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FINANCIAL DISCLOSURE

Dr. Dietrich (editor in chief), Dr. Boulger (author), Dr. Yang (author), Dr. Adewale (peer reviewer), Ms. Behrens (nurse planner), Ms. Mark (executive editor), Ms. Coplin (executive editor), and Ms. Hatcher (editorial group manager) report no relationships with companies related to this field of study.

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Hemorrhage Control: Advances in Trauma Care

Massive hemorrhage is a devastating scenario. Early identification is essential to allow for prompt, potentially lifesaving interventions with the goal of rapid control of exsanguination. Over the last two decades, advances in hemorrhage control and damage control resuscitation have facilitated minimizing blood loss pending definitive surgical intervention. Understanding the utilization of these interventions and procedures may result in a significant improvement in morbidity and mortality for the patient with hemorrhage.

— Ann M. Dietrich, MD, Editor

Case Study

You are working in a single coverage, rural emergency department when a 70-year-old male presents after a motor vehicle collision with HR 103, BP 80/p, evident bruising to his flank, and an unstable pelvis. A second patient presents from the same accident. She is a 20-year-old female with a crush injury, with HR 130, BP 70/p, and a partial right upper extremity amputation. What injuries should be considered? What is the best way to stabilize these patients? What are current advances, pharmacologic and nonpharmacologic, to stabilize these patients?

This article will discuss management strategies for hemorrhage control.

Introduction

Epidemiology

Trauma is a significant global health issue, leading to more than 4.6 million deaths annually worldwide.¹ In the United States, injury is the primary cause of death in people ages 1 to 44 years, and the fourth leading cause of death overall.² Death from hemorrhage often occurs rapidly, with a median time of two to three hours after presentation, and about 50% of these deaths occur within the first 24 hours.^{3,4,5}

Many of these deaths are preventable. Early recognition of subtle but potentially significant hemorrhage, an understanding of the underlying physiology, and timely and appropriate utilization of resources can decrease morbidity and mortality. This has led to the development of a multimodal approach, called damage control resuscitation (DCR), with the goal of minimizing blood loss until definitive hemostasis may be achieved.⁶

Hemorrhage control in trauma has changed drastically over the last two decades, with better understanding of the physiologic changes from trauma and improved approaches to resuscitation.⁶ Crucial management begins in the pre-hospital setting.

EXECUTIVE SUMMARY

- In the guidelines from the Eastern Association for the Surgery of Trauma (EAST), a lower threshold for trauma activation and a high level of care are recommended for geriatric trauma.
- Damage control resuscitation is a multifaceted method for hemorrhage control that includes mechanical hemostasis, limited crystalloid and artificial colloids, permissive hypotension, and balanced resuscitation.
- Recent updates include 1:1 ratios of packed red blood cells to fresh frozen plasma and platelets. This appears to reduce the risk of trauma-induced coagulopathy.
- Tourniquets can provide simple, cost-effective, lifesaving care; however, consideration should be given to certain rare potential complications, such as nerve palsies and ischemia.
- When placing a tourniquet, it is important to document a neurovascular exam prior to placement, as well as the time at which the tourniquet was placed.
- Some military studies suggest a limit of two hours, with take down of the device and assessment every two hours.
- Combat Gauze, Celox Gauze, and Chito Gauze are deemed safe and efficacious and, thus, are considered first-line recommended hemostatic agents by the Committee on Tactical Combat and Casualty Care (CoTCCC). These agents should be packed into the wound, and the provider should apply three to five minutes minimum of direct pressure, followed by a pressure dressing.
- Pelvic fractures can be life-threatening, with mortality reported as ranging between 7.6% and 50% for open pelvic fractures. When an unstable pelvic fracture is suspected or diagnosed, Advanced Trauma Life Support guidelines advise the use of a pelvic circumferential compression device as a temporizing measure until definitive fixation can be achieved.
- Tranexamic acid (TXA) is a synthetic lysine analogue and competitive inhibitor of plasminogen. The EAST guidelines for damage control resuscitation conditionally recommend early TXA for the severely hemorrhaging trauma patient.

Patient Population

Trauma is a unique disease process, as it often affects the young and otherwise healthy individual. However, trauma does not discriminate. Patients with a significant mechanism of injury, at the extremes of life (pediatrics and geriatrics), and with medical co-morbidities and polypharmacy are at higher risk for hemorrhage, shock, and mortality.

