EMERGENCY CE 1.5 HOURS Continuing Education

Trauma-Related Hemorrhagic Shock: A Clinical Review

Assessment and management of this life-threatening emergency.

ABSTRACT: Optimal management of trauma-related hemorrhagic shock begins at the point of injury and continues throughout all hospital settings. Several procedures developed on the battlefield to treat this condition have been adopted by civilian health care systems and are now used in a number of nonmilitary hospitals. Despite the important role nurses play in caring for patients with trauma-related hemorrhagic shock, much of the literature on this condition is directed toward paramedics and physicians. This article discusses the general principles underlying the pathophysiology and clinical management of trauma-related hemorrhagic shock and updates readers on nursing practices used in its management.

Keywords: hemorrhagic shock, hypovolemia, resuscitation, trauma nursing, traumatic injury

Hemorrhagic shock remains a primary cause of death from traumatic injury.[1] Although nurses—particularly those who work in emergency medical services, trauma centers, and ICUs—are vital to the assessment and successful management of traumatic hemorrhage and subsequent shock, the vast majority of literature on the subject has been directed at paramedics or physicians.[2-8]

In 1908, Marie Louis published an article in *AJN* that discussed the typical signs and symptoms of hemorrhagic shock and the lifesaving interventions nurses should perform in such cases (see https://journals.lww.com/ajnonline/Citation/1908/09000/THE_NURSE_S_MANAGEMENT_OF_SHOCK_AND_HEMORRHAGE.13.aspx).[9] Since that time, the medical community's understanding of hemorrhagic shock and its management has evolved, based in large part on insights gained through military operations in Afghanistan and Iraq.

This article reviews the pathophysiology of hemorrhagic shock and discusses the laboratory studies, diagnostic tests, resuscitation principles, and nursing practices currently incorporated in civilian as well as military settings, many of which are based on procedures established on the battlefield and outlined in the Tactical Combat Casualty Care (TCCC) Guidelines, a set of evidence-based guidelines for providing care to injured patients in a prehospital or battlefield setting.[10]

THE PATHOPHYSIOLOGY OF HEMORRHAGIC SHOCK

Shock occurs when there is an imbalance between oxygen delivery to and consumption by the tissues.[11] Based on its root cause, shock can be classified into one of four subtypes: hypovolemic, cardiogenic, obstructive, or distributive.[12]

Hypovolemic shock occurs when inadequate volume within the vasculature reduces perfusion pressure to insufficient levels. This may result from severe dehydration or blood loss related to medical conditions or traumatic injury. Hypovolemic shock brought on by blood loss is called hemorrhagic shock.

Several compensatory mechanisms activated at the onset of trauma-related hemorrhage maintain

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perfusion to vital organs.[13] Arterial baroreceptors respond to reduced blood volume by activating the sympathetic nervous system and triggering the release of circulatory vasoactive hormones.[14] This sympathetic response constricts peripheral arteries, increases heart rate, and shunts blood to the organs most vital to survival. Both increased vascular resistance and elevated heart rate are important in maintaining organ and tissue perfusion.[15]

If hemorrhage persists, shock follows. When circulatory volume becomes too low to maintain a perfusion pressure adequate to sustain tissue oxygenation, cellular respiration, the process by which cells convert food into usable energy, shifts from aerobic to anaerobic metabolism and lactic acidosis ensues.[11] See Figure 1.

Avoiding acidosis is critical, as it reduces the body's ability to form effective clots.[16] Moreover, the resultant coagulopathy may be exacerbated by hypothermia, which frequently occurs after massive blood loss, secondary to reduced tissue perfusion and oxygenation. In patients treated for trauma, the combination of acidosis, coagulopathy, and hypothermia is frequently referred to as the "trauma triad of death."[17] Multisystem organ failure may follow the triad, leading to extremely high rates of mortality.[18]

Photo by Col. Tyson Becker, Brooke Army Medical Center.

