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Penetrating and Blunt Cardiac Trauma

Penetrating and blunt cardiac trauma are serious causes of morbidity and mortality. Presentation for blunt cardiac trauma may be subtle and nonspecific, challenging the clinician to make a timely diagnosis. Since early recognition and aggressive management may make a significant difference in the morbidity and mortality associated with these injuries, heightened awareness and an appropriate diagnostic evaluation are critical. The authors review both penetrating and blunt cardiac trauma, focusing on optimizing clinical care.

— The Editor

Introduction

The emergency department (ED) physician has the ability to intervene in a meaningful, lifesaving way when faced with penetrating and blunt cardiac trauma. Penetrating cardiac trauma is usually the result of gunshot or stab wounds; the incidence of each depends primarily on the geographic location of the ED. All-cause penetrating cardiac trauma is a leading cause of death seen predominantly in urban settings, but given its high lethality, is of equal significance in rural EDs. Gunshot wounds are more lethal than stab wounds due to their high velocity and wide range of impact. The right ventricle is the most commonly injured cardiac structure in both types of cardiac trauma, given its anterior location in the chest. Injuries may involve multiple chambers, coronary arteries, or other structures, such as the aorta or other great vessels.

Blunt cardiac injury (BCI), historically referred to as myocardial contusion, encompasses a broadly defined group of injuries typically occurring after a rapid deceleration injury or a direct blow to the chest. BCI has been associated with valvular or myocardial dysfunction leading to heart failure, dysrhythmias, free wall rupture causing pericardial effusion and tamponade, and, rarely, coronary artery injury leading to acute myocardial infarction.[1] This article will highlight the use of ultrasound in diagnosing pericardial effusion/tamponade, seen in both types of cardiac trauma, as well as the procedural interventions of pericardiocentesis and thoracotomy.

Pericardial tamponade is seen primarily in patients with penetrating trauma,[2] and less commonly in patients with BCI with chamber rupture.[3] Reliance on the physical examination alone to make this critical diagnosis has several important limitations that must be recognized: otherwise healthy patients may be asymptomatic early on; clinical findings are predominantly nonspecific; more specific clinical features (e.g., absent heart tones, jugular venous distension, pulsus paradoxus) occur inconsistently and can be masked by coincident blood loss; and chest radiography is almost always normal in the acute setting. These limitations illuminate the critical importance of emergency ultrasound in the routine assessment of the trauma patient at risk for pericardial tamponade.

Patients with pericardial tamponade can decompensate abruptly, as even small hemorrhage volumes added to the intact pericardium will cause a linear, and lethal, increase in intrapericardial pressure. This is especially likely immediately

Authors:

Liisa O. Carden, MD, Department of Emergency Medicine, Maine Medical Center, Portland, ME.

Michael A. Gibbs, MD, Professor and Chair, Department of Emergency Medicine, Carolinas Medical Center, Charlotte, NC; Professor of Emergency Medicine, University of North Carolina School of Medicine, Charlotte Campus.

Casey Z. MacVane, MD, MPH, Director of Medical Student Education, Department of Emergency Medicine, Maine Medical Center, Portland, ME; Assistant Professor, Tufts University School of Medicine, Boston, MA.

Peer Reviewer:

Perry W. Stafford, MD, FACS, FAAP, FCCM, Professor of Surgery, Robert Wood Johnson Medical School/UMDNJ, New Brunsick, NJ.

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Executive Summary

- The traditional "gold standard" for the diagnosis of pericardial effusion and tamponade is the subxiphoid pericardial window; however, the parasternal long window provides a clear view as well.
- Ultrasound-guided pericardiocentesis has been associated with fewer complications and has higher success rates than the traditional landmarks approach.
- Consider a large pericardial laceration through which blood in the pericardial space decompresses into the chest in a patient with the combination of a penetrating chest wound, a left hemothorax on chest film, and a negative FAST examination.

following intubation and positive-pressure ventilation, when venous return declines sharply in the face of mechanically impaired cardiac output. In the crashing trauma patient with penetrating chest trauma or suspicion for BCI, the diagnosis of tamponade must be considered immediately. Two cases will be presented, both involving traumatic injury to the heart and both demonstrating the utility of bedside ultrasound, pericardiocentesis, and thoracotomy.