Mechanism of Injury

The mechanism of injury is a useful screening tool to determine which patients may be at risk for significant hemorrhage. Advanced Trauma Life Support (ATLS) guidelines describe significant mechanisms of injury as falls from a critical height of 6 m (20 ft),⁷ high-energy deceleration impacts, and penetrating wounds.⁸ It is important to have a higher index of suspicion to facilitate the early identification and management of potential injuries.

Blunt trauma can lead to occult injuries. A deceleration injury involves a difference in speed between fixed and non-fixed parts of the body, causing injuries such as liver and spleen lacerations and bowel damage. The most commonly injured organs in blunt trauma injuries are the spleen (40-55%), liver (35-50%), and small bowel (5-15%),

with the occult injury of retroperitoneal hematoma.⁸

Penetrating trauma leads to different types of injuries. Stab wounds and low-velocity gunshot wounds cause direct tissue damage with laceration and cutting. Stab wounds most commonly cause injury to the liver (40%), small bowel (30%), diaphragm (20%), and colon (15%).⁸ Gunshot wounds can be of low velocity or high velocity. High-velocity gunshot wounds transfer more kinetic energy and cause more damage around the track of trajectory. Explosive devices can cause combined blunt and penetrating damage.

Elderly Patients

The geriatric population is a high-risk group for trauma. In the guidelines from the Eastern Association for the Surgery of Trauma (EAST), a lower threshold for trauma activation and a high level of care are recommended for geriatric trauma patients. This population is at increased risk for adverse outcomes after injury due to comorbidities, limited cardiovascular reserve, and general frailty. In a study by Calland et al, those patients with a base deficit of -6 mEq/L or less correlated with severe injury and significant mortality, up to 60% risk, compared to those with -5 mEq/L and

with less than 23% mortality.⁹ Elderly patients frequently take anticoagulation and antiplatelet agents that increase the risk of hemorrhage; these iatrogenic coagulopathies should be recognized, evaluated, and corrected.⁹

Complications of Trauma

Trauma is a complex process. The injuries themselves often pose a significant risk to the patient. However, the complications associated with trauma can carry a significant increase in morbidity and mortality as well.

Hemorrhagic Shock. Early detection and management of hemorrhagic shock is vital to survival. Multiple studies have been performed to determine early signs of hemorrhagic shock and predict the requirement of blood products.

In severely injured patients, the lethal triad of acidosis, coagulopathy, and hypothermia worsen morbidity and mortality.

Trauma-induced Coagulopathy. One-third of patients with bleeding from trauma show signs of coagulopathy on admission to hospitals.^{5,10} Trauma-induced coagulopathy has been associated with blood product transfusion recommendations, with significant associated morbidity and mortality. Recent updates to existing

Table 1. Classes of Hemorrhagic Shock

	I	II	III	IV
Blood loss	Up to 750 mL	750 to 1,500 mL	1,500 to 2,000 mL	> 2,000 mL
Blood loss (% blood volume)	Up to 15%	15% to 30%	30% to 40%	> 40%
Pulse rate (per minute)	< 100	100 to 120	120 to 140	> 140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure (mmHg)	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate (per minute)	14 to 20	20 to 30	30 to 40	> 35
Urine output (mL/hour)	> 30	20 to 30	5 to 15	Negligible
Central nervous system/mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargic

Adapted from: American College of Surgeons Committee on Trauma. *ATLS® Student Manual*, 9th ed. Chicago, IL: American College of Surgeons; 2012

protocols have been made to include 1:1 ratios of packed red blood cells to fresh frozen plasma and platelets. This appears to reduce the risk of trauma-induced coagulopathy.^{5,10}

Diagnostocs

Hemodynamics: ATLS Classification of Blood Loss

The ATLS classification of hemorrhagic shock is a useful guide to quantify blood loss, but, interestingly, it has not been validated.¹¹ (*See Table 1.*) Blood loss may be obvious in some patients, but even in these patients, vital signs and visualization of blood loss are not good estimates of hemorrhagic shock.^{12,13} New scoring systems to predict the extent of shock and injury have been developed. However, many of these are not practical for application in a timely fashion and none have taken hold as a new standard of care.

