EB MEDICINE

EM Critical Care

UNDERSTANDING AND CARING FOR CRITICAL ILLNESS IN EMERGENCY MEDICINE

Volume 1, Number 3

High-Risk Scenarios In Blunt Trauma: An Evidence-Based Approach

Authors

Michael A. Gibbs, MD, FACEP
Professor and Chief, Department of Emergency Medicine, Maine Medical Center, Portland, ME; Tufts University School of Medicine, Boston, MA

Robert J. Winchell, MD, FACS
Chief of Trauma Surgery, Maine Medical Center, Portland, ME; Associate Professor of Surgery, Tufts University School of Medicine, Boston, MA

Peer Reviewers

Michael Bessette, MD, FACEP
Chairman of Emergency Medicine, The Jersey City Medical Center, Jersey City, NJ

Kelly Gray-Eurom, MD, MMM, FACEP
Associate Chair / Associate Professor and Director of Business & Clinical Operations, Department of Emergency Medicine, University of Florida COM – Jacksonville, Jacksonville, FL

John M. Litell, DO
Chief Fellow, Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, MN

Mark Silverberg, MD, FACEP, MMB
Associate Residency Director and Assistant Professor, Department of Emergency Medicine, SUNY Downstate/Kings County Hospital, Brooklyn, NY

Date of original release: October 1, 2011
Date of most recent review: September 10, 2011
Termination date: October 1, 2014
Medium: Print and Online
Method of participation: Print or online answer form and evaluation
Prior to beginning this activity, see "CME Information" on the back page.

Abstract

Most injuries in the United States result from blunt mechanisms, including motor vehicle crashes and falls as well as from interpersonal violence. Patients who suffer severe blunt trauma typically experience a significant force vector, rapid deceleration, or both. Under these circumstances, multiple potentially life-threatening injuries are likely, requiring careful prioritization of diagnostic and therapeutic interventions. In the unstable patient with multisystem blunt trauma, a useful team strategy: (1) rapidly identifies the cause(s) of traumatic shock, (2) identifies and prioritizes "time-dependent" injuries in need of definitive therapy, and (3) orchestrates an immediate care plan that thoughtfully matches ongoing resuscitation with the identified injuries and the patient's clinical course. This issue of *EMCC* will provide a logical "menu" for the rapid evaluation and management of traumatic shock. Three "high-risk" clinical scenarios will then be discussed: blunt aortic injury (BAI), pelvic ring fractures, and blunt abdominal trauma. These scenarios were chosen because of their lethality and call for complex decision making. The essentials of emergency department (ED) diagnosis and management will be reviewed for each.

Case Presentations

You are on duty at a community hospital ED when 2 patients arrive simultaneously after a high-speed crash between a pickup truck and a small sedan. Both *patients were unrestrained. With the assistance of a partner and the on-call general surgeon, your ED team performs rapid assessments of both patients, with the following initial findings:*

Patient 1 *is the 33-year-old male driver of the pickup truck. The patient indicates that his chest struck the steering wheel, and he reports chest and back pain. He is restless and diaphoretic, his blood pressure reading is 95/72 mm Hg, and his pulse rate is 115 bpm. Upon examination, scattered contusions are observed on his chest and abdomen. The patient's breath sounds are equal, and his abdomen is diffusely tender but not distended. He has no long bone fractures and no neurologic deficit. A supine chest x-ray reveals a wide mediastinum.* ***(See Figure 1.)*** *A pelvic x-ray shows no fractures; however, a FAST examination reveals free fluid in the Morison pouch and around the spleen. As a result of his persistent agitation, the patient is intubated.*

Patient 2 *is the 26-year-old male driver of the small sedan. He reports severe lower abdominal and pelvic pain and screams out with any movement of the backboard splint. His blood pressure reading is 84/60 mm Hg, and his pulse rate is 109 bpm. An examination reveals that the patient's lungs are clear, his abdomen is diffusely tender, there is severe pain on pelvic compression, and he has an obvious closed fracture of the right tibia/fibula with preserved distal pulses and neurologic function. The results of a supine chest radiograph are normal, and a pelvic x-ray reveals an obvious fracture.* ***(See Figure 2.)*** *Results of a FAST examination are negative for free fluid in the peritoneum and pericardium.*

Your facility has limited resources, and rapid decisions need to be made regarding stabilization and transfer. The team gathers to answer several important questions, including the following:

- *Is additional ED testing needed?*
- *What are the essentials of ED stabilization?*
- *How should these 2 patients be prioritized for interfacility transfer?*

Introduction

Injury is a pressing national health issue in the US. Trauma is the leading cause of death in persons aged 1 to 44 years and is among the top 10 causes in all decades of life. In 2007, a total of 182,479 persons died in the US as a result of injury.[1] Most trauma in this country results from blunt mechanisms (primarily vehicular crashes and falls) as well as from interpersonal violence.[1]

These facts provide a compelling argument for investing in systems of care that optimize the early management of the injured patient. Although there are many required system investments, one of the most important for emergency clinicians is continual professional development.

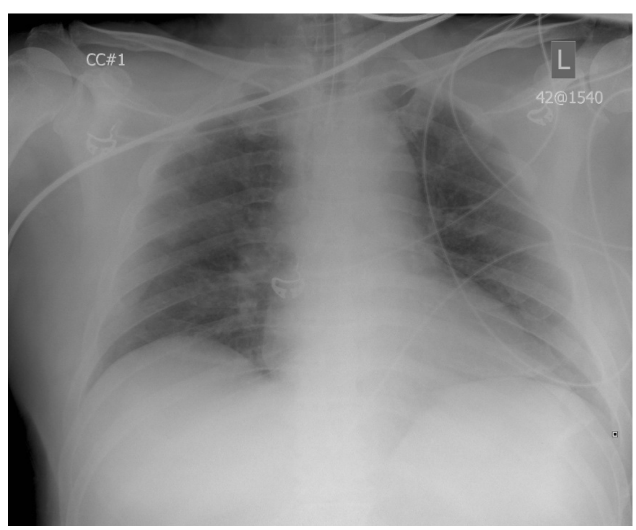
Management of the critically injured patient is fast moving, complex, and diverse. Few disease states demand more rapid decision making, targeted and effective interventions, and teamwork. The emergency clinician must possess bedside clinical acumen, a sophisticated understanding of the strengths and weaknesses of relevant diagnostic studies, excellent communication skills, and the ability to lead a well-coordinated team smoothly through crises.

This issue of *EMCC* will focus on the management of the critically ill blunt trauma patient. A future issue will address high-risk scenarios in penetrating trauma. *EMCC* will also dedicate an entire upcoming issue to the management of severe traumatic brain injury.

Critical Appraisal Of The Literature

A comprehensive search of the literature published from 1950 to the present on the topic areas addressed in this publication was performed using Ovid MEDLINE® and PubMed. The following topics and search terms were used: *shock in the trauma patient* (*traumatic shock, traumatic hypotension, blunt chest injury, massive hemothorax, blunt abdominal injury, massive hemoperitoneum, damage control surgery*); *blunt aortic injury* (*aortic trauma, aortic injury, blunt aortic trauma, blunt aortic injury*); *pelvic ring injury* (*pelvic trauma, pelvic fracture, pelvic hemorrhage*); and *blunt abdominal trauma* (*blunt abdominal trauma, hemoperitoneum, intraperitoneal hemorrhage, splenic injury, hepatic injury*). More than 250 articles were analyzed, providing the background for further literature review. The Cochrane Database of Systematic Reviews, Eastern Association for the Surgery of Trauma (EAST) Guidelines, Western Trauma Association (WEST) Guidelines, American College of

Figure 1. Chest X-ray For Patient 1



This chest x-ray demonstrates a wide mediastinum, blurring of the aortic knob, and loss of the aortopulmonary window.

Emergency Physicians Clinical Policies, Annals of Emergency Medicine Evidence-Based Emergency Medicine reviews, and National Guideline Clearinghouse (www.guideline.gov) were also consulted.

Emergency Department Stabilization Of Injured Patients – A Basic Approach

Trauma is a heterogeneous condition. Nevertheless, decisions that must be made during the early phases of care can be reduced to a straightforward strategy: Problems must first be identified and managed in the order of their immediate threat to life, followed by the immediacy of their threat to function. This process can be distilled to the steps listed in **Algorithm 1 (on page 4)**, which are independent of the specific injury involved.[2] As the resuscitation progresses, the team must remain focused on these fundamental priorities.

Practical Approach To Shock In Blunt Trauma Patients

The causes of shock after injury are numerous, and they may coexist. Effective ED care mandates rapid identification and prioritization of injuries in the overall context of the case and careful ongoing monitoring of the patient's response to resuscitation.

Defining Shock

From a physiologic standpoint, shock results when oxygen delivery is inadequate to meet tissue demands. It follows that the correct approach to treating shock is to restore tissue perfusion rather than to simply achieve a higher systolic blood pressure.

An understanding of certain fundamental principles facilitates a more sophisticated approach to treating injured patients at risk of shock.

First and foremost, the presence of shock should never be simplistically equated with a systolic blood pressure reading < 90 mm Hg. As a result of adaptive postinjury responses, patients often maintain a relatively normal blood pressure reading despite significant hypoperfusion, and hypotension is typically a late finding that indicates significant decompensation. The presence of hypotension does predict morbidity. In a study of 145 severely injured ED patients, patients with a single systolic blood pressure reading < 105 mm Hg were 12.0 times more likely to need immediate therapeutic intervention than were patients with a systolic blood pressure reading ≥ 105 mm Hg (confidence interval [CI], 2.6-59.2; $P = 0.002$).[3] Recent data suggest that a "normal" blood pressure in patients over the age of 65 years is even higher than 105 mm Hg and that a higher blood pressure threshold should be used as a marker for increased risk of injury.[4]

Second, the recognition of clinical shock requires the complex integration of numerous data points including the mechanism of injury and the patient's overall appearance, vital signs, level of mentation, peripheral perfusion, and urine output. During the early phases of resuscitation, it is crucial to rapidly assemble and interpret these data.

