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STATEMENT OF FINANCIAL DISCLOSURE

To reveal any potential bias in this publication, and in accordance with Accreditation Council for Continuing Medical Education guidelines, we disclose that Executive Editor Ms. Mark's spouse works for a company that creates advertising for Uroplasty. Dr. Dietrich (editor in chief), Dr. Pickett (author), Dr. Kallsen (author), Dr. Schott (author), Dr. Menaker (peer reviewer), Ms. Behrens (nurse reviewer), and Mr. Landenberger (continuing education and editorial director) report no relationships with companies related to this field of study.

AHC Media

Damage Control Resuscitation

Damage control resuscitation is critical for patients with massive hemorrhage. Ideally, the first step is termination of the blood loss, then replace fluids and control the lethal triad of acidosis, hypothermia, and coagulopathy. This resuscitative technique is valuable in the trauma setting, but also may be useful in any patient with massive hemorrhage such as a GI bleed or ruptured AAA. Damage control resuscitation is important for all trauma sites, beginning in the prehospital arena, rural hospitals, or Level 1 trauma center.

Adjuncts such as point-of-care testing may further assist with individualizing patient care. Damage control resuscitation continues to be an active area of research, and its management principles continue to be refined to offer our patients the optimal therapy.

— Ann M. Dietrich, MD, Editor

Introduction

Damage control resuscitation is the replacement of lost fluids while controlling the lethal triad of acidosis, hypothermia, and coagulopathy in a patient with massive hemorrhage. Exsanguinating hemorrhage is one of (if not the) most common preventable cause of death after trauma. It causes approximately one-third of the almost six million trauma deaths per year, and is the leading cause of life years lost throughout the world.[1-3] Of the majority of trauma deaths occurring within the first 24 hours, 50% of these are due to hemorrhage.[4] Unfortunately, those patients who do survive a massive resuscitation have a significantly increased risk of sepsis, multi-organ failure, longer hospital stays, and higher healthcare costs.[5] About half of the total mortalities occur before the patient reaches the hospital. All civilian and military trauma systems face the challenge of ensuring that bleeding patients receive timely and effective hemorrhage control.

Early strategies (development of trauma practices in the Vietnam War until the 1990s) revolved around early fluid administration with crystalloid solutions in large quantities if required. As the practice of mass transfusion with red blood cells (RBCs) began to develop, it became evident that large amounts of crystalloids were contributing to coagulopathy through dilution. Protocols

EXECUTIVE SUMMARY

- Damage control resuscitation focuses on stopping hemorrhage, replacing fluids lost, and correcting the lethal triad of coagulopathy, acidosis, and hypothermia.
- Prehospital management is primarily focused on stopping bleeding, using the least amount of required crystalloids for resuscitation, early anticipation of the need for massive transfusion protocol, notification to destination hospital, and quick transport to a trauma center for definitive care.
- If the patient is anticoagulated with warfarin, reversal will require fresh frozen plasma and vitamin K. If available, prothrombin complex concentrate is also effective at reversing the effects of warfarin.
- Adverse effects for massive transfusion protocol range from benign to fatal, including infectious blood-borne pathogens, sepsis, as well as non-infectious, including acute hemolysis, allergic reaction/anaphylaxis, transfusion-related acute lung injury (TRALI), and transfusion associated circulatory overload (TACO).

began adding relatively small volumes of blood component therapy (in addition to RBCs) as a reactionary correction to the resulting coagulopathy.[6] Recent literature analyzing the experience with hemorrhage in the Iraq/Afghanistan conflicts emphasizes early anticipation and management by administering fresh frozen plasma (FFP), platelets, and cryoprecipitate before progression of the coagulopathy cascade. This strategy of early blood component therapy in conjunction with "permissive hypotension" until hemorrhage control has been achieved has led to dramatic improvements in mortality and morbidity.[7] This forward-looking practice has led to the massive transfusion protocols employed today.

Pathophysiology

Patients presenting with fluid loss from bleeding are at risk for hemorrhagic shock, which is a specific type of hypovolemic shock. Blood loss can be external, or internal in the case of trauma, and primarily internal in the case of gastrointestinal hemorrhage, intra-abdominal organ injury, or vascular rupture (i.e., aorta). The American College of Surgeons has classified hypovolemic shock into four stages based on changes in vital signs and presenting clinical features of the patient, outlined in Table 1.[8-9] This classification system can be helpful in assessing initial or at least potential blood loss and predicting what resources may be needed in the forthcoming resuscitation and efforts toward hemorrhage control (massive transfusion protocols, surgery support in the emergency department, etc.).