LABORATORY STUDIES

Laboratory measurements play a critical role in the assessment and care of patients following trauma-related hemorrhage. A blood type and screen with crossmatching should be performed immediately so that the blood bank can begin processing any blood products that may be needed for transfusion.

Coagulation parameters, such as prothrombin time (PT) or international normalized ratio (INR), activated partial thromboplastin time (aPTT), fibrinogen, and platelets, provide a means of estimating the severity of a patient's condition.[8] In particular, when the following thresholds are reached, resuscitation with the appropriate blood products (fresh frozen plasma, cryoprecipitate, or platelets, for example) should be initiated to minimize the risk of microvascular bleeding[19]:

- PT, INR, or aPTT more than 1.5 times the normal laboratory value
- platelets less than 50 to 100 × $10^9/L^{-1}$
- fibrinogen concentration less than 1 g/L^{-1}

Thromboelastography (TEG) and rotational thromboelastometry (ROTEM) are novel assays that measure the viscoelastic properties of blood and can be used at the bedside to monitor and manage trauma-induced coagulopathy.[20] Both can provide data that aid in assessing coagulopathy in as few as 15 to 30 minutes.[21, 22]

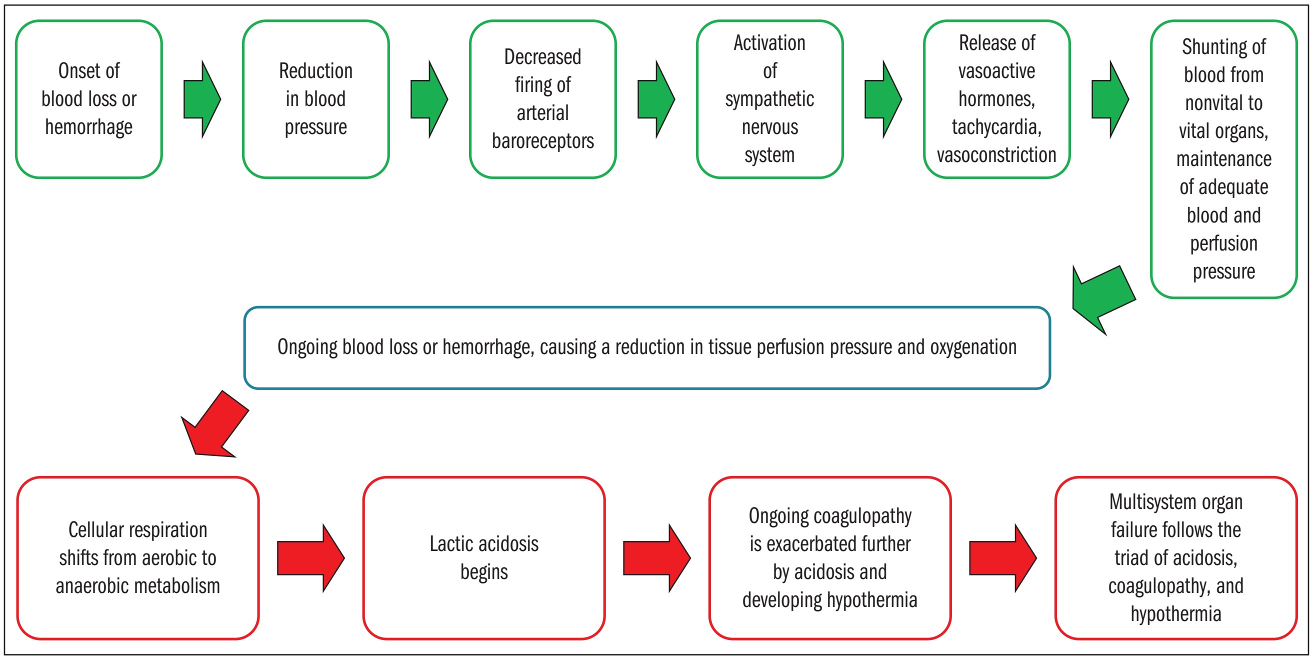
Systemic markers of global tissue perfusion status such as elevated lactate and base deficit or excess have been studied extensively in trauma management and serve both diagnostic and therapeutic purposes. They can be used to detect occult tissue hypoperfusion, which can occur in the presence of normal vital signs.[23-25] Abnormal parameters are greater than 2 mmol/L for elevated lactate, less than –2 for base deficit, and greater than 2 for base excess.[26] Once resuscitation is underway, these markers may be used as end points; delays in normalization are associated with poor outcomes. It's important to note, however, that a number of ingested substances can affect these systemic markers. Ethanol, for example, increases lactate levels. Additionally, laboratory studies suggest that the rise in lactate levels may be only minimal during the early stages of progressive central blood volume loss.[27]