Third, these clinical parameters alone do not adequately quantify the degree of shock or the response to shock therapy.[5] This principle is especially pertinent in elderly patients and in those with limited cardiovascular reserve.[4] In the severely injured blunt trauma patient, clinical parameters should be coupled with objective markers of tissue perfusion (eg, serum lactate level or base deficit). The addition of serum markers to the physical examination significantly improves the ability to assess tissue perfusion, and serial measurements can help to guide resuscitation.[6,7]

Finding The Cause

The causes of *life-threatening* shock in patients who have experienced blunt trauma are relatively few. When faced with a critically injured trauma patient, it is useful to divide the potential causes of shock into 2 basic categories: hemorrhagic and nonhemorrhagic. **(See Table 1 on page 4.)**

As the resuscitation unfolds, a focused physical examination and thoughtful use of diagnostic testing will help elucidate the most important cause(s) of traumatic shock. After these exercises, if the patient fails to respond or deteriorates in the setting of a functioning and controlled airway, the emergency clinician may always return to the "shock menu" in **Table 1** and reassess the patient for problems that may have been overlooked.

Figure 2. Pelvic X-ray For Patient 2

This pelvic x-ray demonstrates a severe anterior-posterior compression ("open book") pelvic fracture with significant diastasis of the pubic symphysis and posterior ring disruption.

When an etiology is sought, a computed tomography (CT) scan may seem like the logical diagnostic solution in all circumstances. Third- and fourth-generation multidetector technology offers outstanding image quality, rapid acquisition time, and impressive reformatting capabilities. Despite the clear value offered by CT in trauma, however, it is important to recognize when the risks of delay in definitive treatment associated with the study outweigh the potential benefits (ie, actionable diagnostic information). A common misconception is to assume that a CT study takes "only a few minutes," but the overall time (including patient transport, transfer to and from the scanner, positioning, set up for contrast administration, and image preparation and interpretation) is rarely less than 30 minutes and can be substantially longer. The implications of contrast and radiation exposure should also be considered.

A recent National Trauma Data Bank® study assessed outcomes in adult trauma patients who arrived in the ED with a systolic blood pressure reading < 90 mm Hg and required laparotomy within 90 minutes of arrival. Patients who underwent abdominal CT had longer times to the operating room (OR) and a higher crude mortality rate than those who did not undergo CT (45% vs 30%, $P = 0.001$). When laparotomy could have occurred within 30 minutes of arrival but was delayed for imaging, the abdominal CT was associated with more than a sevenfold higher risk of death than for patients who received a laparotomy within 30 minutes of arrival (odds ratio, 7.6; $P = 0.038$).[8]

The key is to strike a balance between bedside testing and more definitive diagnostic modalities. Our bedside "diagnostic toolbox" contains several tools including chest radiography, pelvic radiography, and focused assessment with sonography for trauma (FAST). The FAST has effectively replaced diagnostic peritoneal lavage (DPL) in the evaluation of suspected hemoperitoneum. As a result, DPL training has been deemphasized in emergency medicine training programs. Nonetheless, DPL remains a valuable test in experienced hands when ultrasound is not immediately available or its results are equivocal. In the persistently unstable patient, for example, a DPL "aspirate" of > 10 mL of gross blood is an indication for immediate laparotomy.[9]

Table 2 outlines the basic binary questions that can be reliably answered using bedside testing. In the hypotensive trauma patient, the results of the FAST (either positive or negative for free fluid) provide rapid and effective directional guidance in resuscitation and decision making.[10-24]

Optimizing Resuscitation

Normal saline solution and Ringer lactate solution have been the fluids of choice for initial blunt trauma resuscitation, but some evidence suggests that coagulopathy develops very early in the course of hemorrhage and that aggressive efforts to address this may reduce morbidity and mortality.[25] Decisions about when to transfuse and the type of product to infuse (eg, packed red blood cells [pRBCs], whole blood, fresh frozen plasma [FFP], specific clotting factors, platelets) are complex and should be based on the patient's clinical status, the response to resuscitation efforts, and the anticipated ongoing blood loss from the injuries at hand.

A growing body of literature has addressed the concept of massive transfusion, defined as the administration of ≥ 10 U of pRBCs within a 24-hour period. Because massive transfusion is required in only 1% to 3% of civilian trauma patients, institutional protocols should be developed to facilitate execution of this low-frequency intervention. Under ideal circumstances, a protocolized transfusion strategy begins in the ED and continues in the OR, angiography suite, or intensive care unit. When massive transfusion is anticipated, accumulating evidence suggests that a pRBC to platelet to FFP ratio of 1:1:1 may be beneficial. In several observational studies, this approach has resulted in lower overall transfusion requirements, lower incidence of coagulopathy, and lower mortality.[26-28] There is no compelling evidence that colloid therapy improves outcomes.[29]

The goal of volume resuscitation has been to restore circulated intravascular volume and organ

Algorithm 1. A Basic Approach

Step 1: Effectively manage the airway and optimize oxygenation.

↓

Step 2: Identify and control immediate threats to central perfusion.

↓

Step 3: Identify and address severe intracranial injuries.

↓

Step 4: Identify and control other potentially life-threatening thoracic and abdominal injuries.

↓

Step 5: Identify and control potentially limb-threatening injuries.

↓

Step 6: Identify and treat noncritical injuries.

Table 1. Causes Of Shock In The Trauma Patient

Hemorrhagic	Nonhemorrhagic
• External bleeding	• Tension pneumothorax
• Hemothorax	• Pericardial tamponade
• Hemoperitoneum	• Myocardial contusion
• Retroperitoneum (pelvic fracture/renal injury)	• Spinal cord transection/injury
• Long bone fracture	• Coincident medical event (eg, cardiac event, gastrointestinal tract bleed, vasoactive medications)

perfusion. Historically, a systolic blood pressure > 100 mm Hg has been used as a surrogate endpoint for resuscitation. It has been recognized that this approach may be misdirected in patients with ongoing active hemorrhage, leading to increased bleeding, dilutional coagulopathy, and increased mortality.[30] This realization has spurred the use of hypotensive resuscitation in patients in whom definitive hemostasis cannot be achieved. The goal of this strategy is to temper resuscitation endpoints to a systolic blood pressure reading of 80 to 90 mm Hg until definitive control of hemorrhage can be achieved. In a landmark study of 717 penetrating trauma patients, Bickell et al demonstrated that hypotensive resuscitation was associated with a significant reduction in mortality and a trend toward reduced complications.[31] A recent study has corroborated these findings.[32] Hypotensive resuscitation is the preferred resuscitative strategy in hemodynamically unstable patients with penetrating wounds while awaiting emergency surgical hemostasis. (This will be discussed in detail in a future issue of *EMCC* titled "High-Risk Scenarios In Penetrating Trauma.") Though the efficacy of hypotensive resuscitation in the blunt trauma patient has not been demonstrated in a similar study, one could infer a similar value to hypotensive resuscitation in blunt trauma patients with uncontrolled hemorrhage and a delay in definitive hemostasis. However, this hypothesis merits further study before this approach can be advocated. It must be emphasized that hypotensive resuscitation is an emergency temporizing measure only and that it is not a substitute for rapid definitive surgical hemostasis.

Essentials For The Community Physician

Managing a critically injured patient in an environment with limited resources is a major challenge. It is essential that the clinician working in such a facility be familiar with available resources and how to access them and to know when local resources are exceeded. Further, it is equally important that smaller and less resource-rich facilities have established protocols and procedures in place to mobilize available resources to deal with critically injured patients and that these procedures be regularly practiced.

The desire to effectively diagnose injuries often collides with the need to avoid delays and to facilitate early definitive management. In the patient who is unequivocally in shock, or who will clearly require transfer to a higher level of care, diagnostic maneuvers should be limited to those that will lead to an immediate therapeutic intervention (eg, chest x-ray or FAST demonstrates a tension pneumothorax and leads to immediate tube thoracostomy; pelvic x-ray demonstrates an "open book" pelvic fracture and leads to external stabilization; FAST demonstrates major intraperitoneal hemorrhage and leads to early transfusion). **Tables 1 and 2** provide the framework for this evaluation. Unless the emergency clinician plans to act on the findings revealed by CT imaging, this should generally be avoided in the unstable patient or the patient in whom the need for transfer has already been established. Regional protocols and communication pathways will assist the community physician with early diagnostic decision making.

As described in **Algorithm 1**, the airway should be secured early and certainly before transfer. Adequate intravenous (IV) access should be established, and resuscitation should be guided by the injuries at hand, the patient's anticipated course, and the patient's response to treatment. Early contact and effective communication with a regional Trauma Center will ensure that activation is proportional to the needs of the patient.

Key Points

- The determination that a trauma patient is "in shock" is a complex one, and it is not always synonymous with a systolic blood pressure < 90 mm Hg
- The accurate diagnosis of the cause(s) of shock begins at the bedside with a targeted physical examination and the thoughtful use of diagnostic testing (including chest radiography, pelvis radiography, and ultrasound). The use of objective serum markers of tissue perfusion (eg, serum lactate level or base deficit) can be helpful in identifying "subclinical" shock and in following the patient's response to resuscitation.
- In patients requiring massive transfusion (defined as the administration of ≥ 10 U of pRBCs in 24 hours), institutional protocols defining blood product ratios have improved outcomes. When massive transfusion is employed, use of a pRBC to platelet to FFP ratio of approximately 1:1:1 may result in decreased need for blood products.

Table 2. Bedside Testing In The Hypotensive Trauma Patient

Test	Essential Questions to be Answered
Chest radiography	Is there a tension pneumothorax or massive hemothorax? Is there evidence suggestive of aortic injury?
Pelvis radiography	Is there pelvic ring disruption? What is the risk of hemorrhage?
Focused assessment with sonography for trauma (FAST)	Is there sonographic evidence of: Pneumothorax? Hemothorax? Hemopericardium? Hemoperitoneum?
Diagnostic peritoneal aspiration (DPA)[a,b,c]	Is there hemoperitoneum?

[a]Aspiration of gross blood is diagnostic for hemoperitoneum.
[b]FAST (if available) is the preferred approach.
[c]The safe and effective performance of DPA requires experience.