In many disease processes, laboratory studies can be helpful in diagnosing and risk-stratifying patients. Unfortunately, because of the close proximity of most traumatic events to hospital presentation, laboratory studies and other diagnostics generally are not helpful in risk-stratifying this population. The following sections briefly discuss a few studies and their utility and pitfalls.

End Tidal CO₂

Low end tidal CO₂ (ETCO₂), CO₂ < 35, may be a novel early predictor for hemorrhagic shock and the need for

massive transfusion. A study by Caputo et al demonstrated that nasal cannula ETCO₂ had a negative association with lactate and was predictive of operative intervention in penetrating trauma patients.¹⁴ Low ETCO₂ had strong association with standard indicators for shock and was predictive of patients meeting CAT+ (≥ 3 units of packed red blood cells/h) criteria in the first six hours after admission.

Hemoglobin and Hematocrit

In nontraumatic causes of hemorrhagic shock, hemoglobin and hematocrit often are used to assess severity of blood loss, ongoing hemorrhage, and response to treatment. However, in trauma patients, these values often are normal on initial presentation and may take hours to drop.^{15,16} Serial measurements of hematocrit have a high sensitivity for detecting ongoing blood loss.¹⁷ In a study by Bruns et al, an initial hemoglobin below 10 g/dL in the first 30 minutes of patient arrival was associated with a three times higher need for intervention.¹⁸

Base Deficit and Lactate

Base deficit and lactate are measures of perfusion. Both of these studies have been shown to correlate with mortality and adequacy of resuscitation.^{19,20} Elevated lactate levels at presentation have been shown to correlate to mortality in trauma patients.²¹ In addition, failure to clear lactate in the first 24 hours was shown to be a strong negative prognostic marker after injury.²¹

Coagulation Markers

Standard laboratory evaluation of coagulation is the following: prothrombin time (PT), activated partial thromboplastin time, platelet counts, and fibrinogen. However, these tests only monitor the initiation of clot production and may appear normal despite the patient being coagulopathic. Viscoelastic hemostatic assays (VHA), such as thromboelastography (TEG) and rotational thromboelastometry (ROTEM), which promptly evaluate the entire clotting process, are relatively new and may be used to direct blood product resuscitation.^{22,23,24} Early amplitudes in the VHA, TEG, and ROTEM provide fast results, which is critical in the resuscitation of bleeding patients. Introducing the use of early amplitudes can reduce time to diagnosis of coagulopathy and may be used in TEG monitoring of trauma patients.²⁵ The VHAs appear to show promise in tailoring resuscitation to the individual patient as long as they can have quick turnaround times and be cost effective.

Management

Damage control resuscitation (DCR) is a multifaceted method for hemorrhage control. This approach includes mechanical hemostasis, limited crystalloid and artificial colloids, permissive hypotension, and balanced resuscitation.^{5,26}

This is a drastic change from 20 years ago, when trauma teams would infuse 20 to 30 liters of crystalloid, transfuse 10 units of red blood cells, and stay in

Table 2. Principles of Damage Control Resuscitation

- Avoid/reverse hypothermia.
- Minimize blood loss and apply early hemorrhage control measures.
- Target low-normal blood pressures before definitive hemostasis.
- Minimize crystalloid administration.
- Use massive transfusion protocol to ensure blood product is given in pre-specified ratio.
- Avoid delays to surgical and/or angiographic hemostasis.
- Obtain functional laboratory measures to guide resuscitation.
- Give pharmacologic adjuncts to safely promote hemostasis.

Adapted from EAST guidelines. Cannon JW, Khan MA, Raja AS, et al. Damage control resuscitation in patients with severe traumatic hemorrhage. *J Trauma Acute Care Surg* 2017;82:605-661.

the operating room to repair all injuries and close the fascia on all patients.²⁷ Mortality was high, and survivors suffered from coagulopathy, renal failure, abdominal compartment syndrome, wound complications, and acute respiratory distress syndrome.^{26,27} Many studies in the combat setting have advanced the literature about optimal trauma resuscitation and management. The main principles are described in Table 2, adapted from the EAST guidelines on DCR.⁶

Prehospital

Hemorrhage in the field remains the leading preventable cause of death in combat and the second leading cause of death in the civilian setting.^{3,4,5} Patients with traumatic injuries are on the clock. While there is minimal evidence behind the historical “golden hour,” we know that patients with active hemorrhage who achieve hemostasis and receive definitive care sooner have better outcomes.^{28,29} Many of the principles described in the EAST guidelines, such as normothermia, hemorrhage control, and conservative fluid administration, can and should be initiated in the field to optimize conditions for the patient. The subsequent section will discuss means of hemostasis that can be started in the field.