Key principles of damage control resuscitation include the rapid control/containment of exsanguinating hemorrhage (internal vs. external), hypotensive resuscitation (if indicated), avoidance of the overuse of crystalloids and colloids, and the prevention and correction of the "lethal triad" of acidosis, hypothermia, and coagulopathy. Resuscitation is primarily focused on early use of a balanced amount of red blood cells, plasma, and platelets.[10]

As described previously, this lethal triad of acidosis, hypothermia, and coagulopathy works synergistically to worsen outcomes of patients in shock. Coagulopathy in massive hemorrhage is due to multiple underlying etiologies and is present in as many as 25% of severely injured trauma patients on arrival. The coagulopathy primarily stems from depletion of clotting factors due to hemorrhage, dilution by excessive crystalloid resuscitation (normal saline, lactated Ringer's solution, among others), platelet function inhibition from hypothermia, as well as significant acidemia resulting from poor tissue perfusion, which further inhibits pro-coagulant enzyme function.[11] Recent studies have shown that objective measures of coagulopathy, including INR greater than 1.2, BD greater than 3 mmol/L, body temperature less than 35°C, serum lactate greater than 6 mmol/L, and hemoglobin less than 7 g/dL, on hospital presentation are independent risk factors of early mortality.[12] Coagulopathy is worsened by both acidosis and hypothermia.[13] As a patient loses blood and their subsequent ability to properly oxygenate the tissues, lactic acid begins to build up from anaerobic metabolism, which results in a progressively worsening acidosis. Hypothermia then follows with the loss of warm blood, and is further exacerbated by the administration of ambient to cool temperature resuscitative fluids. Ultimately, both of these factors worsen the bleeding by inhibiting the function of the clotting factors, with the cycle continuing until it is addressed. Given the significant deterioration and mortality associated with these processes, early detection/prediction using the factors in Table 2 to mobilize resuscitative blood products has been shown to significantly improve patients' 30-day mortality.[14]

Prehospital Management

In the prehospital setting, the critical first step in caring for a patient with massive hemorrhage is to quickly identify and control sites of bleeding. This has been most apparent in the application of lessons learned from recent military conflicts. The traditional ABC (airway, breathing, circulation) mnemonic has been re-arranged to address circulation, or more specifically the control of exsanguinating hemorrhage, even before establishment of an airway.[15] The benefit provided to a casualty by the simple (yet effective) application of a tourniquet is perhaps the most important intervention that can be performed in the appropriate setting and should be considered and applied without hesitation. The benefit of popular tourniquets, including the CAT (Combat Application Tourniquet, available from North American Rescue www.narescue.com), have been demonstrated time and time again in both military and civilian settings. All medical personnel, regardless of intended area of practice (prehospital, emergency department, etc.), should be familiar with the operation of the most common tourniquet designs

Table 1. Predictors of Hemorrhage Classification[8-9]

	ACS Hemorrhage Class			
Predictor	Class I	Class II	Class III	Class IV
% Loss	< 15%	15-30%	30-40%	> 40%
mL Loss	< 750 mL	750 mL-1.5 L	1.5 L-2 L	> 2 L
Mental status	Appropriate	Anxious	Confused	Lethargic
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse rate (bpm)	< 100	100-120	120-140	> 140
Respiratory rate	14-20	20-30	30-40	> 35
Capillary refill	< 2 sec	> 2 sec	> 2 sec	> 2 sec
Urine output (mL/hr)	> 30	20-30	5-15	< 5
Resuscitative fluids	Saline	Saline	Saline, blood	Saline, blood
Severity of physiological decompensation	Stable	Mild	Moderate	Severe

ACS — American College of Surgeons, bpm — beats per minute; percentiles based on 70 kg patient. Note that young patients may display fewer physiologic changes at higher stages of blood loss, whereas older patients or those which chronic disease/medications may demonstrate physiologic changes at lower stages of blood loss.

and have them easily accessible. (*See Figure 1.*)

Hemorrhage can be internal, external, or a combination of both. Providers must have a high index of suspicion for potential internal blood loss in cases of penetrating trauma and blunt trauma to the abdomen, pelvis, and/or chest, evident from the primary survey. (*See Figures 2 and 3.*) In cases of internal bleeding, management priorities include limited fluid replacement (2 L of crystalloids) and rapid transport to a hospital for definitive care.[16] External sources of bleeding should be readily identifiable on external exam, with priorities for extremity hemorrhage again to include hemorrhage control using compression devices as applicable, rapid transport to an appropriate facility, and judicious use of fluids to maintain systolic blood pressure at or above 90 mmHg. Consideration for permissive or controlled hypotension are discussed later. As was already described, hemorrhage control is achieved first and foremost by applying direct pressure to the wound with the addition of commercial adjuncts as necessary and available. Consistent with common sense, the earlier (prior to the onset of shock) the tourniquet is placed from the time of injury, the better the outcome.[17-19] Improved outcome was demonstrated regardless of the level of medical training of the individual applying the tourniquet.