High-Risk Scenarios In Blunt Trauma

Blunt Aortic Injury

Blunt aortic injury is a commonly lethal injury in blunt trauma. This injury is primarily associated with mechanisms involving significant frontal or lateral deceleration, usually a motor vehicle crash or fall from a height. Aortic injuries occur at points where the great vessel is relatively fixed and therefore subject to shearing forces following abrupt deceleration. The predominant site of injury is the aortic isthmus, adjacent to the attachment of the ligamentum arteriosum.[33,34]

Although restraints and airbags have decreased the overall incidence of traffic fatalities, the percentage of fatalities from BAI is unchanged at 20%.[35,36] Furthermore, crash engineering data identify failure to use restraints and misuse of restraints as persistent and significant risk factors for BAI.[37]

When assessing a critically injured blunt trauma patient at risk for BAI, the treating team must answer 2 important questions:

- What is the best way to make the diagnosis?
- How should BAI be managed in the context of multisystem trauma?

The diagnosis and management of BAI have evolved significantly over the last decade, primarily as a result of advances in the resolution of CT imaging and the development of endovascular techniques for repair. Two prospective multicenter studies by the American Association for the Surgery of Trauma (AAST) — AAST1, published in 1997,[38] and AAST2, published in 2008[39] — provide comprehensive descriptions of this evolution.[40] Each study team collected detailed information about patient demographics, diagnostic testing, and definitive management of traumatic injuries; AAST1 enrolled 274 patients from 50 US trauma centers over a 30-month period (1994-1996), and AAST2 enrolled 193 patients from 18 participating centers over a 26-month period (2005-2007). The results of the studies inform the following discussion. For a summary of published guidelines regarding diagnostic testing in blunt trauma, **see Table 3.**

What Is The Best Way To Make The Blunt Aortic Injury Diagnosis?

Chest Radiography

Chest radiography has been the traditional screening tool for BAI. The numerous radiographic findings described include the following:

- Mediastinal width > 8 cm
- Loss of the aortopulmonary window
- Indistinct aortic knob
- Presence of a left-sided pleural cap
- Rightward deviation of the trachea and/or nasogastric tube
- Depression of the left main bronchus

Table 3. Published Guidelines For Diagnostic Testing In Blunt Trauma

Organization	Topic	Type of Guideline	Recommendations
American College of Emergency Physicians, 2011[24]	Bedside Testing in Unstable Patients with Blunt Trauma Injury and Suspected Abdominal Injury	Evidence based (Level I)	Bedside ultrasound (FAST), when available, should be the initial diagnostic modality in identifying the need for emergency laparotomy.
Eastern Association for the Surgery of Trauma, 2000[9]	Diagnosis and Management of BAI	Evidence based (Level II)	Blunt aortic injury should be considered in all motor vehicle crash patients, regardless of the direction of impact. The most useful findings for BAI on chest radiograph are widening of the mediastinum, an obscured aortic knob, and opacification of the aortopulmonary window. An IV contrast CT scan is the test of choice for diagnosing BAI.
Western Trauma Association, 2008[41]	Bedside Testing and Management in Unstable Patients with a Blunt Trauma Injury and Pelvic Trauma	Evidence based (Levels I and II)	An AP pelvis radiograph and FAST (or DPA) should be performed early. 1. If results of the FAST (or DPA) are positive for hemoperitoneum, the patient should go to the OR. 2. If results of the FAST (or DPA) are negative for hemoperitoneum: • Pelvic stabilization of open injuries should be performed early. • Patients who remain unstable should undergo urgent angiography. • Patients who stabilize with angiography should then undergo a CT scan.

Abbreviations: AP, anterior-posterior; BAI, blunt aortic injury; CT, computed tomography; DPA, diagnostic peritoneal aspiration; FAST, focused assessment with sonography for trauma; IV, intravenous; OR, operating room.

In both AAST1 and AAST2, the first 3 features on this list were by far the most common, with a wide mediastinum found in 85% of patients with BAI, loss of the aortopulmonary window in 40%, and an indistinct aortic knob in 25%.[38,39] **Figure 3B** demonstrates these findings in a young patient with an aortic injury; **Figure 3A** shows a normal chest x-ray *from the same patient* that was obtained 6 months before the injury.

Despite the valuable clues that a chest radiograph can provide, it is an imperfect tool in the detection of BAI, with reported sensitivities varying widely from 56% to 93%.[35,36,38,39] These statistics have led several authors to suggest that additional imaging of the chest should be routine in patients at risk for BAI.[42,43] Although no randomized controlled studies unequivocally support this stance, it is logical to aggressively evaluate this catastrophic injury.

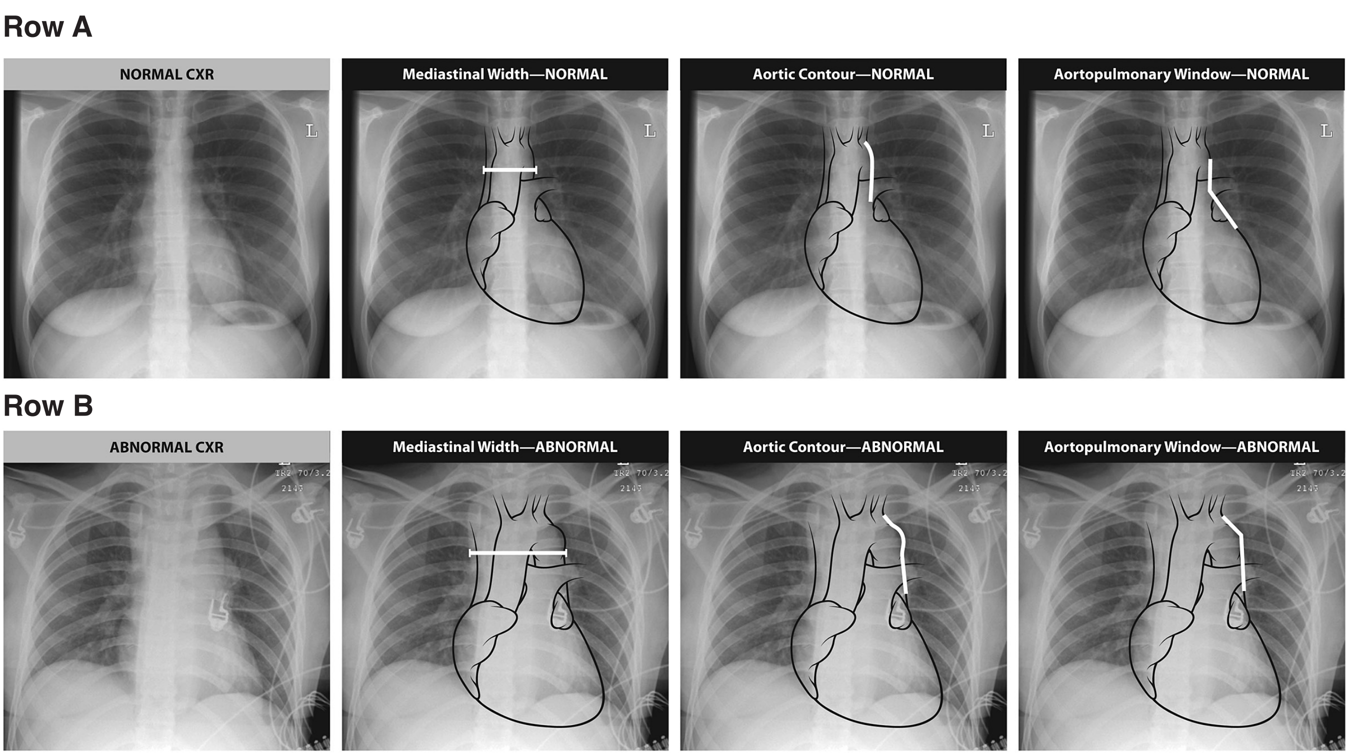
Definitive Testing

In years past, patients considered to be high risk for BAI underwent aortography, typically ordered on the basis of an abnormal finding on chest radiograph or mechanism of injury alone. With the advent of third- and fourth-generation multidetector (spiral) CT, that invasive diagnostic approach has been virtually eliminated. In AAST1, aortography was used in 87% of patients and CT in only 35%; in AAST2, CT was the primary diagnostic modality (93% of patients), and aortography was used in only 8% of patients.[38,39]

With contemporary sensitivities approaching 100%, CT is the current criterion standard in the diagnosis of BAI. Given the high sensitivity, ease of performance, and relatively low risk of CT, it should be ordered in all patients with a chest radiograph suggestive of BAI. Computed tomography should also be broadly used in patients with severe blunt trauma to the chest, especially those with a history of frontal or lateral deceleration, even when results of the chest radiograph are normal. Conventional biplanar angiography has largely been supplanted by CT angiography and is rarely utilized except in special circumstances at the discretion of the operating surgeon.

Transesophageal echocardiography (TEE) can also be useful in the detection of BAI, especially in patients who are too unstable to leave the resuscitation suite. It is also a logical strategy for intraoperative evaluation when patients must travel rapidly to the OR for laparotomy or craniotomy. Transesophageal echocardiography is also a useful strategy in patients with significant contrast allergies. That being said, it is important to recognize that TEE is operator dependent. In a 2004 review of published trials describing the use of TEE in aortic injury, sensitivities varied widely (56%-99%), and this variation was primarily a function of how often the test was performed at the institution.[44] Translating this finding to clinical

Figure 3. Chest X-ray



Chest x-ray interpretation for suspected blunt aortic injury (BAI) should focus on the evaluation of: (1) mediastinal width, (2) aortic contour, and (3) the appearance of the aortopulmonary window. The top x-ray is normal, as are these 3 features. The bottom x-ray was obtained in the same patient 6 months later, after BAI. The mediastinum is widened, the aortic contour is disrupted, and the angle of the aortopulmonary window is distorted and reversed.

practice, TEE is a useful diagnostic tool if clinicians are experienced, but it is error prone if they are not. Transesophageal echocardiography should be used primarily in circumstances where a CT scan cannot be obtained or as an adjunct in the evaluation of suspicious lesions identified with CT.

How Should Blunt Aortic Injury Be Managed In The Context Of Multisystem Trauma?

Consider Patient 1, the 33-year-old male with diffuse chest pain, signs of shock, a wide mediastinum on chest x-ray, and hemoperitoneum on FAST. How should the immediate and definitive management of this patient's injuries proceed?