Direct Pressure and Pressure Dressings

Direct pressure and pressure dressings often are the first line of defense in hemorrhage. This technique requires little to no resources and has been

shown to be an effective and safe means of hemostasis for smaller wounds.³⁰ Successful direct pressure usually involves irrigating the wound, identifying the bleeding vessel, and applying direct one- to two-finger manual compression of the region uninterrupted for five to 15 minutes.³¹ The downside

We know that patients with active hemorrhage who achieve hemostasis and receive definitive care sooner have better outcomes.

of this technique is that the source is not always easily visualized, the method requires personnel available to attend only to that wound, and the technique is useful only for smaller wounds with a clear, single source.

This technique can be combined with a pressure dressing, with or without hemostatic agents, and possible temporary closure. When applied, pressure dressings should not be bulky and should be tight enough to provide hemostasis while maintaining distal

perfusion and sensation. If distal neurovascular status is compromised, the pressure dressing now begins to function as a tourniquet. Some commercial products are available for temporary wound hemostasis. Wound closure clamps essentially grab the wound edges, pull them together, and lock in place. Wound closure clips are placed on the wound margin, typically the scalp, to provide compression on the edges. Both of these devices typically can be applied in a minute or less. The drawbacks of such devices are cost and availability.

Temporizing Mechanical Compression Devices

Multiple hemorrhage control devices exist, including truncal, junctional, extremity, intravascular, and intraperitoneal. These are temporary adjuncts, primarily for the prehospital setting and initial hospital assessment phase, until definitive hemostasis can be achieved.

Extremities Trauma: Tourniquets

Exsanguination from extremity trauma is a preventable cause of death.^{32,33} Tourniquets have been well studied on the battlefield and found to have significant association with lives saved, leading to a policy of all military personnel carrying tourniquets.³³

In 2009, Kragh et al published a prospective study that was conducted in Baghdad over seven months in 2006. They evaluated 2,838 injuries and admitted civilian and military casualties with major limb trauma. A total of 232 patients had 428 tourniquets applied to 309 limbs. Early tourniquet placement, prior to the onset of shock, was associated strongly with survival.³³

Tourniquets serve as the standard of care for control of severe external hemorrhage in the military setting, even though civilian data remain limited.^{34,35} Both the American College of Surgeons Committee on Trauma (ACS-COT) and the American College of Emergency Physicians (ACEP) recommend tourniquets in the setting of life-threatening extremity hemorrhage.^{36,37}

If indicated, placement of a tourniquet before extrication and transport is advised whenever possible. Tourniquets have a few varieties. The common

categories are open or closed, and manual or pneumatic. Open tourniquets do not require the provider to fully cinch around a limb prior to engaging the tourniquet, and they come apart completely for placement around the limb. Pneumatic tourniquets tend to be more expensive than the manual versions. Despite these differences, most studies demonstrate similar hemostasis among the various models when applied properly.^{38,39} Multiple commercial tourniquets are available. Common items, such as belts, sheets, and other cords, may be used, but they are less efficient.⁴⁰ Tourniquet placement should be maintained until definitive surgical management can be accomplished.^{26,37,41}

Tourniquets can provide simple, cost-effective, lifesaving care; however, consideration should be given to certain rare potential complications, such as nerve palsies and ischemia.³³ When placing a tourniquet, it is important to document a neurovascular exam prior to placement, as well as the time at which the tourniquet was placed. Some military studies suggest a limit of two hours, with take down of the device and assessment every two hours.⁴² Other studies have shown limb viability up to six hours with tourniquet use.⁴¹ Additional tourniquets can be applied if the first did not achieve hemostasis. Once hemostasis has been achieved, the tourniquet should not be removed until definitive surgical management is possible.

Junctional Hemorrhage and Other Sites of Significant Blood Loss

Junctional hemorrhage is bleeding that occurs at the junction of an extremity with the abdomen and pelvis that cannot be controlled adequately by an extremity tourniquet.⁴³ Four mechanical devices have been FDA-approved for junctional hemorrhage, but they are not well studied. The Committee on Tactical Combat Casualty Care recommends three of the four devices.⁴³ Another type of junctional hemorrhage control device also has been approved for axillary use.

