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TACTICAL COMBAT CASUALTY CARE: TRANSITIONING BATTLEFIELD LESSONS LEARNED TO OTHER AUSTERE ENVIRONMENTS

Remote Damage Control Resuscitation in Austere Environments

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Hemorrhage is the leading cause of preventable military and civilian trauma death. Damage control resuscitation with concomitant mechanical hemorrhage control has become the preferred in-hospital treatment of hemorrhagic shock. In particular, plasma-based resuscitation with decreased volumes of crystalloids and artificial colloids as part of damage control resuscitation has improved outcomes in the military and civilian sectors. However, translation of these principles and techniques to the prehospital, remote, and austere environments, known as remote damage control resuscitation, is challenging given the resource limitations in these settings. Rapid administration of tranexamic acid and reconstituted freeze-dried (lyophilized) plasma as early as the point of injury are feasible and likely beneficial, but comparative studies in the literature are lacking. Whole blood is likely the best fluid therapy for traumatic hemorrhagic shock, but logistical hurdles need to be addressed. Rapid control of external hemorrhage with hemostatic dressings and extremity tourniquets are proven therapies, but control of noncompressible hemorrhage (ie, torso hemorrhage) remains a significant challenge.

Keywords: remote damage control resuscitation, hemorrhage, hemorrhagic shock

Introduction

Exsanguination can occur rapidly[1–3] and is the leading cause of potentially preventable civilian[4,5] and combat[6,7] trauma deaths. Optimization of prehospital hemorrhage control and resuscitation therefore are critical,[8,9] especially when transport to a facility capable of definitive hemorrhage control is delayed. “Remote” or “forward” has been proposed to define the prehospital phase of resuscitation, and “austere” or “far-forward” as “the environment where professional health care providers normally do not operate, and basic equipment and capabilities necessary for resuscitation are often not available.”[10] The translation of hospital-based damage control resuscitation (DCR) techniques to remote and austere settings forms the crux of remote damage control resuscitation (RDCR).[11] RDCR is applicable in a wide range of settings: rural, frontier/wilderness, ships at sea, and mass casualty incidents. Given the inherent logistical and resource limitations in these settings, however, translation of DCR to RDCR is challenging.

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DAMAGE CONTROL RESUSCITATION

DEFINITION

DCR with concomitant effort to achieve definitive hemorrhage control is the preferred in-hospital treatment of traumatic hemorrhagic shock. Core principles of DCR include minimization of crystalloid, hemostatic (balanced) resuscitation, and permissive hypotension. Overall, the goal of DCR is to quickly perform maneuvers that promote hemostasis while minimizing (iatrogenic) insults that would exacerbate bleeding.

IMPLEMENTATION OF DCR IN OPERATION IRAQI FREEDOM AND OPERATION ENDURING FREEDOM

Prior to the advent of DCR, clinicians infused large volumes of crystalloid, artificial colloid, and red blood cells (RBCs) for resuscitation of hemorrhagic shock.[12,13] However, this changed after a retrospective study of 246 massively transfused patients treated at a combat support hospital in Iraq found that increasing the plasma:RBC ratio was associated with increased survival (odds ratio [OR], 8.6; 95% confidence interval [CI], 2.1−35.2), primarily by reduced risk of exsanguination.[14]

Based on these data, a subsequent Joint Trauma System clinical practice guideline recommended a 1:1 plasma:RBC ratio for any patient at risk for massive transfusion, which was soon revised to a 1:1:1 plasma: platelet:RBC ratio. A study of Operation Iraqi Freedom/ Operation Enduring Freedom resuscitation practice between 2003 and 2012 found increasing survival over time despite increasing injury severity, which correlated with decreased crystalloid and artificial colloid use and increased plasma:RBC and platelet:RBC ratios.[15]

LESSONS LEARNED: EVIDENCE-BASED BENEFITS OF DCR IN MILITARY AND CIVILIAN SECTORS

In the civilian sector, the prospective, observational, multicenter, major trauma transfusion (PROMMTT) study found that plasma:RBC and platelet:RBC ratios varied significantly over time during active resuscitation of bleeding trauma patients and that increased plasma: RBC and platelet:RBC ratios were associated with decreased 6-hour mortality when risk of exsanguination was greatest.[1] After 6 hours, however, product ratios no longer correlated with mortality as competing risks (eg, traumatic brain injury [TBI]) became more important.

The multicenter pragmatic randomized optimal platelet and plasma ratios trial randomized 680 bleeding civilian trauma patients to resuscitation with 1:1:1 vs 1:1:2 plasma:platelet:RBC ratios.[2] Although 24-hour and 30-day mortality did not differ, the 1:1:1 group had a significantly decreased risk of exsanguination (9 vs 15%) and increased hemostasis (86 vs 78%).

A recent systematic review and meta-analysis that analyzed 5292 patients across 15 studies found that mortality was reduced significantly for patients who received a high (approaching 1:1) vs low (≤1:2) plasma:RBC ratio (31 vs 38%).[16] The mechanism behind this benefit is unclear but likely involves plasma-mediated endothelial repair[17,18] in addition to replacement of volume and clotting factors. The same systematic review also found that mortality was reduced for 1607 patients across 4 studies who received a high vs low platelet:RBC ratio (28 vs 43%).[16] Overall, this supports a 1:1:1 plasma:platelet:RBC ratio for resuscitation of hemorrhagic shock. Increasing volumes of crystalloid, on the other hand, are associated with inflammation (eg, acute respiratory distress syndrome),[19] edema (eg, abdominal compartment syndrome),[20] and mortality.[21]

RDCR

DEFINITION

Hospital-based DCR practices and mechanical hemorrhage control techniques translated into the prehospital, remote, and austere settings are the central tenets of RDCR. However, the resource limitations and logistical restraints inherent in these settings preclude direct application of all DCR principles.

TRANSLATION OF DCR COMPONENTS TO RDCR

Permissive hypotension

In an animal model of uncontrolled hemorrhage, fluid resuscitation induced reproducible rebleeding ("popping the clot") when the mean arterial pressure was increased above 64±2 mm Hg.[22] Several clinical studies have shown either improved outcome[23] or no difference[24,25] in civilian patients randomized to hypotensive vs normotensive resuscitation. However, these studies were performed in urban environments where prehospital transport times were relatively short. In remote and austere environments, permissive hypotension will undoubtedly lead to some accumulation of oxygen debt.

The question of how low and how long hypotension may be allowed to persist remains unresolved but is likely contingent on a number of factors, including baseline health status and injury acuity. Real-time monitoring modalities are limited in the prehospital setting, which has been identified as a critical technological gap.[26] Closing this critical knowledge gap would enable resuscitation to be titrated both to reduce risk of rebleeding and optimize tissue perfusion. Although no such technology currently exists, advances in computer-generated decision support tools utilizing continuous vital sign measures, tissue oxygen saturation monitoring,[27] and serial lactate measurements[28] all have demonstrated promising early results.

Balanced (hemostatic) resuscitation

Plasma is used as the primary volume expander in DCR. Storage conditions and therefore immediate availability of plasma products differ with implications for RDCR.[29] Fresh frozen plasma and thawed plasma are ill suited for RDCR; liquid plasma has fewer constraints, enabling wider use (Table 1).

Freeze-dried (lyophilized) plasma (FDP) has been "rediscovered" as a more suitable plasma product for