The first step is to recognize that the patient's hypotension is most likely caused by a source other than aortic injury. Although a small number of patients will experience exsanguinating hemorrhage from a BAI, this scenario is most commonly associated with scene mortality. Patients who survive to hospital evaluation typically have a contained pseudoaneurysm. Patients with active bleeding usually present with massive hemothorax, often in the absence of rib fractures. A diligent search for intracavitary hemorrhage and nonhemorrhagic causes of shock should proceed as outlined previously. In the case of Patient 1, the presence of FAST findings positive for free fluid and the lack of hemothorax should trigger CT evaluation for intraperitoneal injury if he is stable enough to do so or exploratory laparotomy if he is not.

The second step is to recognize that in the setting of BAI, hemorrhage control of other injuries and the surgical correction of dangerous space-occupying intracranial lesions should come first. As part of this approach, all injuries should be "staged" and repaired in a defined sequence. Because BAI typically occurs with other important injuries, staging of definitive repairs should play a major role in decision making.

Once other coincident injuries have been identified and stabilized, evidence supports the pharmacologic control of blood pressure and of the heart rate until definitive aortic repair is accomplished. This reduces shear stress on the aortic wall and decreases the risk of rupture.[9,45] Short-acting beta-blockers (eg, esmolol) are the agents of choice. Given the complexities of comprehensive injury identification, staging, and stabilization, this step may take place *after* patient transfer to a regional trauma center.

A growing and convincing body of literature has demonstrated improved outcomes with endovascular repair of the aorta when compared with open surgical repair. In AAST1, 100% of patients underwent open repair. In AAST2, most repairs (64.8%) were performed with endovascular stent grafts. In the AAST2 cohort, endovascular stent graft repair was associated with reductions in mortality (13% vs 22%) and postoperative paraplegia (1.6% vs 8.7%). Subsequent systematic reviews of the literature have confirmed these findings.[46-48]

As noted previously, the diagnosis and stabilization of BAI are complex exercises. Effective management requires a high degree of trauma expertise and experience.

Key Points For Blunt Aortic Injury

- A BAI is a potentially lethal injury that should be considered in all blunt trauma patients who experience major deceleration, including motor vehicle crashes, automobile-versus-pedestrian injuries, and falls from a significant height.
- A CT scan is the current criterion standard in the diagnosis of BAI. Although TEE can be useful, it is operator dependent.
- Chest radiography is a useful screening tool in the diagnosis of BAI. In large trials, the most important radiographic findings suggestive of BAI were: (1) widening of the mediastinum (> 8 cm), (2) blurring of the aortic knob, and (3) loss of the aortopulmonary window.
- A BAI seldom occurs in isolation. A diligent search for other potential causes of shock and time-sensitive conditions is essential.
- In the setting of BAI, other causes of ongoing hemorrhage and/or neurosurgical lesions should be rapidly identified. Management of these conditions often requires thoughtful staging of interventions and is best done in experienced trauma centers.

Pelvic Ring Fractures

Because of the inherent strength of the pelvic bones and ligaments, pelvic ring fractures are a marker of major energy transfer. Pelvic ring fractures are also an independent risk factor for death in patients with blunt trauma.[49] Patients with pelvic trauma and shock on presentation have a mortality rate as high as 40% to 50% despite optimal resuscitation.[41,50]

When assessing a critically injured blunt trauma patient with a pelvic ring fracture, the treating team must answer several important questions:

- What type of fracture(s) is it?
- What immediate steps should be taken (eg, should the pelvis be stabilized)?
- What is the role of bedside testing?
- Where should the patient go next?

What Type Of Fracture(s) Is It?

Pelvic fracture classification has important implications in early decision making. This classification can be done with a single anterior-posterior (AP) pelvis radiograph or the scout view on an abdominal/pelvic CT scan. The objectives are to predict the likelihood of pelvic hemorrhage and associated injuries, to assess the need for urgent pelvic stabilization, and to communicate effectively with downstream providers. The most practical classification system is based on the direction of the causative force vector and divides pelvic ring fractures into 3 types:

(1) lateral compression injuries, (2) AP compression injuries, and (3) vertical shear injuries.[51]

Lateral Compression Injuries

Lateral compression injuries are the most common type of pelvic fracture, accounting for roughly two-thirds of cases.[51] As the name suggests, the causative force is delivered laterally, as might occur in a "T-bone" motor vehicle crash or when a pedestrian is struck from the side. Laterally directed forces cause inward displacement of the ipsilateral hemipelvis, hinging on the sacroiliac joint. **(See Figure 4a.)** Radiographic features of lateral compression injuries **(see Figure 4b)** include the following:

- Distinctive horizontal fractures of the anterior pelvic ring
- Crush fractures of the ipsilateral sacrum or iliac wing

Anterior-Posterior Compression Injuries

Anterior-posterior compression fractures account for 20% to 30% of pelvic ring injuries.[51] The force vector is delivered directly to the front of the patient, as might occur during a head-on motor vehicle crash or when a pedestrian is struck in the same manner.

A force vector delivered to the anterior elements of the pelvic ring causes diastasis of the symphysial ligaments and/or fracture of the pubic rami. With progressive disruption of the anterior elements of the pelvis, the posterior ring is pulled apart, usually through the sacroiliac joint. These injuries are often referred to as "open book" pelvic fractures. **(See Figure 5a on page 10.)** Radiographic features of AP compression injuries **(see Figure 5b on page 10)** include the following:

- Symphysial diastasis, vertical fractures of the anterior ring, or both
- Varying degrees of sacroiliac joint disruption and/or fractures through the iliac wing

Vertical Shear Injuries

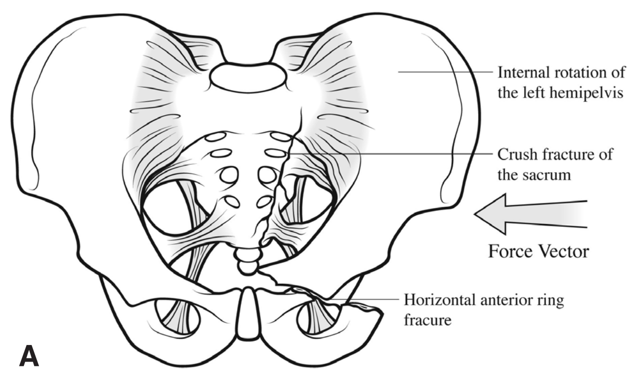
Vertical shear injuries, which occur when a vertically directed force is transmitted via the extended lower extremity, are rare. Vertical shear injuries may result from a fall on the extended extremity or from a head-on motor vehicle crash in which the occupant has the leg braced against the brake pedal or the floorboard. Significant vertically oriented forces cause disruption of both the anterior and posterior pelvic rings, forcing one hemipelvis up relative to the other. Severe ligamentous injury is the rule. **(See Figure 6a on page 11.)** Radiographic features of vertical shear injuries **(see Figure 6b on page 11)** include the following:

- Severe posterior disruption manifesting as complete sacroiliac disruption, a vertical sacral fracture, or an iliac wing fracture
- Proportional disruption of the anterior ring in the form of vertical symphysial diastasis or pubic rami fractures
- "Combined" injury patterns are common, especially AP compression/vertical shear injuries **(See Figure 7.)**

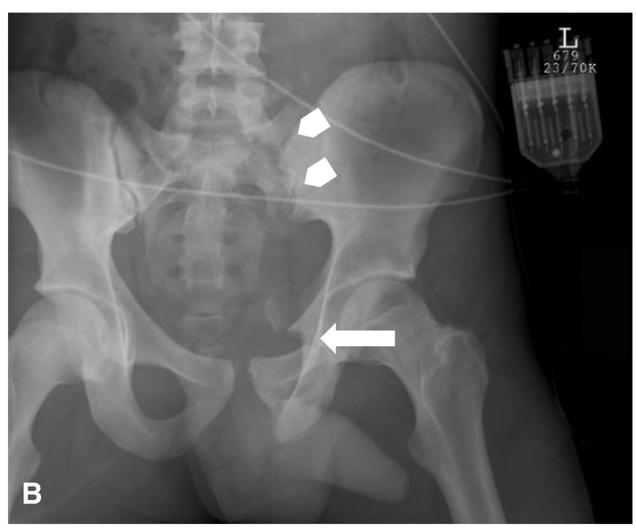
Immediate Steps: Should The Pelvis Be Stabilized?

Once the fracture pattern has been appropriately characterized, it is important to ascertain if the injury has caused the pelvic ring to open or not. Generally speaking, fractures that open the pelvic ring are associated with a significantly greater degree of hemorrhage and a higher mortality rate.[52] Two reasons account for this: First, pelvic vessels are more likely to be torn when the pelvic ring is pulled apart by the inciting force; second, the potential space for hemorrhage (ie, the pelvic volume) increases as the diameter of the pelvic ring increases. Injuries causing AP compression fractures and/or vertical shear fractures have a much higher propensity to open the pelvic ring than do lateral compression injuries. Regardless of the fracture pattern, any injury

Figure 4. Lateral Compression Injury



The laterally-directed force causes inward rotation of the left hemipelvis.

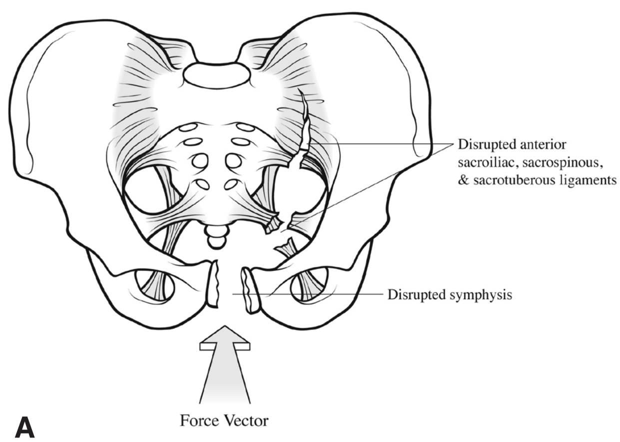


A horizontal fracture of the anterior pelvic ring (arrow) and ipsilateral crush fracture of the sacrum (arrowheads) indicate that the causative force was delivered from the patient's left.