Table 2. Predictors of the Need for Massive Transfusion Protocol (MTP)

- Systolic BP < 110 mmHg
- HR > 105 bpm
- Hct < 32%
- pH < 7.25
- INR > 1.4
- SaO2 < 75%

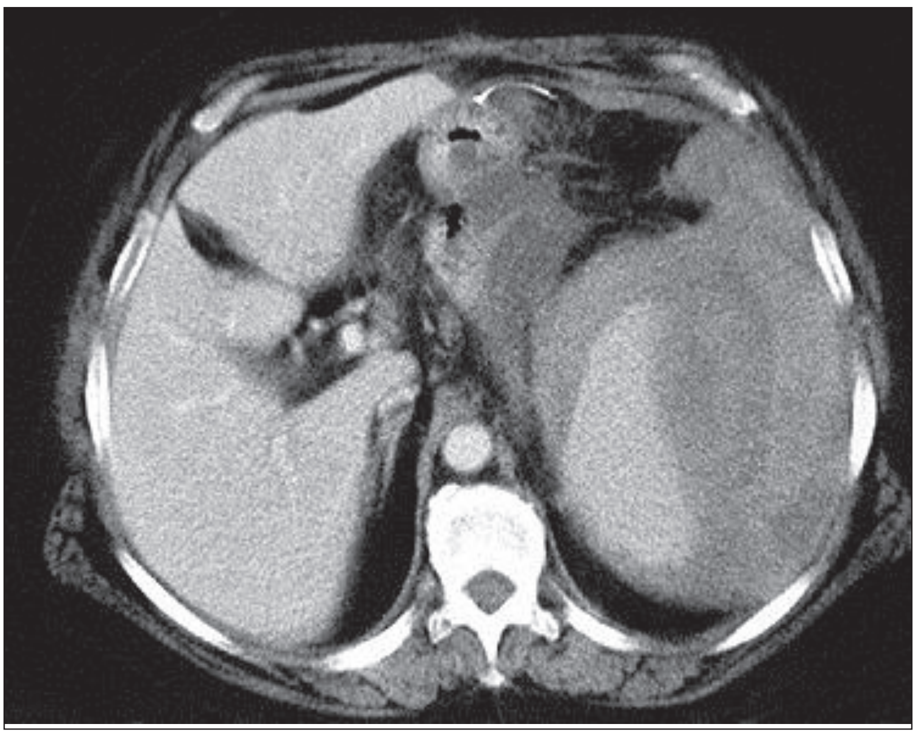
Prediction criteria shown to increase likelihood that activation of an MTP (massive transfusion protocol — greater than 10 units of blood) will be required. Note that the presence of three vs. four of the four initial criteria (systolic blood pressure, heart rate, hematocrit, pH) indicates a 70% vs. 85% likelihood of eventual need, respectively.

Hemostatic Dressings

Hemostatic dressings are an additional strategy to provide wound packing in a hemorrhaging patient. However, there has not been significant literature yet to provide a strong recommendation for a specific product. The 2009 Tactical Combat Casualty Care (TCCC) update recommends QuikClot Combat Gauze (QCG; Z-Medica, Wallingford, CT) as first-line treatment for life-threatening hemorrhage not amenable to traditional tourniquet application.[20] This includes wounds in junctional areas (those involving the proximal most end of a long bone), torso, and elsewhere. The two primary mechanisms through which these clotting agents promote hemostasis are: absorption of water, which increases the concentration of clotting factors in the blood, and the production of chemical reactions that stimulate the intrinsic coagulation pathway.[21] QuikClot gauze is impregnated with a kaolin, an inorganic material that demonstrates activation of the coagulation cascade.[22] While there are many different agents and specific mechanisms available for purchase and use, the ideal agent should stop bleeding in 2 minutes or less, cause no toxicity to surrounding tissue, cause

Figure 1. Tourniquet

Figure 2. Spleen Trauma



no pain or thermal injury, be ready to use with little training, be easily applied under all conditions, fit both simple and complex wounds, be easily removed, have a long shelf life, and be economical.[23-24] The 2014 TCCC guidelines recommend Combat Gauze but also approve Chitogauze and Celox Gauze, chitosan-based hemostatic dressings that may even be slightly better in coagulopathic patients.[25]

While these agents are most commonly used in the combat or other prehospital scenario, they should be considered at any point in the treatment timeline when there is need for hemostasis and immediate surgical support is not available. As with tourniquets, hemostatic dressings should not be removed until in the operating theater or other setting within reach of definitive surgical intervention.