THE ROLE OF DIAGNOSTIC IMAGING IN TRAUMA

Diagnostic imaging is used in trauma management to discover and determine the severity of injuries, as well as to detect bleeding and identify potential sources of bleeding.

Plain film X-rays are easily accessible; quick to allow visualization of orthopedic injuries and lung fields; and often able to provide indirect evidence of hemorrhage, such as hemothorax.

Figure 1. The Pathophysiology of Hemorrhagic Shock



When trauma causes significant blood loss, the body's compensatory mechanisms (top row, green) attempt to compensate for the initial drop in blood pressure. If, despite their efforts, tissue oxygenation falls too low, cellular respiration shifts from aerobic to anaerobic metabolism (bottom row, red), and the resulting lactic acidosis can exacerbate coagulopathy and lead to multisystem organ failure.

The focused assessment with sonography for trauma (FAST) examination, however, is often preferred for early assessment of traumatic injury because it

- allows for rapid detection of hemoperitoneum.
- is noninvasive.
- can be reproduced.
- uses no radiation.
- can be easily performed at the bedside.

The accuracy of the FAST exam, however, is highly dependent on the user's skill and training. Furthermore, false-positive findings may result if fluid from nontraumatic sources is in the abdomen.[28]

Computed tomography (CT) can provide detailed images of internal cavities and organs, as well as of the vasculature. Whole-body CT scans, which can be obtained rapidly, play an important role in the management of severely injured patients.[29] Since CT scanners are typically located outside of the resuscitation or trauma bay, it's important for patients to be closely monitored for acute decompensation during transport and scanning.

PHYSICAL ASSESSMENT

In preventing death from hemorrhagic shock, recognizing its clinical presentation is of utmost importance, so that lifesaving interventions can be implemented quickly. Hemorrhagic shock is commonly precipitated by severe injuries in the following body regions:

- thorax (mediastinal or chest wall injuries causing a hemothorax, for example)
- abdomen (solid organ injuries causing intraperitoneal or retroperitoneal bleeding, for example)
- pelvis (pelvic fractures causing vascular injuries, for example)
- extremities (femoral fractures causing compartmental bleeding, for example)

Although blood loss is frequently obvious with injuries to these regions, occult hemorrhage may also occur, so it's important for nurses to assess and closely monitor injuries when caring for patients with traumatic injury.

Hemorrhage from blunt injury may be more challenging to detect than hemorrhage from penetrating injury, which is usually easily identified. Vital signs and perfusion markers may signal the presence of hemorrhage from blunt trauma, but during the early stages of blood loss, compensatory mechanisms may prevent these parameters from changing. Moreover, even after the loss of 15% to 30% of blood volume, skin mottling may be difficult to detect and, unless serial blood pressure measurements are taken, increases in diastolic blood pressure may go unnoticed because of compensatory vasoconstriction.[30] Circulatory collapse typically occurs following a blood volume loss of 30% to 40%, after which reductions in systolic and diastolic blood pressures are easily detected, as are mental status changes, elevated respiratory rate, poor peripheral perfusion, pallor, and diaphoresis.[30]