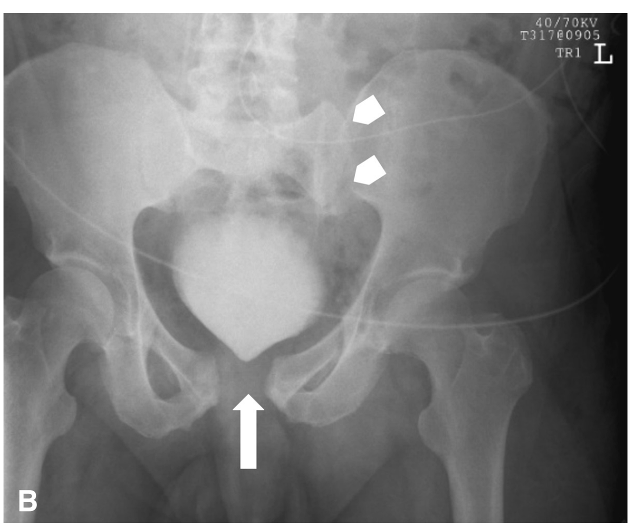
that opens the pelvic ring must be treated with the highest degree of urgency. Adequate IV access, aggressive resuscitation, and measures to stabilize the pelvis should be instituted immediately.

Pelvic stabilization reduces the potential for ongoing hemorrhage by decreasing "pelvic volume" and providing a tamponade effect. This intervention has been shown to decrease transfusion requirements and subsequent morbidity and mortality.[53,54] External compression can be achieved rapidly by wrapping a sheet around the pelvis at the level of the greater trochanter or by the application of a commercial compression device. Such bedside stabilization should be undertaken very early in patients with suspected pelvic fracture, especially if there is associated hypotension. The device can be easily

Figure 5. Anterior-Posterior Compression Injury



The anteriorly-directed force disrupts the pubic symphysis and ligaments of the posterior pelvic ring. This "opens" the pelvic ring and increases pelvic volume.



Pubic diastasis (arrow) and disruption of the left sacroiliac joint (arrowheads) indicate that the causative force was delivered against the front of the patient.

removed after diagnostic testing if no significant fracture is found.

Available compression devices have differing strengths and weaknesses. Sheets are easy to apply and can be held in place with a knot or towel clips. External fixation devices, which are drilled into the pelvic bones, are much more stable, although some are large and do not fit in the CT scanner while smaller models may contribute to significant imaging artifact and reduce CT image quality. Pelvic binders are effective and relatively cheap and can be applied by prehospital personnel.

What Is The Role Of Bedside Testing?

As with all critically injured blunt trauma patients, those with pelvic injuries will benefit from the rapid diagnosis of the predominant cause(s) of shock. Because major chest and abdominal injuries are frequent companions to pelvic ring fractures, the *bedside* identification of these injuries is highly desirable. A single AP chest x-ray, a pelvic x-ray, and a FAST examination will help detect major sources of traumatic shock within minutes. It is important to understand that the FAST examination in pelvic trauma can miss small fluid collections because of disruption of the retroperitoneum and that intra-abdominal free fluid in the pelvic trauma patient may rarely represent uroperitoneum rather than hemoperitoneum.[55] Institutional pelvic fracture management protocols that apply this diagnostic approach along with early external pelvic binding, aggressive resuscitation, and early definitive therapy have been shown to improve outcomes.[41,56-58]

Where Should The Patient Go Next?

Imagine yourself caring for Patient 2, the 26-year-old male crash victim with severe lower abdominal and pelvic pain and hypotension, a pelvic fracture on plain film **(see Figure 2 on page 3),** a normal chest x-ray, and a FAST result that is negative for free fluid in the peritoneum and pericardium. What should be done in the ED now?

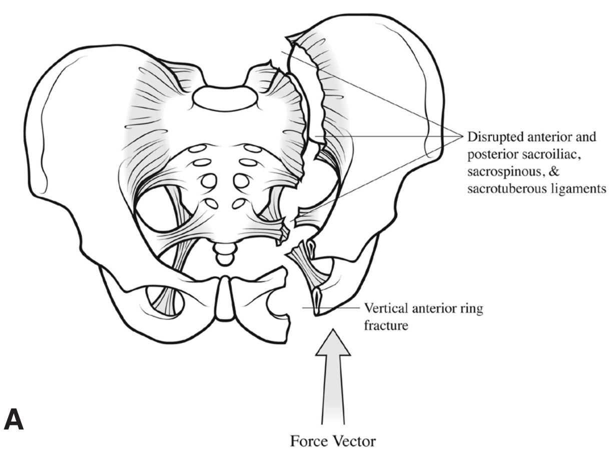
You immediately recognize that the patient has an AP compression injury with significant diastasis of the pubic symphysis. With resuscitation ongoing, the team places an external pelvic compression device to stabilize the fracture and decrease pelvic volume. A blood type and crossmatch are sent in anticipation of a transfusion. Despite 2 L of crystalloid solution, the patient remains relatively hypotensive, and 2 U of pRBCs are ordered. Consideration is also given to prevention of coagulopathy, including aggressive warming, laboratory assessment, and possible administration of clotting factors and platelets. At this point, you anticipate the need to activate your institutional massive transfusion protocol that calls for the early use of pRBCs, platelets, and FFP using a 1:1:1 ratio. Your team also works diligently to keep the patient warm to minimize the risk of coagulopathy.

Where should the patient go next? It is important to recognize that you have reached a critical branch point decision in the care of this complex patient. From here, there are several possible "destinations" for the patient, including the CT scanner, the OR, or the angiography suite. In transiently hypotensive patients who respond to initial fluid therapy with sustained improvement in perfusion (fluid "responders"), CT imaging is a logical choice. In patients who remain persistently hypotensive despite aggressive initial resuscitation ("nonresponders") or who have repeated periods of hypotension ("transient responders"), travel to the CT scanner is likely a bad choice.

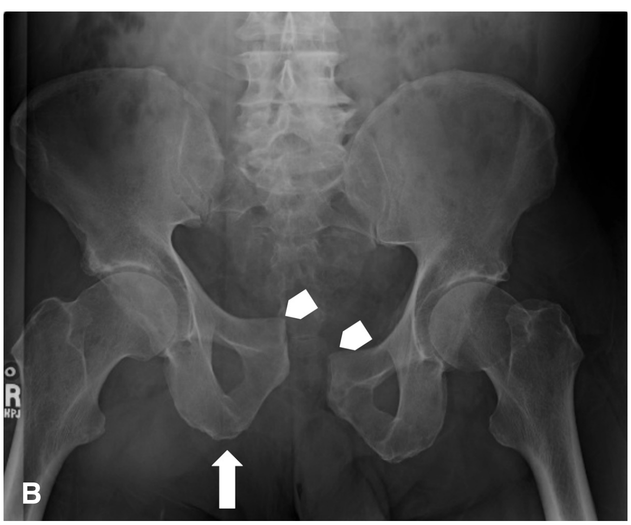
The key step is to identify the *predominant* cause of persistent shock with the aim of undertaking definitive therapy. In the persistently hypotensive patient with pelvic ring trauma, bedside testing with ultrasound, a diagnostic peritoneal aspiration (DPA), or both can help lead the way. **(See Algorithm 2 on page 12.)** An unequivocally and dramatically positive abdominal FAST result or a dramatically positive DPA (≥ 10 mL of gross blood) suggests major intraperitoneal hemorrhage and therefore the need for immediate laparotomy. Conversely, an unequivocally negative FAST or DPA result suggests extraperitoneal bleeding as the primary source (most commonly related to pelvic fracture, though renal injury or vascular injury must also be considered). In such circumstances, immediate angiography should be undertaken with the goal of controlling arterial hemorrhage. In selected patients with complex pelvic fracture and active bleeding, retroperitoneal packing through a suprapubic approach may be a useful adjunct to improve hemostasis.[59,60] The decision between use of laparotomy and angiography in patients with a positive FAST or DPA result but no signs of massive hemoperitoneum is a complex and difficult one that must be carefully individualized, ideally in consultation with the on-call surgeon.

Patients with persistent or recurring hypotension indicative of ongoing bleeding despite pelvic compression are at extremely high risk of mortality and should not be considered candidates for transfer until their condition has stabilized unless there are truly no local resources to address the hemorrhage. Definitive first steps to control hemorrhage — in this case angiography or laparotomy — should be undertaken at the initial receiving facility if at all possible, with subsequent transfer after stabilization. The desire to transfer severely injured patients to a higher level of care in the shortest possible time is understandable; however, the resuscitative capacity of even a small hospital ED far exceeds that available in the back of an ambulance, and the treatment

Figure 6. Vertical Shear Injury



The superiorly-directed force forces the left hemipelvis upwards. This causes major ligamentous disruption of both the anterior and posterior ring.



Upward migration of the right hemipelvis versus the left hemipelvis (arrowheads) indicates that the causative force was delivered superiorly (arrow).

Figure 7. Plain Film Pelvic X-ray

This pelvic x-ray demonstrates a combination anterior-posterior compression/vertical shear injury.

delay from mobilizing local resources may be more readily tolerated in this setting than the delay caused by a seemingly short transfer.

Key Points For Pelvic Ring Fracture

- Pelvic ring fractures are a sign of major energy transfer and should be viewed as markers of potentially severe multisystem trauma.
- Pelvic ring fractures can be classified as: (1) lateral compression injuries, (2) AP compression injuries, or (3) vertical shear injuries. Classification is helpful to predict risk of ongoing hemorrhage. Fractures that increase pelvic volume (ie, AP compression injuries and vertical shear injuries) pose the highest risk of ongoing bleeding.
- Institutional protocols that incorporate stabilization, aggressive resuscitation, and early definitive therapy improve outcomes.
- For community physicians, the essential steps are to: (1) recognize the pelvic injury pattern on plain film x-ray, (2) institute aggressive resuscitation early, (3) employ external pelvic stabilization when fracture patterns lead to increased pelvic volume, and (4) orchestrate timely transfer to a Trauma Center.