Transport Decision

Early notification to the emergency department of a possible need for massive transfusion has also shown a significant benefit.[17] This allows hospital personnel time to coordinate the proper individuals and resources, being better prepared to act quickly upon the patient's arrival. As mentioned earlier, use of prehospital data such as blood pressure, pulse, and level of consciousness can help estimate blood loss volume and predict the need for damage control resuscitation techniques.[16] While assessing and transporting the patient, manage the airway as needed. Establish vascular access, but limit any infusion to the minimum amount necessary to correct obvious shock as evidenced by pallor, diaphoresis, weak peripheral pulses, altered mental status, and delayed cap refill. Time of transport to an appropriate definitive care facility is very important.

Consider bypassing hospitals in favor of quicker transport to a trauma center if indicated by local protocols. Studies have shown that care at a designated trauma center improves mortality and functional outcomes for survivors of major trauma.[26] Judicious use of air medical resources also may be considered. In some cases, especially those with suspected internal hemorrhage or instances in which transport will be prolonged (i.e., rural setting, weather conditions), it may be appropriate to stop at a non-trauma center, especially if a surgeon is available to control bleeding and stabilize the patient before proceeding to a center for definitive care. Prehospital strategies for patient management is an active and on-going area of research that includes strategizing methods to bring lifesaving resources, such as plasma, to the point of patient contact in the field to reduce time to resuscitation and improve overall mortality.[27-30]

Emergency Department Management

When a patient arrives in the emergency department with massive hemorrhage, it is important to quickly perform

Figure 3. Traumatic Aortic Rupture

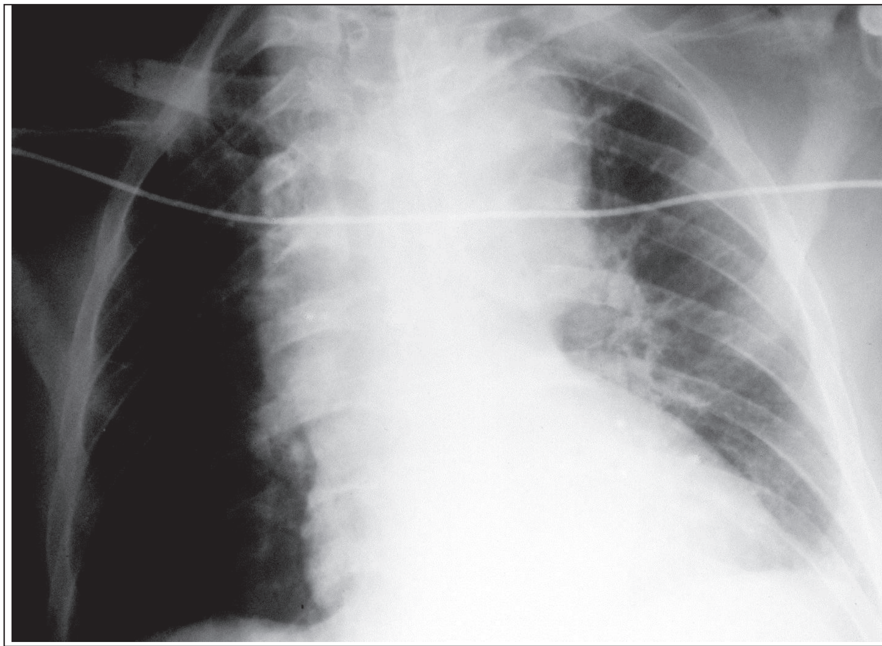


Table 3. Potential Blood Loss Based on Fracture Location[54]

