Towards Hemostatic Resuscitation

The Changing Understanding of Acute Traumatic Biology, Massive Bleeding, and Damage-Control Resuscitation

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KEYWORDS

• Trauma • Acute traumatic coagulopathy • Coagulation • Bleeding
• Massive transfusion

KEY POINTS

- By the close of the 1990s, severely injured trauma patients were routinely resuscitated with large volumes of salt water and red blood cells with little attention paid to coagulation abnormalities or correcting coagulopathy.
- Acute traumatic coagulopathy (ATC) results from both severe tissue injury and blood loss resulting in shock. ATC has a very high associated mortality.
- ATC is partially mediated by activation of the protein C system. Activated protein C affects coagulopathy by both inhibiting clot formation and de-repressing fibrinolysis.
- Taken together, the recognition of ATC and the benefits of plasma-based resuscitation represent a paradigm shift in the resuscitative conduct after severe trauma.

INTRODUCTION

Transfusion and resuscitation practices in military and civilian trauma have undergone revolutionary shift over the past decade. New understandings of posttrauma physiology and biology have occurred in parallel with the acquisition of new clinical data on resuscitation practices. Together these understandings have radically changed the resuscitation and treatment patterns of severely injured solders and civilians resulting in decreased morbidity and reduced mortality and a fundamental reassessment of both the underlying biology and clinical manifestations of injury and resuscitation.

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Those lucky enough to both clinically practice and conduct research during this period have experienced a true paradigm shift in the understanding of posttrauma biology and physiology and a revolutionary change in the manner in which patients are resuscitated. Together, these have fundamentally changed the way patients, both military and civilian, behave in the operating room (OR), ICU, hospital and after discharge. This article aims to outline the history of resuscitation and transfusion practices in trauma and the changes in the understanding of the biology of coagulation and inflammation as well as clinical data that have driven changes in resuscitative conduct. Finally, the current state of the science (clinical and biological) is examined, suggesting future basic science and clinical investigation that will drive further changes in transfusion and resuscitation in severely injured military personnel and civilian patients.

THE HISTORY OF RESUSCITATION

The history of resuscitation parallels the history of armed conflict and its examination is essential to understanding how trauma resuscitation evolved to the current era. A complete history of trauma resuscitation is far beyond the scope of this article and has been covered well elsewhere.[1,2] Briefly, the modern understanding of resuscitation begins during the early to middle 1900s.[3] Before and continuing through World War I, there was essentially little or no resuscitation after injury. The prevailing belief regarding why injured solders did poorly centered on deleterious mediators (evil humors) and wound toxins. In this era, significant injury most often led to death.

Beginning in World War II, there was an understanding of resuscitation with blood and colloid (albumin) with a resultant increase in early survival.[4] Shock was better understood as an entity; however, there was little understanding of its underlying biology or mechanistic physiology. In keeping with this knowledge deficit, there was no understanding of differential resuscitation of the intravascular and intracellular compartments and, as a result, the reduced early mortality from blood transfusion was often followed by significant organ failure (generally renal and pulmonary failure), infection (if patients lived long enough), and late death. This was in the context of limited forward surgical care; difficult, slow, and often impossible evacuation; and increasing injury severity. Although there were significant advances in forward care, rapid surgical care, and evacuation to formal treatment, the World War II resuscitation paradigm continued through the Korean War.

Further improvements in field triage, forward surgical care, and casualty evacuation continued through the Vietnam Conflict. Additionally, advances in understanding of posttrauma physiology and biology, as well as blood banking, emerged during this time.[3,5] There was now an understanding of intravascular and intercellular physiology. Concurrently, there was, for the first time, the availability of banked blood and plentiful crystalloid. The combined early large-volume blood and crystalloid resuscitation resulted in better early survival and a significant reduction of the organ failure seen during World War II and Korea. Unfortunately, the early survival and reduction in renal failure unmasked a new entity of rapid and devastating pulmonary failure. This new entity, then termed Da Nang lung, now known as acute lung injury (ALI) or acute respiratory distress syndrome (ARDS), manifested as early survival followed by rapid pulmonary collapse.[6]

Through the 1970s and 1980s, two events and paradigms led to a resuscitation regime that was maintained for years. First, the advent of blood banking and component separation eliminated whole blood from the resuscitation supply. Indeed, by the early 1980s, because of resource allocation and cost concerns, the blood supply was converted from whole blood to components.[5,7] Hence, a unit of whole blood was