Penetrating Cardiac Trauma

Case 1. *A 21-year-old male is transferred to the ED after a 911 call reporting a domestic assault and stabbing injury to his chest. The transport time is 20 minutes. His vital signs en route reveal a heart rate of 92, respiratory rate of 20, blood pressure of 100/60, and oxygen saturation of 92% on 2 L nasal cannula. On arrival he is conversant. During the primary survey, you note pulmonary rales throughout the left chest, with a 2 cm laceration to the left anterior chest wall. The patient's pulses, initially palpable, become nonexistent, and he becomes unresponsive. You secure his airway immediately with endotracheal intubation, and CPR is initiated. IV access has been obtained and fluids are given wide open with blood products ordered. Readdressing his primary survey, you note that his trachea is midline, but there is clear jugular venous distension with aberrant pulsations. Bedside ultrasound reveals a small pericardial effusion, and you suspect his penetrating wound ruptured both a cardiac chamber and the pericardium, with enough clotting to produce the effusion seen. With sonographic assistance, you perform a pericardiocentesis and remove 200 mL of blood. Hemodynamics transiently improve and you mobilize your surgical colleagues immediately while preparing the patient for emergent thoracotomy.*

Figure 1. Probe Position for Parasternal Long View of Pericardial Effusion

Initial Assessment

Patients with penetrating cardiac injuries should be assessed initially as all trauma patients are with a primary survey focused on vital signs, airway, breathing, and circulation, followed by a secondary survey. Patients deemed unstable during the primary assessment may require immediate intervention to treat life-threatening conditions such as tension pneumothorax, hemorrhage, or pericardial tamponade. As demonstrated in case 1, ultrasound is an extremely helpful diagnostic tool.

Bedside ultrasound is a valuable tool in the assessment of cardiac injury and pericardial tamponade, with reported sensitivities for detecting pericardial effusion approximating 100%. In addition, ultrasound is noninvasive, repeatable, portable, and rapid.[4-8] The traditional "gold standard" for the diagnosis of pericardial effusion and tamponade is the subxiphoid pericardial window; however, the parasternal long window provides a clear view as well.[3,9] (*See Figures 1-4.*) Bedside ultrasound has become a useful adjunct in the management of the trauma patient,[10] and when applied correctly, serves as an extension of the physical examination.[11]

Once a pericardial effusion is identified, you may evaluate further for sonographic evidence of tamponade. Diastolic collapse of the right ventricle and atria are the most frequently cited findings. Compression of the right atrium and/or ventricle may be visualized during diastole as the intrapericardial pressure exceeds the right chamber pressure. It is important to distinguish between collapse of the right ventricle and atria during systole (physiologic) or diastole (always pathologic). This distinction may be difficult to appreciate, especially in the tachycardic patient. The advanced sonographer can use M-mode (motion mode) to capture an image of the right ventricle and mitral valve. The period of diastole is the time from mitral valve opening to closure. During this period, if there is any posterior motion of the right ventricle, then there is diastolic collapse and evidence of tamponade.[12]

However, given the urgency of intervention, a technically adequate bedside echocardiogram with no evidence of pericardial effusion virtually excludes the diagnosis of cardiac tamponade, and further sonographic imaging is less likely to be helpful. In unstable or arresting patients with evidence of effusion on bedside ultrasound, tamponade physiology should be inferred and pericardiocentesis should be performed emergently. Bedside ultrasound can further be used for this procedure, as ultrasound-guided pericardiocentesis has been associated with fewer complications and has higher success rates than the traditional landmarks approach.[13,14] (*See Table 1.*)

The utility of bedside ultrasound in diagnosing and treating pericardial tamponade is clear. However, an important exception becomes manifest when patients with cardiac wounds harbor a large pericardial laceration through which blood in the pericardial space decompresses into the chest, rendering the ultrasound examination negative or equivocal for evidence of effusion or tamponade.[15] The combination of a penetrating chest wound, a left hemothorax on chest film, and a negative FAST examination should prompt the clinician to consider this important pitfall.

Figure 2. Parasternal Long View of Pericardial Effusion

Parasternal long view of pericardial effusion. While the normal pericardium appears as a single, brightly echogenic stripe adjacent to the myocardium, fluid within the pericardial space between the visceral and the parietal pericardium will appear as a large, nonbeating, anechoic area adjacent to the ventricular myocardium (arrows). A small amount of fluid in the dependent portion of the pericardial space is normal, but the amount of fluid seen above and below, as imaged here, is distinctly abnormal. The sonogram will reveal a hyperkinetic heart within a circumferential pericardial effusion, with diastolic collapse of the right-sided chambers. This reflects pressures within the pericardial space that are greater than the right ventricular filling pressure during diastole.

Figure 3. Probe Position for Subxiphoid View of Pericardial Effusion

Table 1. Performing Pericardiocentesis

Step 1

Pericardiocentesis is performed by advancing a 5- to 10-cm, 18-gauge spinal needle attached to a 60 mL syringe into the pericardial space. Complete prepackaged pericardiocentesis sets that include a pigtail catheter and guidewire are helpful and available. If ultrasound guided, have a small amount of saline aspirated into your syringe prior to needle insertion.

Step 2

If conditions allow, elevate the chest to a 45-degree angle to bring the heart closer to the anterior chest wall. Prepare the skin with sterile solution. Several potential approaches to needle placement have been described, with the subxiphoid approach being the most commonly recommended. Insert the needle 1 cm inferior to the left xiphocostal angle, at an angle of 45 degrees to the abdominal wall, and directed toward the left shoulder. Reduce the angle of contact between the needle and skin to 15 degrees once the tip has passed the posterior margin of the bony thorax.