Type of Fracture	Potential Internal Blood Loss (mL)
Rib	125
Radius or Ulna	250-500
Humerus	500-750
Tibia or Fibula	500-1000
Femur	1000-2000
Pelvis	1000+

a primary survey, establish two large bore IVs (18 gauge or larger), place the patient on telemetry, and assess volume status. As demonstrated in Table 3, the location of suspected injuries can give some insight to the potential extent of internal blood loss. It is important not to wait to control bleeding, and in some cases it will be prudent to make this the top priority before doing anything else. Initiate fluid resuscitation with crystalloids (if they have not already been initiated during prehospital transport) and immediately coordinate for the availability of blood products. An important part of resuscitation is permissive hypotension. The goal should be to keep the patient's SBP above 90 mmHg but not much higher, as a high pressure can destabilize newly forming clots, worsening the bleeding.[31-33]

It is important to limit the total amount of crystalloid administered while at the same time minimizing the delay before blood products are given; this cannot be stressed enough.[34-38] Overzealous fluid administration will aggravate bleeding by elevating blood pressure, dislodging blood clots, and diluting coagulation factors and platelets.[39] A four-fold increase in morbidity was appreciated in patients who received a 24-hour crystalloid volume of between 5-10 L.[40] While not yet supported by significant clinical evidence, initial studies looking at resuscitation of trauma patients with Plasma-Lyte vs. normal saline resulted in improved acid-base status and less hyperchloremia at 24 hours post injury.[41] It should be noted, however, that normal saline is the only compatible fluid that can be given concomitantly with blood. In cases in which blood products may not be immediately available for use, colloids (such as hetastarch) should be considered, as they have demonstrated an improved survival when compared to traditional crystalloids in some studies.[42]

Many hospitals have a massive transfusion protocol that can be initiated for patients with suspected massive hemorrhage. This enables the coordinated and continued dispatch of blood products from blood bank stores and appropriate administration by providers. Massive transfusion is commonly defined as the administration (or need thereof) of more than 10 units of pRBCs within a 24-hour period.[43] While there have been several scoring systems proposed to predict which patients will require MTP, their superiority to clinical judgment (and use of the basic predictors from Table 3) is unclear and warrants further review.[44-47]

The cornerstone of damage control resuscitation is 1 to 1 replacement of blood loss, better approximating the composition of fluids that the patient is losing, whole blood. There have been several ratios described in the literature, but perhaps the most widely used strategy is a 1:1:1 ratio of pRBCS, fresh frozen plasma, and platelets.[2-3,48] Table 4 outlines the most common blood products utilized in damage control resuscitation. In trauma patients, consider administering tranexamic acid (TXA).[49] This is an antifibrinolytic, which has been well studied in both the civilian and military settings with the CRASH-2 and MATTERs trials, respectively. TXA has been shown to reduce all-cause mortality, improve coagulopathy, and reduce blood transfusions if given within 3 hours of trauma. After 3 hours, it has been shown to increase thrombotic events.[50-51] Another well-studied adjunctive treatment for coagulopathy is therapy with the recombinant factor VII (rFVII), a coagulation factor concentrate. This has been demonstrated to reduce overall transfused pRBCs but has not yet demonstrated a significant improved effect on mortality.[52]

After the initial stabilization has been

Table 4. Resuscitative Blood Products[50]

Blood Product	Volume	Contents	Grouping	Storage
Whole blood	450 mL		Cross match	21 days at 4°C
Packed red blood cells	250 mL,	70% HCT	Cross match	21-42 days
Fresh frozen plasma	250 mL	70% HCT, all factors	Cross match	1 year (frozen) 24 hours (thawed)
Platelets	30 mL/unit	10^{10} platelets	N/A	5 days
Cryoprecipitate	10–25 mL/bag	Fibrinogen, factors VIII/XIII/vWF	ABO	1 year (frozen) 6 hours (thawed)
HCT – Hematocrit, vWF – von Willebrand Factor				

Table 5. Fibrinogen Content Present in Units of Blood Products

Blood Product	Fibrinogen Content
Fresh whole blood	1000 mg
Fresh frozen plasma	400 mg
Platelets	80 mg
Cryoprecipitate	2500 mg

initiated, the physician can then complete a secondary survey. Ancillary studies including labs and imaging will vary depending on particular patient/situation specifics. Standard ordering should include complete blood count, coagulation studies, electrolytes, renal function, ionized calcium, and blood gasses. It is important to closely monitor potassium, as its concentrations can vary widely with dilution, acidosis, and fluid shifts affecting its concentration. Calcium is important to monitor as well, as the preservative citrate contained in pRBCs chelates the ionized calcium and leads to calcium depletion. Ionized calcium should be checked every few hours; keep levels greater than 0.9 mmol/L.[53] Given the importance of maximizing the body's ability to promote hemostasis during damage control resuscitation, the fibrinogen level should also be checked and managed as appropriate. Table 5 outlines the fibrinogen content of common blood products used in damage control resuscitation.