Tachycardia has traditionally been regarded as an early sign of hemorrhage because heart rate may rise slightly above normal with as little as 15% blood loss.[31] However, heart rate may be affected by a number of factors, including pain, anxiety, and spinal injuries. Moreover, it's well documented that hemorrhage triggers bradycardia in some patients, and heart rate is neither sensitive nor specific for predicting hypotension in the acute period following trauma or clinical outcomes.[15]

Tachypnea may signal hemorrhage, with respiratory rates sometimes rising above 20 breaths per minute following the loss of 15% to 30% blood volume.[30] As with tachycardia, however, tachypnea may not occur during the early stages of blood loss.[32]

Hypothermia can have detrimental effects on coagulation factors, even in the absence of acidosis. For this reason, during hemorrhagic shock, patients' body temperature should be monitored by esophageal or rectal thermometer and maintained at values close to normal: 36°C to 37°C (96.8°F to 98.6°F).[33]

Nurses have been using external warming measures, such as blankets, heated water bottles, and warmed IV fluid as far back as the early 1900s.[9, 34] Today, because of the large amounts of cold-stored blood or blood products that may be needed for patients in hemorrhagic shock, all products administered during resuscitation should be warmed to 37°C, if possible, with approved in-line blood heaters.[35]

Normal vital signs. When patients have normal vital signs following trauma, perfusion markers, such as base deficit, elevated lactate, and the shock index may be more helpful in identifying occult hemorrhage in its early stages. The shock index (heart rate divided by systolic blood pressure) is particularly predictive of trauma-related death risk and the need for massive transfusion despite normal vital signs.[36] Values significantly higher than the normal range of 0.5 to 0.7 (specifically, those greater than 0.9) are considered grossly abnormal.[26]

Nursing Considerations in Hemorrhagic Shock[10]

- Assess patient for unrecognized hemorrhage and control all sources of bleeding.
- Apply hemostatic dressings using direct pressure for at least three minutes.
- Apply tourniquet for life-threatening hemorrhage directly to the skin, two to three inches above the bleeding site. Apply a second tourniquet next to the first if bleeding is not controlled.
- Obtain vascular access through an intravenous or intraosseous line.
- Administer a resuscitation fluid (in order of preference):
  - whole blood
  - plasma, red blood cells (RBCs), and platelets in a 1:1:1 ratio
  - plasma and RBCs in a 1:1 ratio
  - plasma or RBCs alone
  - 6% hetastarch, a nonblood volume expander, in lactated electrolyte solution
  - crystalloid (lactated Ringer's solution or Plasma-Lyte A)
- As soon as possible (not later than three hours after injury), administer 1 g of tranexamic acid in 100 mL normal saline or lactated Ringer's solution.
- Warm resuscitation fluids if possible.
- Monitor airway, breathing, and circulation, particularly in those given pain or sedation medications.

EVALUATING MENTAL STATUS

While the ability to interact and concentrate is suggestive of adequate perfusion to the brain, cerebral blood flow is initially preserved by many of the body's compensatory mechanisms.[37] However, as patients begin to decompensate, they become increasingly anxious and confused. Therefore, changes in mental status not attributable to traumatic brain injury should also be considered a sign of shock. Nurses can evaluate mental status while assessing patients' vital signs.

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STOP THE BLEED

Once hemorrhage is detected, the care team's primary duty is to achieve hemostasis. In cases of severe hemorrhage, lifesaving interventions may need to be initiated in less than five minutes after injury, often in a prehospital setting.[38] Management should begin with the fastest and least invasive interventions (see *Nursing Considerations in Hemorrhagic Shock*[10]). For example, depending on the severity, location, and type of injuries, it may be appropriate for caregivers to apply manual pressure to wounds until appropriate hemorrhage control dressings or devices can be applied. For most small or nonextremity wounds, direct pressure can be applied in conjunction with traditional dressing pads and hemostatic gauze to further mitigate blood loss. Exceptions include injuries to the eyes and those involving embedded objects. Such wounds should be covered with clean dry gauze, with embedded objects secured to prevent dislodgment and further damage.