Meusnier et al evaluated the Combat Ready Clamp (CRoC) compared to the SAM Junctional Tourniquet (SJT) for ease of use and complete interruption of popliteal flow. Both devices were equally effective in arterial occlusion, but the

SJT was preferred by users for ease of application and had quicker “hemostasis” in this small study.⁴⁴ In a study by Rall et al, the Abdominal Aortic and Junctional Tourniquet (AAJT) was able to increase mean arterial pressure (MAP) in hemorrhagic swine without any clear adverse consequences.⁴⁵ These devices have been used and studied primarily in simulation and military settings. Many of these devices require assembly and can be very bulky to store and transport. Their broad applicability to the civilian setting has yet to be demonstrated.⁴⁶

Hemostatic Agents

Since direct manual pressure and tourniquet application are not feasible for all types of injuries, multiple topical hemostatic agents have been developed. These hemostatic dressings can be classified by their mechanism of action: factor concentrators, mucoadhesives, and procoagulant supplementers.⁴⁷ The FDA has approved a number of these agents.⁴⁷ These agents are used widely, but have not been validated or well-studied.

The benefit of these products is that they typically are compact and lightweight, making them easy to store and transport for both in-hospital and out-of-hospital use. Most of these agents have similar efficacies; however, they may be caustic to surrounding tissue. Combat Gauze, Celox Gauze, and Chito Gauze are the only ones deemed safe and efficacious and, thus, considered first-line recommended hemostatic agents by the Committee on Tactical Combat and Casualty Care (CoTCCC).^{48,49,50} These agents should be packed into the wound, and the provider should apply three to five minutes minimum of direct pressure, followed by a pressure dressing.

In 2016, the CoTCCC also proposed the addition of XStat to its hemorrhage control guidelines. XStat is a radiopaque hemostatic sponge system that can be deployed into deep tracks of wounds. Currently it cannot be used on the neck or torso. It is in early phases of use and is fairly costly, but it could reduce the need for extremity tourniquets.^{51,52}

Unstable Pelvic Injuries: Binders

Pelvic fractures can be life-threatening, with mortality reported as ranging

between 7.6% and 50% for open pelvic fractures.⁵³ Pelvic injuries can be overlooked easily in normotensive trauma patients with distracting injuries. A retrospective cohort study that examined blunt trauma between August and December 2011 found a high proportion of missed fractures (31%).⁵³

If pelvic instability exists or if the patient is persistently hypotensive without a clear source, pelvic binding with a pelvic circumferential compression device (PCCD) should be considered. Pelvic circumferential compression can provide tamponade by “closing” the pelvis and reducing the potential volume of the pelvis from nearly 6 L of potential space to 1–2 L.⁵⁴ (*See Figures 1 and 2 for X-rays of pelvis before and after placement of a pelvic binder.*) When an unstable pelvic fracture is suspected or diagnosed, ATLS guidelines advise the use of a PCCD as a temporizing measure until definitive fixation can be achieved.⁸ Several commercial products exist for these purposes, or a simple bedsheet can be used.

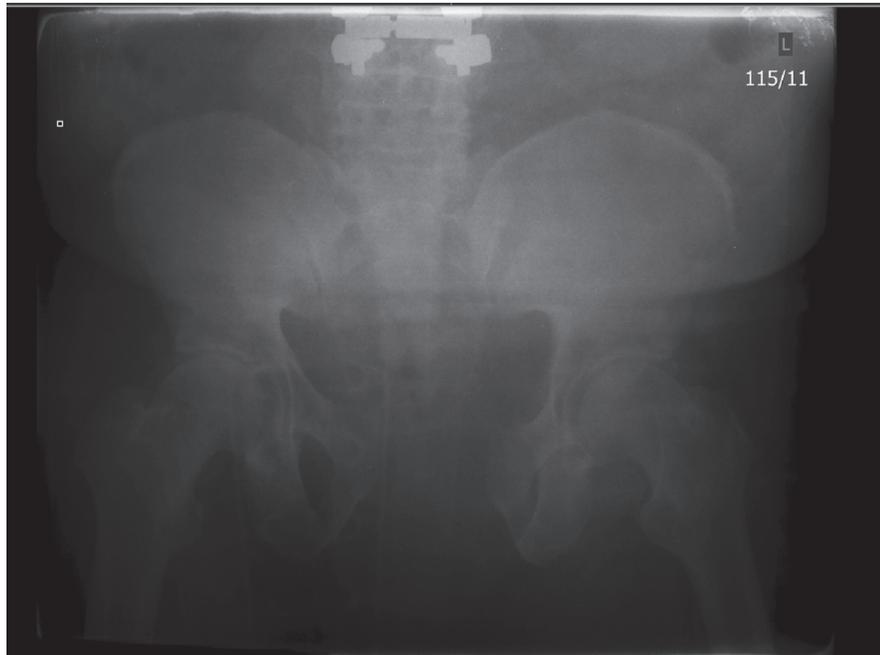
Many studies indicate that when placed correctly, these various modalities have similar efficacies.^{55–59} Appropriate placement is crucial to efficacy. The PCCD should be placed at the level of the greater trochanter, not the abdomen, to optimize compression. In addition, efforts should be made to minimize friction and pressure points on the skin, as this can lead to skin breakdown and ulcerations. Binders should be used only as temporizing measures until definitive hemostasis can be achieved, as prolonged use can cause skin breakdown and nerve damage.⁶⁰

