together with our civilian trauma colleagues will provide the basis for new medical practice, grounded in appropriate and relevant pre-clinical and human studies. Further experience, research and development will generate new information and ongoing modifications.^{39,40}

REFERENCES

- Moore EE, Thomas G. Orr Memorial Lecture. Staged laparotomy for the hypothermia, acidosis, and coagulopathy syndrome. *Am J Surg*. 1996;172:405–410.
- Kiraly LN, Differding JA, Enomoto TM, et al. Resuscitation with normal saline (NS) vs. lactated ringers (LR) modulates hypercoagulability and leads to increased blood loss in an uncontrolled hemorrhagic shock swine model. *J Trauma*. 2006;6:57–64, discussion 64–55.
- Watts J. Fluid resuscitation with colloid or crystalloid solutions. Comparing different studies is difficult. *BMJ*. 1998;317:277, author reply 279.
- Barbee RW, Kline JA, Watts JA. A comparison of resuscitation with packed red blood cells and whole blood following hemorrhagic shock in canines. *Shock*. 1999;12:449–453.
- Hirshberg A, Dugas M, Banez EI, et al. Minimizing dilutional coagulopathy in exsanguinating hemorrhage: a computer simulation. *J Trauma*. 2003;54:454–463.
- Ho AM, Dion PW, Cheng CA, et al. A mathematical model for fresh frozen plasma transfusion strategies during major trauma resuscitation with ongoing hemorrhage. *Can J Surg*. 2005;48:470–478.
- Mohr R, Goor DA, Yellin A, et al. Fresh blood units contain large potent platelets that improve hemostasis after open heart operations. *Ann Thorac Surg*. 1992;53:650–654.
- Traverso LW, Hollenbach SJ, Bolin RB, et al. Fluid resuscitation after an otherwise fatal hemorrhage: II. Colloid solutions. *J Trauma*. 1986;26:176–182.
- Practice guidelines for perioperative blood transfusion and adjuvant therapies: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Transfusion and Adjuvant Therapies. *Anesthesiology*. 2006;105:198–208.
- Brohi K, Singh J, Heron M, et al. Acute traumatic coagulopathy. *J Trauma*. 2003;54:1127–1130.
- Faringer PD, Mullins RJ, Johnson RL, et al. Blood component supplementation during massive transfusion of AS-1 red cells in trauma patients. *J Trauma*. 1993;34:481–485, discussion 485–487.
- MacLeod JB, Lynn M, McKenney MG, et al. Early coagulopathy predicts mortality in trauma. *J Trauma*. 2003;55:39–44.
- Ayuste EC, Chen H, Koustova E, et al. Hepatic and pulmonary apoptosis after hemorrhagic shock in swine can be reduced through modifications of conventional Ringer's solution. *J Trauma*. 2006;60:52–63.
- Coimbra R, Hoyt DB, Junger WG, et al. Hypertonic saline resuscitation decreases susceptibility to sepsis after hemorrhagic shock. *J Trauma*. 1997;42:602–606, discussion 606–607.
- Cotton BA, Guy JS, Morris JA Jr, et al. The cellular, metabolic, and systemic consequences of aggressive fluid resuscitation strategies. *Shock*. 2006;26:115–121.
- Rhee P, Koustova E, Alam HB. Searching for the optimal resuscitation method: recommendations for the initial fluid resuscitation of combat casualties. *J Trauma*. 2003;54(Suppl 5):S52–62.
- Rhee P, Wang D, Ruff P, et al. Human neutrophil activation and increased adhesion by various resuscitation fluids. *Crit Care Med*. 2000;28:74–78.
- Hebert PC, Wells G, Blajchman MA, et al. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. Transfusion Requirements in Critical Care Investigators, Canadian Critical Care Trials Group. *N Engl J Med*. 1999;340:409–417.
- Malone DL, Dunne J, Tracy JK, et al. Blood transfusion, independent of shock severity, is associated with worse outcome in trauma. *J Trauma*. 2003;54:898–905, discussion 905–897.
- Sheppard FR, Moore EE, Johnson JL, et al. Transfusion-induced leukocyte IL-8 gene expression is avoided by the use of human polymerized hemoglobin. *J Trauma*. 2004;57:720–724, discussion 724–725.
- Como JJ, Dutton RP, Scalea TM, et al. Blood transfusion rates in the care of acute trauma. *Transfusion*. 2004;44:809–813.
- Eastridge BJ, Malone D, Holcomb JB. Early predictors of transfusion and mortality after injury: a review of the data-based literature. *J Trauma*. 2006;60(Suppl 6):S20–25.
- Hoyt DB. A clinical review of bleeding dilemmas in trauma. *Semin Hematol*. 2004;41(Suppl 1):40–43.
- Holcomb JB, Hess JR, et al. Early massive trauma transfusion: current state of the art. *J Trauma*. 2006;60(Suppl 6):S1–59.
- Beecher HK. Preparation of battle casualties for surgery. *Ann Surg*. 1945;21:769–792.
- Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med*. 1994;331:1105–1109.
- Burris D, Rhee P, Kaufmann C, et al. Controlled resuscitation for uncontrolled hemorrhagic shock. *J Trauma*. 1999;46:216–223.
- Cannon WB, Fraser J, Cowell EM. The preventive treatment of wound shock. *JAMA*. 1918;70:618–621.
- Dutton RP, Mackenzie CF, Scalea TM. Hypotensive resuscitation during active hemorrhage: impact on in-hospital mortality. *J Trauma*. 2002;52:1141–1146.
- Holcomb JB. Fluid resuscitation in modern combat casualty care: lessons learned from Somalia. *J Trauma*. 2003;54(Suppl 5):S46–51.
- Sondeen JL, Coppes VG, Holcomb JB. Blood pressure at which rebleeding occurs after resuscitation in swine with aortic injury. *J Trauma*. 2003;54(Suppl 5):S110–117.
- Ketchum L, Hess JR, Hiippala S. Indications for early fresh frozen plasma, cryoprecipitate, and platelet transfusion in trauma. *J Trauma*. 2006;60(Suppl 6):S51–58.
- Malone DL, Hess JR, Fingerhut A. Massive transfusion practices around the globe and a suggestion for a common massive transfusion protocol. *J Trauma*. 2006;60(Suppl 6):S91–96.
- McMullin NR, Holcomb JB, Sondeen JL. Hemostatic resuscitation. In: *Yearbook of Intensive Care and Emergency Medicine 2006*. Berlin Heidelberg: Springer-Verlag 2006:265–278.
- Perkins JP, Schreiber MA, Wade CE, et al. Early versus late rFVIIa in combat trauma patients requiring massive transfusion. *J Trauma* (submitted).
- Kauvar DS, Holcomb JB, Norris GC, et al. Fresh whole blood transfusion: a controversial military practice. *J Trauma*. 2006;61:181–184.
- Repine TB, Perkins JG, Kauvar DS, et al. The use of fresh whole blood in massive transfusion. *J Trauma*. 2006;60(Suppl 6):S59–69.
- Wiedemann HP, Wheeler AP, Bernard GR, et al. Comparison of two fluid-management strategies in acute lung injury. *N Engl J Med*. 2006;354:2564–2575.
- DeBakey ME. The torch that illuminates: lessons from military medicine. *Mil Med*. 1996;161:711–716.
- Pruitt BAJ. Combat casualty care and surgical progress. *Ann Surg*. 2006;243:715–729.