Tourniquets. For severe bleeding, especially in the prehospital setting, tourniquets should be used, as they are versatile and effective in controlling bleeding in several body regions. Nurses who work primarily in hospitals care for patients with traumatic injuries only after they have had a tourniquet placed; therefore, they need to be aware of complications that can occur as a result of tourniquet use, such as nerve palsies, local infections, compartment syndrome, deep vein thromboses, ischemia-reperfusion injury, and secondary amputations. Although these complications are relatively infrequent, an eight-year retrospective study that compared a cohort of adult patients with traumatic injuries and prehospital tourniquet placement with a matched group of patients without tourniquet placement found that prehospital tourniquet use could safely control bleeding with no increased risk of major complications.[39] Prehospital tourniquet placement was associated with increased survival rates, and rates of fasciotomy and secondary amputation were higher among patients who had not been treated with tourniquets.

Resuscitative endovascular balloon occlusion of the aorta (REBOA) may be used to control noncompressible torso hemorrhage. This procedure requires the trauma team to insert a balloon catheter into the femoral artery and then thread it into an appropriate section of the aorta, where it will be inflated to occlude blood flow and stop the hemorrhage.[40]

Following REBOA catheter placement, nurses should continue assessing vital signs for indications of hemodynamic instability and closely monitor[40]

- the extremity through which the catheter was placed for signs of neurovascular compromise or poor perfusion.
- the vascular access site in the groin for excessive bleeding.
- muscle compartments of the extremity for evidence of compartment syndrome and rhabdomyolysis.

PERMISSIVE HYPOTENSION

Blood pressure management is an important strategy for minimizing blood loss prior to surgical hemostasis. The Department of Defense Joint Trauma System Clinical Practice Guideline (JTS CPG) on damage control resuscitation (DCR) suggests that patients without central nervous system injury prior to surgical control of hemorrhage should maintain a target systolic blood pressure of 90 to 110 mmHg.[35]

Resuscitation should not delay surgical control of hemorrhage when required, but rather should be ongoing as patients are brought to the operating room.

Two meta-analyses of randomized controlled trials that compared survival benefit among adults with hemorrhagic shock who were treated with either hypotensive (limited-fluid) resuscitation or normotensive (aggressive-fluid) resuscitation found that patients who received hypotensive resuscitation had a statistically significant survival benefit.[41, 42] However, both analyses cited important limitations related to clinical and methodological heterogeneity as well as small sample sizes among the studies analyzed; consequently, research attempting to identify optimal blood pressure targets for patients with traumatic hemorrhagic shock is ongoing. Nurses caring for patients with hemorrhagic shock need to ensure that attending physicians consistently clarify blood pressure goals.

DAMAGE CONTROL RESUSCITATION

For patients in hemorrhagic shock, IV access should be established as soon as possible. Large-bore catheters are preferred, and rapid infusers can be used to speed delivery of blood products and fluid if necessary. Intraosseous access may be established quickly and easily in hypovolemic patients with poor vascular access.[43] Resuscitation should not delay surgical control of hemorrhage when required, but rather should be ongoing as patients are brought to the operating room. Following surgical stabilization, in addition to monitoring PT, INR, or aPTT, and platelets or fibrinogen concentration, point-of-care ROTEM or TEG can provide an additional means of evaluating coagulopathy. These tests produce graphic and numeric representations of blood clot initiation, formation, and lysis.[44] Although definitive parameters for ROTEM and TEG are not well established, serial tests during and after resuscitation can be used to establish clotting trends that support other laboratory and clinical findings.