Blunt Abdominal Trauma

Review of the 2010 National Trauma Data Bank® Annual Report reveals that abdominal trauma accounts for 7% of all injuries treated at regional trauma centers, with an associated mortality rate as high as 10%.[61] Injuries captured by the term "blunt abdominal injury" are vast, and management strategies vary. This discussion will focus on the initial approach to the *hemodynamically unstable* patient with known or suspected blunt abdominal injury, which is summarized in **Algorithm 3**. Using this approach, the clinician should answer 2 questions:

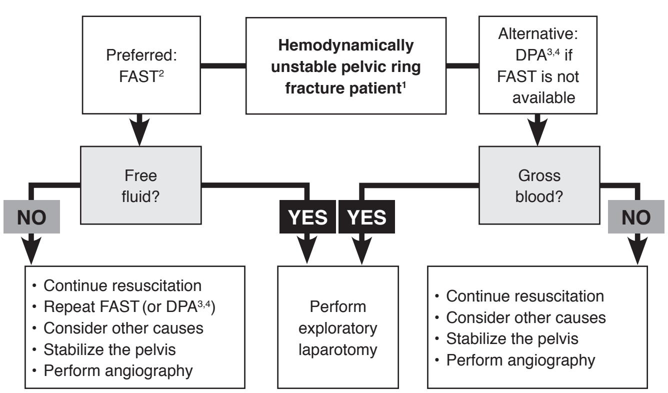
- Is there hemoperitoneum?
- Is the patient responsive to resuscitation?

Is There Hemoperitoneum?

As with all multisystem blunt trauma patients in shock, a comprehensive search for all hemorrhagic and nonhemorrhagic causes should be undertaken, guided by the principles outlined in **Tables 1 and 2 (on pages 4 and 5).** In the critically injured patient, the assessment for abdominal injury centers on the rapid bedside evaluation for the presence or absence of hemoperitoneum. Hemoperitoneum is usually the result of solid organ injury (eg, liver, spleen) that damages parenchymal arteries and veins. A much smaller number of cases involve injury to named blood vessels. These injuries often occur in combination.

Bedside ultrasound (FAST) is the test of choice for the initial evaluation for hemoperitoneum in the unstable patient.[24,62,63] This should be performed after completion of the primary survey. If the FAST is negative, the study should be repeated after the secondary survey has been completed. A "negative" FAST in the setting of blunt trauma and clinical shock poses an important dilemma. Unless there is clear and convincing evidence of another cause of shock, the search for intraperitoneal hemorrhage should not cease with sonography. Despite the FAST examination's excellent sensitivity in unstable patients,[64,65] guidelines continue to support DPA in unstable patients in whom a FAST is negative (although, DPA is seldom performed — or taught — at this time).[23,62,63]

Algorithm 2. Bedside Testing In Hemodynamically Unstable Patients With A Pelvic Fracture



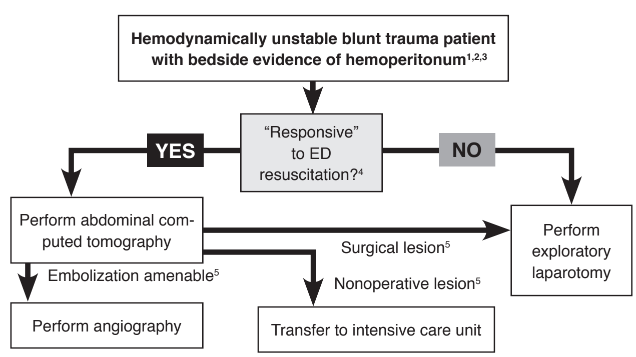
[1]These recommendations are based on Class II Evidence

[2]FAST = Focused assessment with sonography for trauma

[3]DPA = Diagnostic peritoneal aspiration (the aspiration of 10 cc of gross blood is positive)

[4]Safe and effective performance of DPA requires experience

Algorithm 3. Initial Approach To The Hemodynamically Unstable Patient With Known Or Suspected Blunt Abdominal Trauma



[1]These recommendations are based on Class II Evidence

[2]Focused assessment with sonography for trauma (FAST) is preferred; diagnostic peritoneal aspiration can be used if FAST is not applicable or equivocal.

[3]The decision to transfer is based on local resources, regional protocols, and expert consultation.

[4]Vital signs and serial lactates should be used to assess "responsiveness." Patients who experience transient improvement are best characterized as "non-responders."

[5]Surgical consultation will help the emergency physician make this determination.

For patients who stabilize after initial resuscitation, CT imaging of the abdomen and pelvis is the usual next step. Contemporary CT scanners provide excellent image quality with short acquisition times and allow for solid organ injury staging. Despite these advantages, the use of CT should be tempered by the associated risk of time and exposure to contrast and radiation.[8]

Is The Patient Responsive To Resuscitation?
Definitive management (ie, the most appropriate "next step") is dependent first and foremost on the patient's response to resuscitation. Persistent or recurrent hypotension in the face of ongoing resuscitation is an indication for immediate exploratory laparotomy.[62,63] Patients with hemoperitoneum who stabilize after an initial period of hypotension will ultimately fall into 1 of 3 categories: (1) those with injuries requiring surgical repair, (2) those with injuries amenable to angiographic embolization, and (3) those with injuries amenable to nonoperative management and close observation.[55,61-65] Consultation with an experienced trauma surgeon will help the team determine the most appropriate disposition. Early involvement of interventional radiology should also be considered.

The decision to transfer the patient with blunt abdominal trauma is complex, and this should be based on the careful consideration of patient factors, local resources, and regional protocols. As mentioned previously, the resuscitative capabilities in the ED greatly exceed those in the back of an ambulance, and patients who have persistent or recurrent hypotension are at very high risk of mortality during even a short transfer. Immediate laparotomy for control of hemorrhage should be undertaken if at all possible and represents the best chance for survival. For community physicians, 2 of the most important pitfalls are unnecessary delays for imaging (eg, obtaining a CT in an unstable patient with a positive FAST) and failure to consider immediate laparotomy prior to transfer.

Key Points For Blunt Abdominal Trauma

- In the hemodynamically unstable blunt trauma patient, ultrasound is the study of choice for the initial evaluation for hemoperitoneum.
- Persistent or recurrent hypotension in the patient with hemoperitoneum is an indication for immediate laparotomy.
- Computed tomography imaging provides valuable information in patients who stabilize with resuscitation and assists with injury staging and planning for definitive management. The most common injuries are to the liver and spleen, and many of these injuries can be managed nonoperatively in patients without hypotension or ongoing transfusion requirement.

Summary

Effective blunt trauma management is an essential skill for the emergency clinician. With much at stake for the patient and the team, it is essential to follow consistent care strategies that adhere to basic principles while, at the same time, providing the flexibility to address a multitude of injury patterns. A systematic approach to the evaluation and management of traumatic shock is a vital part of this strategy. **(See Algorithm 1 and Table 1 on page 4).**

Blunt trauma is the most common cause of serious injury; thus, identifying high-risk scenarios in this patient population is especially relevant. Close behind traumatic brain injury, BAI and pelvic ring fractures are among the most lethal injuries in the blunt trauma patient. Intra-abdominal injury is also common and is associated with significant morbidity. The rapid identification and effective stabilization of these injuries saves lives.

Case Conclusions

Your team immediately recognized the need to transfer both patients to a Level I trauma center, and air medical transport was arranged. As the team leader, you reviewed the mechanisms of injury with the on-call trauma surgeon, emphasizing that because both patients were unrestrained in high-speed collisions, multisystem injuries were almost certain. You then provided the following brief, targeted summaries for these patients:

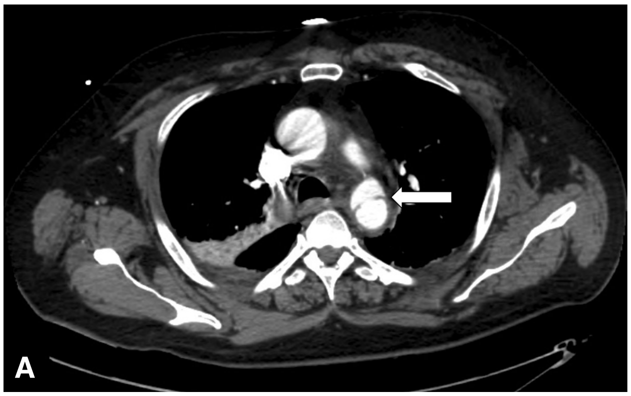
Patient 1: *The patient's vital signs have improved somewhat with crystalloid infusion, and he has attained a blood pressure reading of 105/81 mm Hg and a pulse rate of 97 bpm. There is concern about BAI based on chest radiography, and the positive FAST result has raised the specter of a coincident intra-abdominal injury. Vital signs will be carefully monitored during transport, with crystalloid therapy ongoing. Uncrossmatched blood will be on hand if needed. In consultation with the receiving trauma surgeon, it is agreed that heart rate control with a beta-blocker should be deferred until all injuries are identified and the patient is stabilized.*

Patient 2: *After reviewing the pelvic x-ray demonstrating a significant AP compression injury with pubic diastasis, you immediately recognized the risk of hemorrhage. Although it is not definitive, the negative FAST result has made life-threatening intra-abdominal hemorrhage less likely. A pelvic stabilizer has been applied, and fluid therapy has been continued with crystalloid solution and 2 U of pRBCs. A repeated blood pressure reading is 108/77 mm Hg, and the patient's pulse rate has decreased to 109 bpm. You have splinted the patient's right leg, and distal pulses have remained intact. Aggressive resuscitation with normal saline and blood will continue during transport, and efforts will be made to keep the patient warm.*

After hanging up the phone, the trauma surgeon worked quickly to mobilize a number of vital resources, *including the ED, the OR, and the angiography suite. The cases were discussed with the on-call orthopedic surgeon, an interventional radiologist, and a thoracic surgeon. Forty minutes later, both patients arrived at the trauma center.*

Patient 1: *The patient stabilized with fluid therapy. An immediate CT scan of the chest abdomen and pelvis reveals a contained aortic rupture* ***(see Figures 8a and 8b)*** *and a ruptured spleen* ***(see Figure 9)****. The patient underwent an uncomplicated splenectomy. He was then taken to interventional radiology, where the trauma surgeon, radiologist, and thoracic surgeon partnered to perform endovascular stenting of the aorta.*

Figure 8. Chest Computed Tomography Images For Patient 1



Demonstrating a blunt aortic injury (arrows in A and B).