For pelvic injuries that continue to be hemodynamically unstable despite stabilization and closure, further invasive intervention should be implemented, such as external fixation, open fixation, or embolization. (*See Figure 3.*)

Definitive Hemostasis

To optimize care, patients should be transported to a hospital with trauma capabilities as soon as possible. The authors of a systematic review in 2006 showed a 15% reduction in mortality for patients treated in a trauma system, with a reported 50% decrease in preventable deaths.⁶¹ In addition to the

Figure 1. Patient With an APC2 Fracture



There is pubic diastasis of more than 2.5 cm and there is anterior widening of the SI joint.

Source: Uzcategui M, Menaker J. Blunt pelvic trauma. *Trauma Reports* 2014;15:6.

Figure 2. Patient With APC2 Fracture After Placement of a Pelvic Binder



Placement of the pelvic binder with approximation and stabilization of the anterior and posterior elements, resulting in decreased pelvic volume.

Source: Uzcategui M, Menaker J. Blunt pelvic trauma. *Trauma Reports* 2014;15:6.

aforementioned methods of hemorrhage control, which also can be applied in-hospital, once in the hospital, efforts should be made to expedite definitive surgical or angiographic management of bleeding.

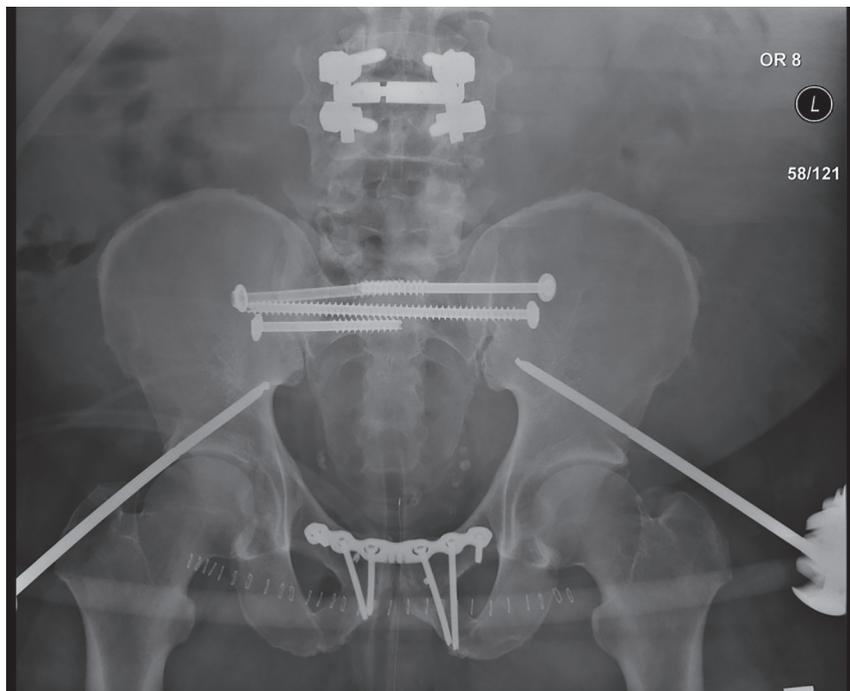
In a study by Clarke et al, in hypotensive patients with isolated intra-abdominal injuries, the degree of hypotension and duration in the emergency department increased mortality by 1% for every three minutes in the emergency department. Meizoso et al studied hypotensive gunshot wound patients, and found that delays greater than 10 minutes increased the likelihood of death by threefold, highlighting the crucial push to the operating room.⁶² To improve morbidity and mortality in the trauma patient, definitive surgery or angiography should not be delayed.