Fibrinogen concentrate or cryoprecipitate should be strongly considered (and has shown some promise in small studies) when 6 U-12 U RBCs have been infused.[54] For cryoprecipitate, the general rule is 1 unit of cryoprecipitate per 10 units of resuscitation at the 1:1:1 ratio. Remember throughout resuscitation to keep the patient warm. This can include use of blankets, active warming units, and warming the resuscitation fluids. There are a wide variety of fluid warmers, including dry heat, water bath, and countercurrent heat exchange technologies.

Response to the effect of transfusion should be monitored by laboratory analysis (Hgb, lactate, ABG) in addition to vital signs (HR, BP), as these will oftentimes improve after initial resuscitation despite a persistent hypoperfused state.[55-56] Try to keep the patient's hemoglobin between 7 gm/dL and 9 gm/dL.[57] The goal is to adequately replace fluid loss while not over-transfusing and increasing the risk of transfusion-related injury.

While there is more than one potential reason for acidosis in the hemorrhaging patient, it is largely due to tissue hypoperfusion as described earlier. The best way to manage this acidosis is by promoting tissue perfusion by aggressive resuscitation with blood and blood products. The use of bicarbonate or tris-hydroxymethyl aminomethane (THAM) remains unclear. While use of these therapies can transiently improve acidosis and theoretically improve the negative effects of acidosis on coagulation factor efficacy, current literature has not shown evidence of improvement in mortality. If using these therapies, it is recommended to wait until pH is less than 7.2 before implementing.[58-59]

There are some special considerations for patients taking blood-thinning agents. Coagulation studies are important to assess if the patient is therapeutic on these agents. This has become more difficult with the growing use of newer agents that do not have ways of measuring effectiveness and do not have reversal therapies. If the patient is anticoagulated with warfarin, reversal will require fresh frozen plasma and vitamin K. If available, prothrombin complex concentrate is also effective at reversing the effects of warfarin. Antiplatelet medications clopidogrel, aspirin, or Aggrenox do not have such an easy reversal agent. Simple administration of platelets provides a benefit; however, there is limited literature to recommend its use in patients who are otherwise healthy.[57]

Early surgical management is the core of trauma resuscitation and should never be delayed. The emergency medicine physician's role in trauma resuscitation is to control hemorrhage to the extent possible, delay irreversible shock, optimize physiologic parameters, manage the airway, and provide appropriate oxygenation and ventilation.

The Risks

While damage control resuscitation

has been shown to improve outcomes when applied in the appropriate situation, it should be used carefully, as this therapy can also cause significant harm to the patient.[57] Adverse effects range from benign to fatal, including infectious blood-borne pathogens, sepsis, as well as non-infectious, including acute hemolysis, allergic reaction/anaphylaxis, transfusion-related acute lung injury (TRALI), and transfusion associated circulatory overload (TACO).

TRALI is the development of a non-cardiac pulmonary edema through the activation of the patient's immune system resulting in acute hypoxemia within six hours of initial transfusion. It has been reported to occur in 0.08% to 8% of transfused patients in the recent literature.[60] TRALI is difficult to detect in the early stages of neutrophil activation; however, it appears to be associated with resuscitation protocols containing large amounts of plasma. Signs include acute respiratory distress, hypoxemia ($PaO_2/FiO_2 \leq 300$ or $SPO_2 < 90\%$ on room air or other clinical evidence of hypoxemia), bilateral infiltrates, and absence of left atrial hypertension, all within 6 hours of transfusion. Management includes immediate discontinuation of the transfusion and initiation of supportive therapies including positive pressure ventilation (CPAP, BiPAP, or intubation) with maintenance of hemodynamic support, including fluids and vasopressors as needed.