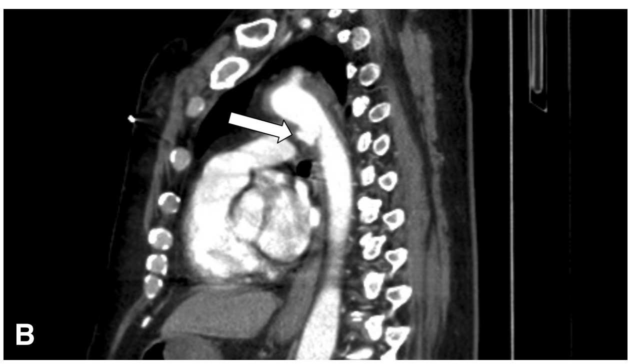
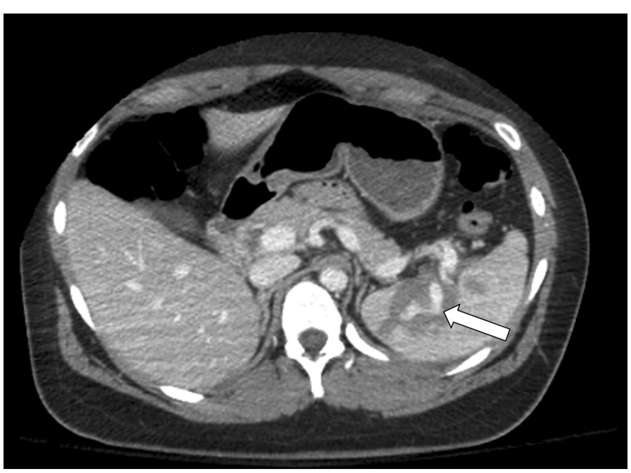


Figure 9. Abdominal Computed Tomography Image For Patient 1



Demonstrating a splenic laceration with active arterial bleeding (arrow).

Patient 2: *The patient remained intermittently labile during transfer despite several liters of crystalloid solution and 4 U of pRBCs. His blood pressure reading on arrival was 95/70 mm Hg, and his pulse rate was 115 bpm. A FAST examination repeated in the ED was still negative for free fluid. With this information, the patient was taken directly to the angiography suite, where an arterial injury of the posterior pelvic ring was successfully embolized.*

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

1. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Injury Prevention & Control: Data & Statistics (WISQARS™). www.cdc.gov/injury/wisqars/. Updated February 24, 2011.
2. Gibbs MA, Winchell RJ. The crashing trauma patient. In: Winter M, DeBlieux P, Marcolini E, et al (eds.) *Emergency Department Resuscitation of the Critically Ill.* Dallas, TX: American College of Emergency Physicians. In press. **(Book chapter)**
3. Seamon MJ, Feather C, Smith BP, et al. Just one drop: the significance of a single hypotensive blood pressure reading during trauma resuscitation. *J Trauma.* 2010;68(6):1289-1295. **(Prospective; 145 patients)**

4.* Jacobs DG, Plaisier BR, Barie PS, et al. Practice management guidelines for geriatric trauma: the EAST Practice Management Guidelines Work Group. *J Trauma.* 2003;54(2):391-416. **(Clinical practice guideline)**

5.* Tisherman SA, Barie P, Bokhari F, et al. Clinical practice guideline: endpoints of resuscitation. *J Trauma.* 2004;57(4):898-912. **(Clinical practice guideline)**

6. Paladino L, Sinert R, Wallace D, et al. The utility of base deficit and arterial lactate in differentiating major from minor injury in trauma patients with normal vital signs. *Resuscitation.* 2008;77(3):363-368. **(Retrospective; 1435 patients)**
7. Callaway DW, Shapiro NI, Donnino MW, et al. Serum lactate and base deficit as predictors of mortality in normotensive elderly blunt trauma patients. *J Trauma.* 2009;66(4):1040-1044. **(Retrospective; 588 patients)**

8.* Neal MD, Peitzman AB, Forsythe RM, et al. Over reliance on computed tomography imaging in patients with severe abdominal injury: is the delay worth the risk? *J Trauma.* 2011;70(2):278-284. **(Retrospective; 3218 patients)**

9. Nagy K, Fabian T, Rodman G, et al. Guidelines for the diagnosis and management of blunt aortic injury: an EAST Practice Management Guidelines Work Group. *J Trauma.* 2000;48(6):1128-1143. **(Practice management guideline)**
10. Sisley AC, Rozycki GS, Ballard RB, et al. Rapid detection of traumatic effusion using surgeon-performed ultrasonography. *J Trauma.* 1998;44(2):291-297. **(Prospective; 360 patients)**
11. Knudtson JL, Dort JM, Helmer SD, et al. Surgeon-performed ultrasound for pneumothorax in the trauma suite. *J Trauma.* 2004;56(3):527-530. **(Prospective; 328 patients)**
12. Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med.* 2005;12(9):844-849.
13. Zhang M, Liu ZH, Yang JX, et al. Rapid detection of pneumothorax by ultrasonography in patients with multiple trauma. *Crit Care.*