Non-compressible Truncal Hemorrhage

Patients with non-compressible truncal hemorrhage (NCTH) have high mortality rates, from 18% to 50%, and are known to be at risk of imminent decompensation.⁶³ These patients have limited bedside options for stabilization. One option is aortic occlusion (AO), which remains controversial for traumatic shock. The goal of AO is to preserve cerebral perfusion and coronary filling in life-threatening hypotension and hypovolemia due to hemorrhage in the chest.⁶⁴ AO can be obtained in the more traditional method via a resuscitative thoracotomy or endovascularly. Resuscitative thoracotomy is achieved with a large open incision with aortic cross clamping. This technique typically is reserved for patients who have lost vital signs. This dramatic procedure has a poor survival rate of 0% to 15%.⁶³

Comparing open approach, endovascular approach, and resuscitative thoracotomy, Chang et al conducted a multicenter, retrospective study of patients with NCTH. A total of 543 patients with NCTH were treated with open management (n = 309, 31%), endovascular management (n = 166, 31%), and resuscitative thoracotomy (n = 68, 12%). Mortality was 20%, 15%, and 79%, respectively.⁶⁵ Endovascular management is recommended to be reserved for

Figure 3. Internal Fixation of Pelvic Fracture



Patient originally stabilized with external fixation was bridged to definitive stabilization of the anterior and posterior elements with internal fixation.
Source: Uzategui M, Menaker J. Blunt pelvic trauma. *Trauma Reports* 2014;15:7.

more hemodynamically stable patients, whereas open hemorrhage control is recommended for the unstable patient.

Resuscitative endovascular balloon occlusion of the aorta (REBOA) offers a less invasive alternative to open aortic occlusion.^{64,66,67,68} A retrospective case series by Moore et al between October 2011 and September 2015 examined 31 patients who underwent REBOA. A return to spontaneous circulation was observed in 60% of patients who had arrested prior to insertion (n = 10). After REBOA placement and balloon inflation, a significant increase in systolic blood pressure was observed in all patients with vital signs.⁶³ The survival rate in this study was 32%.

Currently, the American Association for the Surgery of Trauma (AAST) Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) registry is prospectively observing patients with AO in traumatic shock at eight Level I Trauma Centers. In one study by Dubose et al, data comparing REBOA and open

AO were collected between November 2013 and February 2015. Overall, hemodynamic improvement was observed after AO in 62.3%. Overall survival was 21%, with no significant difference between REBOA and open AO. Further evidence is needed to understand the true potential of these two methods.⁶⁴

As with open AO, REBOA is not without risk. Rare REBOA complications have been reported, including pseudoaneurysm, embolism, and limb ischemia.⁶⁴ A recent Japanese case series found three cases of vascular injury or ischemia in the placement of 24 REBOA for blunt trauma.⁶³

Adjunctive Agents

Tranexamic Acid (TXA).

The Clinical Randomization of Antifibrinolytic Therapy in Significant Haemorrhage (CRASH-2) trial was a randomized, controlled trial that examined the administration of TXA in 20,211 adult trauma patients.^{69,70} TXA is a synthetic lysine analogue and competitive inhibitor of plasminogen. At

four weeks after injury, all-cause mortality was reduced by 1.5%. When TXA was administered between one and three hours of injury, mortality was reduced by 1.3%, whereas TXA administered after three hours increased risk of death by 1.3%.^{69,70} The EAST guidelines for DCR conditionally recommend early TXA for the severely hemorrhaging trauma patient.⁶

Conclusion

Early identification of massive hemorrhage is essential. Simple yet lifesaving interventions, such as good vascular access, tourniquet placement, and pelvic binding should be used. Imaging and laboratory studies are of little use in the initial evaluation and management of the trauma patient in hemorrhagic shock.