TACO, on the other hand, is the result of a rapid transfusion of a blood volume that is more than the total capacity of the patient's circulatory system, occurring in 1-8% of transfusions. Unlike TRALI, it is not related to an immune system activation, and is most common in patients with underlying diseases such as a history of congestive heart failure, renal failure, chronic anemia, cardiopulmonary compromise, and extremes of age.[61] Prevention includes limiting the total amount of plasma administered and reducing the rate of infusion in those patients with significant risk factors for overloading with recommended rates of 42 mL/hr to 120 mL/hr, depending on risk factors.[62] Potential harm not only results from the adverse events that may be associated with the administration of blood products; it should be noted that blood products are precious resources that should be carefully conserved and utilized only as needed.[63]

Controlled Hypotension

Given the significant risk of aggressive resuscitation, the idea of controlled hypotension (allowing the SBP to range between 70 and 90 during the initial resuscitative efforts) has been explored and is beginning to take hold in the setting of extensive hemorrhage, including those cases of penetrating trauma.[33,57,64] Some studies have even used the patient's mental status as the barometer to regulate the ultimate "safe" limit of this controlled hypotension.[65] Despite a lack of established, randomized data touting its benefits, initial studies have demonstrated improved 24-hour mortality as well as no statistically significant differences with regard to 30-day mortality.[35,66] Patients who were allowed to remain slightly hypotensive required significantly fewer blood product transfusions and yet experienced no significant differences in the incidence or severity of coagulopathy, thrombocytopenia, or anemia.

Patients presenting in hemorrhagic shock due to stab/penetrating wounds, especially those in the torso, secondary to gunshot wounds, cases of blunt injury, and especially those with obvious or even suspected brain injury or other intracranial process, should be resuscitated to goal blood pressures (SBP > 90 mmHg, MAP > 65 mmHg) due to concerns of under-perfusing tissue. Secondary brain injury is driven by a combination of systemic derangements (hypoxia, hypotension, hypercarbia, hypocarbia, hyperglycemia, and hypoglycemia) following the initial traumatic insult. Hypotension (SBP < 90 mmHg) has been identified as an independent risk factor for increased mortality/morbidity in cases of traumatic brain injury, including multisystem diseases such as neurogenic pulmonary edema.[31,67-70]

Progressing Technology

The goal of damage control resuscitation is to replace what the patient has lost given their specific mechanism of injury and pertinent comorbidities. The ideal situation would be to tailor replacement to a patient's specific needs versus algorithm-based therapies. This would reduce waste of blood product resources, limit risks to the patient, and make replacement more effective by ensuring the patient is getting the product that he or she needs. In order to achieve this goal, we need point-of-care testing that is reliable, fast, and gives us information on the whole spectrum of the coagulation cascade. Two commercially available technologies include Thromboelastography (TEG) and Rotational Thromboelastometry (ROTEM). These tests have been widely adopted in Europe and the military, and are quickly becoming the standard of care in the United States. Both of these tests are available as point-of-care testing and are able to give a dynamic assessment of the coagulation cascade, including initiation, progression, final clot stability, and lysis of clot. The information gathered allows for guided coagulation specific transfusions. One study demonstrated that 30% of patients with resuscitation guided by ROTEM received only fibrinogen and prothrombin complex concentrate with no need for platelet transfusion.[11] Another retrospective analysis showed improved observed mortality over predicted using mainly coagulation factor concentrates guided by ROTEM.[71] Current research in this area is aimed at better realizing the clinical applications of the information derived from these coagulation tests.

New strategies for resuscitation are also being explored, including algorithms that place emphasis on the plasma first, as studies have shown that early replacement of plasma has prevented patients from needing massive transfusion.[72] Some have suggested that there will be a benefit to bringing this component of the resuscitation forward into the field, although more research is needed to establish this as a practice.[73]

Freeze dried plasma was developed to address the complications of storage and management of plasma and make it available in more austere environments. The French army has been using this since 1994, and recent studies have shown it to be both effective and safe in resuscitation.[74] Resuscitative endovascular balloon occlusion of the aorta (REBOA) is another technology being explored for hemorrhage control. REBOA aims at gaining proximal hemorrhage control similar to thoracotomy with aortic cross clamping; however, it utilizes arterial access at the femoral artery with sheath and catheter setup that is advanced to the desired level and balloon tip inflated. While not conceptually new, there is renewed interest in understanding which patients would benefit from this application and streamlining the process for vascular access and balloon deployment at the desired level.[75]

Summary

In summation, damage control resuscitation is the pathway for optimal care of patients who present with massive hemorrhage. The core principles are to stop the source of blood loss, replace fluids, and control the lethal triad of acidosis, hypothermia, and coagulopathy. It is important to keep in mind that while it is commonly implemented in the trauma setting, any patient with massive hemorrhage such as a GI bleed or ruptured AAA would benefit from implementing this strategy. Damage control resuscitation is a concept and plan of action critical across the trauma system, from the rural care setting to the level 1 trauma center. Damage control resuscitation may be necessary in a patient while awaiting surgical management or during transfer to a trauma center. This resuscitation relies on a system-ready approach that involves a protocol so that resources can be made available and staff ready to implement them. Damage control resuscitation continues to be an active area of research and its management principles continue to be refined to offer patients the optimal therapy.