Correction can be achieved through targeted replacement of blood products.[45, 46] Patients' vital signs, hemodynamic measurements, and perfusion markers should be monitored closely for signs of ongoing tissue hypoxia, a driver of coagulopathy and the primary focus of hospital-based resuscitation.[5] End points of resuscitation may include lactate and base excess levels at or approaching normal values of 0.5 to 1 mmol/L and −2 to +2 mEq/L, respectively.[3] Other considerations include assessment of intravascular volume status (based on heart rate, mean arterial pressure, central venous pressure, and urine output), signs of anemia, and electrolyte abnormalities.

Preventing the trauma triad. The ultimate goal of modern DCR following traumatic injury is to prevent or correct existing oxygen debt, which can trigger the trauma triad of hypothermia, coagulopathy, and acidosis. DCR combines hemorrhage control and immediate blood transfusion to maintain adequate tissue oxygenation in order to prevent multisystem organ failure and death.[3] Timing is an important aspect of DCR, as research has shown that the 24-hour mortality rate is significantly reduced when blood is administered within 15 minutes of medevac rescue.[47] For hemorrhaging patients, current best practices include using primarily blood products while limiting crystalloid fluid administration.[46]

WHOLE BLOOD VS. COMPONENT THERAPY

Based in part on the experience of the U.S. military during conflicts in Afghanistan and Iraq, there is renewed enthusiasm for using whole blood rather than component therapy, such as packed red blood cells, platelets, or fresh frozen plasma, to resuscitate patients with traumatic hemorrhagic shock. In some studies, the use of whole blood has demonstrated not only safety but improved patient survival compared with the use of component therapy alone.[48, 49]

In addition to improved survival, whole blood offers the following benefits over component therapy:

- A single unit of whole blood is more concentrated than stored components, typically containing more red blood cells, platelets, and coagulation factors than would be available in whole blood delivered as individual units of these components in a 1:1:1 ratio (reconstituted whole blood).[50]
- Compared with blood components, which may come from multiple donors, whole blood comes from a single donor, thereby lessening recipient donor exposure.[51]
- Whole blood reduces the potential for trauma-induced coagulopathy, which may be caused by anticoagulants and infusion of crystalloids.[50]
- Preparing whole blood requires no special separation, washing, or storage equipment.[52]
- Whole blood need not be type-specific to mitigate the risk of hemolysis and adverse effects due to incompatibility; transfusion of type O whole blood contains low titers of anti-A and anti-B antibodies and has been used effectively and safely by the military in combat casualties with a very low rate of hemolytic transfusion reactions.[53] Women of childbearing potential who are Rh negative or of unknown blood type should be provided with Rh-negative blood products if possible. If, however, the limited supply of Rh-negative blood products necessitates the transfusion of Rh-positive blood products instead, it should be clearly documented in the patients' medical records because of the risks of alloimmunization to Rh and hemolytic disease of the fetus or newborn in subsequent pregnancies.[53]

There is renewed enthusiasm for using whole blood rather than component therapy to resuscitate patients with traumatic hemorrhagic shock.

The current JTS CPG for DCR recommends whole blood as the initial resuscitation fluid when possible.[35] Moreover, in recognition of the growing experience and positive outcomes associated with whole blood transfusion in military settings, civilian organizations have started to create whole blood transfusion programs and protocols.

It's recommended that trauma bays be stocked with blood component therapy packs in a 1:1:1 ratio.

In alignment with the JTS CPG for DCR, the Eastern Association for the Surgery of Trauma DCR guideline concluded that "we believe most patients would value a high-ratio DCR strategy, if not whole blood."[4] "High-ratio" refers to blood component ratios during transfusion that attempt to replicate the component availability seen in whole blood by providing plasma, platelets, and red blood cells in ratios as close as possible to 1:1:1. Further recommendations include that trauma bays be stocked with component therapy packs in a 1:1:1 ratio for immediate use when needed. With this recent, developing change in practice toward using whole blood and transfusing components in a similar ratio to that found in whole blood, recent conversations have focused on how best to balance the advantages of whole blood with the longer shelf life and ability to tailor treatment of blood component therapy.[54] Researchers continue to address these questions. ▼

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