Hemorrhage is a significant cause of death in trauma patients. Many advances have changed the way trauma patients are managed, especially those in hemorrhagic shock. We have come full circle and returned to a more damage control-based system. While much of the research on newer techniques, such as MTP, TXA, REBOA, ROTEM, is still in its early phases, several of these methods show promise in improving outcomes for trauma patients.

Case Conclusions

The 70-year-old male presents after a motor vehicle collision with HR 103, BP 80/p, evident bruising to flank, and unstable pelvis.

What injuries should be considered? What is the best way to stabilize this patient?

His airway, breathing, and pulses in all four extremities are intact. The vital signs, tachycardia, and hypotension suggest significant hemorrhage, even though his heart rate is not extremely high. The unstable pelvis suggests a pelvic fracture. A pelvic binder should be placed to tamponade the pelvis and reduce the potential 6 L of blood loss down to 1-2 L. The flank bruising suggests concern for a retroperitoneal bleed. If there is blood available immediately, this patient would benefit from trauma blood. If there is no blood, minimal crystalloid intravenous fluid should be given with the goal of systolic blood pressure of 80-90s.

In the elderly patient population, it is important to ask about past medical problems, specifically if they are taking blood thinners. Reversal agents can be given to facilitate hemostasis.

Once in the hospital, there can be further evaluation of hemorrhage. In this case, the patient is fluid responsive. The FAST exam reveals no free fluid in the abdomen. A CT scan shows continued extravasation into the pelvis and retroperitoneal hemorrhage. Angiography is performed to stop the bleeding.

The second patient from the same accident is a 20-year-old female with a crush injury, with HR 130, BP 70/p, and a partial right upper extremity amputation.

What injuries should be considered? What is the best way to stabilize this patient?

Her airway and breathing were intact at the scene. Her vital signs indicate significant hemorrhage. A tourniquet was placed proximal to the right upper extremity amputation site, but bleeding continued. Another tourniquet was placed with successful hemostasis. The time the tourniquet was placed was documented. This may be the source of her significant blood loss, but the mechanism and crush injury are concerning for internal hemorrhage. Beyond the tourniquet and initial fluid or blood resuscitation, her transfer to a trauma center should be expedited.

Her vital signs remain unstable on arrival. Despite initial blood and fluid, she remains hypotensive. MTP is activated, with blood products being given in a 1:1:1 ratio of packed red blood cells to fresh frozen plasma to platelets through two large-bore IVs. The crush injury with bruising to her chest and abdomen is concerning for intraperitoneal hemorrhage. FAST reveals significant intraabdominal fluid in the right upper quadrant and left upper quadrant. With her persistent tachycardia and hypotension, she is taken emergently to the operating room for exploratory laparotomy for definitive management. A partial hepatectomy and splenectomy are performed, which stops the bleeding.

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CME/CE 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.

70. CRASH-2 collaborators; Roberts I, Shakur H, Afolabi A, et al. The importance of early treatment with tranexamic acid in bleeding trauma patients: An exploratory analysis of the CRASH-2 randomised controlled trial. *Lancet* 2011;377:1096-1101, 1101.e1-1101.e2.

CME/CE Questions

1. A 37-year-old man had a tourniquet placed on the left upper thigh after a gunshot wound. How long should a tourniquet be left in place before reassessment?
a. As soon as possible

b. 2 hours
c. 10 hours
d. 20 hours

2. A 23-year-old unrestrained driver presents after ejection from a motor vehicle collision with HR 130, BP 70/40, and positive FAST. Resuscitation has been started, but she continues to be hemodynamically unstable. What is the next step?
a. CT scan
b. REBOA
c. Norepinephrine
d. Operative management

3. A 40-year-old motorcyclist presents after a collision. What is your goal systolic blood pressure?
a. 60-70
b. 80-90
c. 120-130
d. > 140

4. All of the following are mechanisms that may lead to significant trauma, *except*:
a. penetrating wound to calf.
b. automobile vs. pedestrian.
c. fall from 20 feet.
d. penetrating wound to chest.

5. Which of the following is true?
a. Pelvic circumferential compression can provide tamponade by "closing" the pelvis.
b. When an unstable pelvic fracture is suspected or diagnosed, ATLS guidelines advise the use of a PCCD as a temporizing measure until definitive fixation can be achieved.
c. Several commercial products exist for these purposes.
d. The PCCD should be placed at the level of the greater trochanter.
e. All of the above

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