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CME/CNE Questions

1. You arrive at the scene of a motor vehicle accident. You have assessed that the scene is safe and find a middle-age male lying on the ground. Initial size-up demonstrates a minimally responsive adult, moaning in pain, fully clothed with blood-soaked pants with a moderate amount of blood pooling underneath him. On initial assessment, he is responsive but lethargic. What is the FIRST priority in stabilizing this patient?
   A. Quickly establish IV access.
   B. Expose the rest of the patient to identify and stop potential sources of bleeding.
   C. Administer narcotics urgently to provide pain relief, possibly facilitating so the patient can give you a better history of the accident.
   D. Place patient on back board and prepare for quick transport.
2. A patient arrives in the emergency department after being transported by helicopter from the field. The patient has no obvious signs of bleeding, but was involved in a high-speed motor vehicle collision.

TRAUMA REPORTS

CME Objectives

Upon completing this program, the participants will be able to:

- discuss conditions that should increase suspicion for traumatic injuries;
- describe the various modalities used to identify different traumatic conditions;
- cite methods of quickly stabilizing and managing patients; and
- identify possible complications that may occur with traumatic injuries.

Vital signs are heart rate of 126, respiratory rate 32, blood pressure is 82/55, and the patient is confused. You suspect possible internal bleeding. What is the hemorrhage classification for this patient?
A. Class 1
B. Class 2
C. Class 3
D. Class 4

3. A patient is brought to your trauma bay with significant injuries and massive hemorrhage. What is the lethal triad you need to be concerned about preventing and correcting?
A. acidosis, coagulopathy, hypothermia
B. hyperthermia, coagulopathy, acidosis
C. hypotension, alkalosis, hypercoagulopathy
D. acidosis, hypothermia, hypercoagulopathy

4. You are medical control and you get a call about a patient from the scene of an accident. The patient is intubated, has no external signs of bleeding, has class four hemorrhage shock, and paramedics are concerned about internal hemorrhage. You recommend judicious crystalloid resuscitation, but are concerned this patient is quickly going to decompensate, and are trying to decide the most appropriate location to take the patient. What would be the most appropriate choice?
A. the level 1 trauma center one hour away by ambulance
B. the nearest community hospital with on-call surgeon 15 mins
C. level 2 trauma center 30 minutes away
D. hospital around the block without surgical services but with blood products

5. A patient presents with multiple trauma to your emergency department. A quick initial review of the vital signs reveals tachycardia and a slightly hypotensive patient. Your primary survey demonstrates findings suspicious for a closed femur fracture. How much blood could be potentially lost from this injury?
A. 250-500 mL
B. 750-1000 mL
C. 100-250 mL
D. 1000-2000 mL

6. You have begun initial resuscitation in a patient with hemorrhagic shock. You have finished with 2 liters crystalloid and are now getting ready to start blood products; labs have been sent off. What is your hemoglobin and blood pressure goal?
A. Hgb 7-9, BP 90/60
B. Hgb 7-9, BP 120/70
C. Hgb 10-12, BP 120/70
D. Hgb 10-12, BP 90/60

7. A patient is undergoing a massive transfusion protocol at your hospital after arriving with a ruptured abdominal aorta. The patient has received 10 units of pack red blood cells. What specific electrolyte do you need to be monitoring with regard to large volume resuscitation with pRBCs?
A. potassium
B. sodium
C. calcium
D. magnesium

8. A 60-year-old female arrives at your emergency department after being shot while at the grocery store. After the initial evaluation and resuscitation, lab results indicate that her INR is 4.5. What is the next step in correcting her INR quickly?
A. platelets
B. cryoprecipitate
C. vitamin K
D. fresh frozen plasma

9. A patient is undergoing blood transfusion as part of damage control resuscitation after massive hemorrhage. Which of the following is *not* a serious adverse effect from transfusion?
A. transfusion-related lung injury
B. blood-borne pathogens
C. fever
D. volume overload

10. A 45-year-old female is brought to your trauma center after a motorcycle accident. The patient appears to have several obvious extremity deformities, abrasions and bruising over the abdomen and chest, and significant hematoma and abrasions over her left face and temporal area. What would be a contraindication to hypotensive resuscitation?
A. splenic or liver laceration
B. pneumothorax
C. traumatic brain injury
D. blunt cardiac injury

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