2006;10(4):R112. **(Prospective; 135 patients)**
14. Soldati G, Testa A, Sher S, et al. Occult traumatic pneumothorax: diagnostic accuracy of lung ultrasound in the emergency department. *Chest.* 2008;133(1):204-211. **(Prospective; 109 patients)**
15. Wilkerson RG, Stone MB. Sensitivity of bedside ultrasound and supine anteroposterior chest radiography for the identification of pneumothorax after blunt trauma. *Acad Emerg Med.* 2010;17(1):11-17.
16. McKenney M, Lentz K, Nunez D, et al. Can ultrasound replace diagnostic peritoneal lavage in the assessment of blunt trauma? *J Trauma.* 1994;37(3):439-441. **(Prospective; 200 patients)**
17. McKenney MG, Martin L, Lentz K, et al. 1,000 consecutive ultrasounds for blunt abdominal trauma. *J Trauma.* 1996;40(4):607-610. **(Prospective; 1000 patients)**
18. Lentz KA, McKenney MG, Nuñez DB Jr, et al. Evaluating blunt abdominal trauma: role for ultrasonography. *J Ultrasound Med.* 1996;15(6):447-451. **(Prospective; 54 patients)**
19. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. *J Trauma.* 1996;41(5):815-820. **(Retrospective; 69 patients)**
20. Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg.* 1998;228(4):557-567. **(Retrospective; 1540 patients)**
21. Holmes JF, Harris D, Battistella FD. Performance of abdominal ultrasonography in blunt abdominal trauma patients with out-of-hospital or emergency department hypotension. *Ann Emerg Med.* 2004;43(3):354-361. **(Retrospective; 447 patients)**
22.* Melnicker LA, Leibner E, McKenney MG, et al. Randomized controlled clinical trial of point-of-care, limited ultrasound for trauma in the emergency department: the first Sonography Outcomes Assessment Program trial. *Ann Emerg Med.* 2006;48(3):227-235. **(Prospective, randomized; 262 patients)**
23. Rozycki GS, Root HD. The diagnosis of intraabdominal injury. *J Trauma.* 2010;68(5):1019-1023. **(Literature review)**
24.* Diercks BD, Mehrotra A, Nazarian DJ, et al. Clinical policy: critical issues in the evaluation of adult patients presenting to the emergency department with acute blunt abdominal trauma. *Ann Emerg Med.* 2011;57(4):387-404. **(Systematic literature review and policy statement)**
25. Larson CR, White CE, Spinella PC, et al. Association of shock, coagulopathy, and initial vital signs with massive transfusion in combat casualties. *J Trauma.* 2010;69 Suppl 1:S26-S32. **(Retrospective)**
26. Gonzalez EA, Moore FA, Holcomb JB, et al. Fresh frozen plasma should be given earlier to patients requiring massive transfusion. *J Trauma.* 2007;62(1):112-119. **(Retrospective; 97 patients)**
27. Teixeira PG, Inaba K, Shulman I, et al. Impact of plasma transfusion in massively transfused trauma patients. *J Trauma.* 2009;66(3):693-697. **(Retrospective; 484 patients)**
28. Dente CJ, Shaz BH, Nicholas JM, et al. Improvements in early mortality and coagulopathy are sustained and better in patients with blunt abdominal trauma after institution of a massive transfusion protocol in a civilian level I trauma center. *J Trauma.* 2009;66(6):1616-1624. **(Prospective; 116 patients)**
29. Perel P, Roberts I. Colloids versus crystalloids for fluid resuscitation in critically ill patients. *Cochrane Database Syst Rev.* 2011;(3) CD0000567. **(Systematic literature review)**
30. Mapstone J, Roberts I, Evans P. Fluid resuscitation strategies: a systematic review of animal trials. *J Trauma.* 2003;55(3):571-589. **(Systematic review of animal data)**
31.* Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med.* 1994;331(17):1105-1109. **(Prospective, randomized; 717 patients)**
32. Morrison CA, Carrick MM, Norman MA, et al. Hypotensive resuscitation strategy reduces transfusion requirements and severe postoperative coagulopathy in trauma patients with hemorrhagic shock: preliminary results of a randomized controlled trial. *J Trauma.* 2011;70(3):652-663. **(Prospective, randomized; 90 patients)**
33. Burkhart HM, Gomez GA, Jacobson LE, et al. Fatal blunt aortic injuries: a review of 242 autopsy cases. *J Trauma.* 2001;50(1):113-115. **(Autopsy review)**
34. Teixeira PG, Inaba K, Barmparas G, et al. Blunt thoracic aortic injuries: an autopsy study. *J Trauma.* 2011;70(1):197-202. **(Autopsy review)**
35. Newman RJ, Rastogi S. Rupture of the thoracic aorta and its relationship to road traffic accident characteristics. *Injury.* 1984;15(5):296-299. **(Autopsy review)**
36. Schulman CI, Carvajal D, Lopez PP, et al. Incidence and crash mechanism of aortic injury during the past decade. *J Trauma.* 2007;62(3):664-667. **(Autopsy review)**
37. Conroy C, Hoyt DB, Eastman AB, et al. Motor vehicle–related cardiac and aortic injuries differ from other thoracic injuries. *J Trauma.* 2007;62(6):1462-1467. **(CIREN crash data review)**
38.* Fabian TC, Richardson JD, Croce MA, et al. Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma. *J Trauma.* 1997;42(3):374-380. **(Prospective, multicenter; 274 patients)**
39.* Demetriades D, Velmahos GC, Scalea TM, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma multicenter trial. *J Trauma.* 2008;64(3):561-570. **(Prospective, multicenter; 193 patients)**
40. Demetriades D, Velmahos GC, Scalea TM, et al. Diagnosis and treatment of blunt thoracic aortic injuries: changing perspectives. *J Trauma.* 2008;64(6):1415-1418. **(Review article)**
41. Davis JW, Moore FA, McIntyre RC Jr, et al. Western Trauma Association critical decisions in trauma: management of pelvic fracture with hemodynamic instability. *J Trauma.* 2008;65(5):1012-1015. **(Practice management guideline)**
42. Cook AD, Klein JS, Rogers FB, et al. Chest radiographs of limited utility in the diagnosis of blunt traumatic aortic lacerations. *J Trauma.* 2001;50(5):843-847. **(Retrospective; 188 patients)**
43. Ekeh AP, Peterson W, Woods RJ, et al. Is chest x-ray an adequate screening tool for the diagnosis of blunt thoracic injury? *J Trauma.* 2008;65(5):1088-1092. **(Retrospective; 45 patients)**
44. Cinnella G, Dambrosio M, Brienza N, et al. Transesophageal echocardiography for diagnosis of traumatic aortic injury: an appraisal of the evidence. *J Trauma.* 2004;57(6):1246-1255. **(Meta-analysis; 758 patients)**
45. Fabian TC, Davis KA, Gavant ML, et al. Prospective study of blunt aortic injury: helical CT is diagnostic and antihypertensive therapy reduces rupture. *Ann Surg.* 1998;227(5):666-676. **(Prospective; 494 patients)**
46. Xenos ES, Abedi NN, Davenport DL, et al. Meta-analysis of endovascular vs open repair for traumatic descending aortic rupture. *J Vasc Surg.* 2008;48(5):1343-1351. **(Meta-analysis; 589 patients)**
47. Hoffer EK, Forauer AR, Silas AM, et al. Endovascular stent-graft or open surgical repair for blunt aortic trauma: systematic review. *J Vasc Interv Radiol.* 2008;19(8):1153-1164. **(Systematic review; 638 patients)**
48. Mousa AY, Dombrovskiy VY, Haser PB, et al. Thoracic aortic trauma: outcomes and hospital resource utilization after endovascular and open repair. *Vascular.* 2010;18(5):250-255. **(Retrospective; 510 patients)**
49. Schulman JE, O'Toole RV, Castillo RC, et al. Pelvic ring fractures are an independent risk factor for death after blunt trauma. *J Trauma.* 2010;68(4):930-934. **(Retrospective; 1017 patients)**
50. Smith W, Williams A, Agudelo J, et al. Early predictors of mortality in hemodynamically unstable pelvic fractures. *J Orthop Trauma.* 2007;21(1):31-37. **(Retrospective; 187 patients)**
51. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation compendium 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007;21(10 suppl):S1-S133. **(Practice management guideline)**
52.* Blackmore CC, Cummings P, Jurkovich GJ, et al. Predicting major hemorrhage in patients with pelvic fractures. *J Trauma.* 2006;61(2):346-352. **(Retrospective; 627 patients)**
53. Bottlang M, Simpson T, Sigg J, et al. Noninvasive reduction of open-book pelvic fractures by circumferential compression. *J Orthop Trauma.* 2002;16(6):367-373. **(Biomechanical cadaveric study)**
54. Kreig JC, Mohr M, Ellis TJ, et al. Emergent stabilization of pelvic ring injuries by controlled circumferential compression: a clinical trial. *J Trauma.* 2005;59(3):659-664.
55. Tayal VS, Nielsen A, Jones AE, et al. Accuracy of trauma ultrasound in major pelvic injury. *J Trauma.* 2006;61(6):1453-1457. **(Retrospective; 87 patients)**
56.* Jeske HC, Larndorfer R, Krappinger D, et al. Management of hemorrhage in severe pelvic injuries. *J Trauma.* 2010;68(2):415-420. **(Prospective; 45 patients)**
57. Ruchholz S, Waydhas C, Lewan U, et al. Free abdominal fluid on ultrasound in unstable pelvic ring fracture: is laparotomy always necessary? *J Trauma.* 2004;57(2):278-285. **(Prospective; 1472 patients)**
58. Balogh Z, Caldwell E, Heetveld M, et al. Institutional practice guidelines on management of pelvic fracture–related hemodynamic instability: do they make a difference? *J Trauma.* 2005;58(4):778-782. **(Prospective; 31 patients)**
59. Osborn PM, Smith WR, Moore EE, et al. Direct retroperitoneal pelvic packing versus pelvic angiography: A comparison of two management protocols for haemodynamically unstable pelvic fractures. *Injury.* 2009;40(1):54-60. Epub 2008 Nov 30. **(Retrospective review)**
60. Tai DK, Li WH, Lee KY, et al. Retroperitoneal Pelvic Packing in the Management of Hemodynamically Unstable Pelvic Fractures: A Level I Trauma Center Experience. *J Trauma.* 2011 May 23. Epub ahead of print. **(Retrospective)**
61. American College of Surgeons, Committee on Trauma. National Trauma Data Bank Report, 2010. Available at www.facs.org/trauma/ntdbannualreport2010.pdf. Accessed June 23, 2011. **(Trauma registry database)**
62. Hoff WS, Holevar M, Nagy KK, et al. Practice management guidelines for the evaluation of blunt abdominal trauma: The EAST practice management guidelines work group *J Trauma.* 2002;53:602-615. **(Practice management guideline)**
63. Kozar RA, Moore FA, Moore EE, et al. Western trauma association critical decisions in trauma: Nonoperative management of adult blunt hepatic trauma. *J Trauma.* 2009;67:1148-1149. **(Practice management guideline)**
64. Rozycki GS, Ballard RB, Feliciano D, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg.* 1998;228(4):557-567.
65. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. *J Trauma.* 1996;41(5):815-820. **(Prospective; 400 blunt trauma patients)**

CME Questions

Take This Test Online!

Visit www.ebmedicine.net/CME today to receive your free CME credits.

1. **Shock results when:**
   a. Systolic blood pressure is < 90 mm Hg
   b. Oxygen delivery is inadequate to meet tissue demands
   c. Tachycardia or hypotension is nonresponsive to crystalloid infusion
   d. There is uncontrollable hemorrhage

2. **Which of the following is not a benefit of administering pRBCs, platelets, and FFP in a 1:1:1 ratio?**
   a. Less likelihood of requiring exploratory laparotomy
   b. Lower incidence of coagulopathy
   c. Lower mortality
   d. Lower overall transfusion requirements

3. **Which of the following is not a radiographic finding suggestive of BAI?**
   a. Indistinct aortic knob
   b. Left-sided pleural cap
   c. Loss of the aortopulmonary window
   d. Leftward deviation of the trachea and/or nasogastric tube
   e. Widening of the mediastinum

4. **The most common type of pelvic fracture is:**
   a. Lateral compression injury
   b. AP compression injury
   c. Vertical shear injury

Volume 1, Number 2 Errata

In Volume 1, Number 2 of *EMCC,* there was an error in the Clinical Pathway, "The Reevaluation Of Patients Placed On Noninvasive Ventilation," on page 10. The boxes following "Prepare for immediate tracheal intubation" should have been removed, as it is not required to use bi-level NIV or to continue conventional trauma resuscitation ***after*** you prepare for immediate tracheal intubation. Some practitioners may choose to preoxygenate using NIV immediately prior to induction for intubation; however, this is not a required step or part of any evidence-based guideline.

We apologize for any confusion this may have caused. A corrected PDF of this pathway is now available online at www.ebmedicine.net/NIVpathway.

CME Information

Date of Original Release: October 1, 2011. Date of most recent review: September 10, 2011. Termination date: October 1, 2014.

Accreditation: EB Medicine is accredited by the ACCME to provide continuing medical education for physicians.

Credit Designation: EB Medicine designates this enduring material for a maximum of 3 *AMA PRA Category 1 Credits™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

AOA Accreditation: *EMCC* is eligible for up to 18 American Osteopathic Association Category 2A or 2B credit hours per year.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents as well as intensivists and hospitalists.

Goals: Upon completion of this article, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Objectives: Upon completion of this article, you should be able to: (1) understand the nuances of shock diagnosis in the injured patient; (2) develop a practical approach to the *bedside evaluation* of the causes of life-threatening shock in the severely injured blunt trauma patient; (3) understand the strengths and weaknesses of chest radiography, CT imaging, and TEE in the diagnosis of BAI; (4) describe a clinically relevant classification system for pelvic ring injuries, and understand how this system influences acute care and decision-making; (5) understand the importance of injury prioritization in patients with BAI and/or pelvic ring fractures in the setting of multisystem trauma; and (6) understand the essentials of ED assessment and management of the hemodynamically unstable patient with known or suspected blunt abdominal trauma.

Discussion of Investigational Information: As part of the newsletter, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration-approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product.

Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: **Dr. Gibbs, Dr. Winchell, Dr. Bessette, Dr. Gray-Eurom, Dr. Litell, Dr. Silverberg, Dr. Arntfield, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.**

Earning Credit: Two Convenient Methods: (1) Go online to www. ebmedicine.net/CME and click on the title of this article. (2) Mail or fax the Answer and Evaluation form included with your December issue to EB Medicine.

Hardware/Software Requirements: You will need a Macintosh or PC to access the online archived articles and CME testing. Adobe Reader is required to view the PDFs of the archived articles.

Additional Policies: For additional policies, including our statement of conflict of interest, source of funding, statement of informed consent, and statement of human and animal rights, visit www.ebmedicine.net/policies.

CEO: Robert Williford **President & Publisher**: Stephanie Ivy **Managing Editor:** Dorothy Whisenhunt **Director of Member Services**: Liz Alvarez
Managing Editor & CME Director: Jennifer Pai **Director of Marketing:** Robin Williford

EB Medicine
1-800-249-5770 or 1-678-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150, Norcross, GA 30092
E-mail: **ebm@ebmedicine.net**
Website: **www.ebmedicine.net**
To write a letter to the editor, please email: arntfieldmd@ebmedicine.net

EMCC Subscription Information:

6 print issues per year, 18 *AMA PRA Category 1 Credits™*, and full online access to searchable archives and additional CME: $299 (Call 1-800-249-5770 or go to www.ebmedicine.net/EMCCinfo to order)