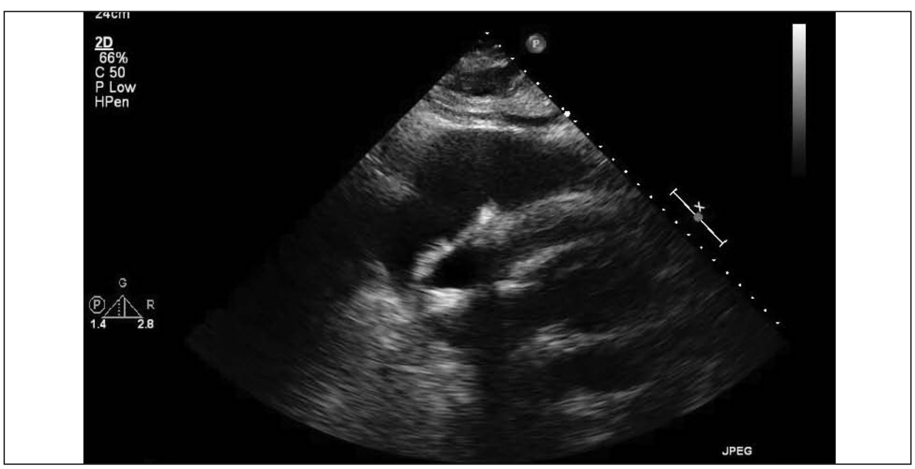
Step 3

Slowly advance the needle up to a depth of 5 cm while applying negative pressure on the syringe. Blood should be aspirated until hemodynamic improvement is demonstrated. If the cardiac monitor waveform shows an injury pattern, then slowly withdraw the needle until it normalizes as this indicates direct contact with the myocardium.

Step 4

Hemopericardium often reaccumulates, so a catheter should be left in place for recurrent drainage, if possible. For this type of prolonged drainage, a guide wire passed through the sheath will facilitate the introduction of a pigtail angiographic catheter.

Figure 4. Subxiphoid View of Pericardial Effusion. Note Subtle RA and RV Collapse.



If the patient with cardiac tamponade is not in PEA/asystolic arrest, the cardiac monitor or the ECG often demonstrates sinus tachycardia and overall low voltage. Electrical alternans, a phenomenon whereby the size and morphology of the QRS complex alternates with every other beat, is caused by the swinging of the heart's position within the pericardial space. (*See Figure 5.*) While this finding is very specific for pericardial tamponade, it is seen less often in acute pericardial effusions that develop with penetrating trauma or BCI with associated chamber rupture, than in larger, subacute effusions.

Stable patients with penetrating cardiac trauma will require a chest X-ray, primarily looking for other thoracic injuries such as hemothorax, pneumothorax, or aortic dissection. In acute pericardial tamponade, the heart may not appear enlarged on X-ray. This is because in order for the cardiac silhouette to be distorted on X-ray, at least 200 mL of fluid must be present.[16] The rapidly developing effusion requires less volume to cause the same tamponade physiology than does a slowly progressing nontraumatic effusion. It is the nontraumatic, more subacute pericardial effusion that contains large volumes of fluid that produces the "water bottle" appearance of the heart seen on chest X-ray.

Computed tomography (CT), a common diagnostic modality in the contemporary evaluation of the trauma patient, generally has a limited role in the diagnosis of traumatic pericardial tamponade. Because patients with pericardial tamponade may decompensate abruptly, it is mandatory that all at-risk patients be evaluated with bedside ultrasound before moving to the radiology suite. Pericardial effusions that are found in stable patients on CT can be correlated with other findings such as bowing of the intraventricular septum and compression of cardiac chambers to assess for the presence of tamponade.

Clinical Presentation

Cardiac injury should be suspected in any patient with a penetrating injury to the "box," which is defined as the region extending from the clavicles to the lower costal margins and medial to the nipples. This anatomic box includes posterior injuries as well, with the scapulae defining the lateral margins. It is additionally important to remember that penetrating injuries to the thorax often involve anatomic regions other than the thorax, such as the neck, abdomen, and diaphragm. Patients with penetrating cardiac trauma often have severe, immediate hemorrhage as a result of myocardial and pericardial rupture, leading to exsanguination and death at the scene. Those patients with a penetrating cardiac injury who do survive transport to the ED often present with pericardial effusion/tamponade.

Cardiac tamponade at its worst presents as obstructive shock, which is a result of impaired preload and decreased stroke volume. The physical presentation of cardiac tamponade is classically referred to in terms of Beck's triad, which includes hypotension, jugular venous distension (JVD), and muffled heart sounds. Patients rarely present with all three of these findings, although most will have at least one. Poor perfusion and shock may also be evidenced by cool extremities, peripheral cyanosis, tachycardia, and tachypnea. Subjective complaints may include chest pain or dyspnea. Alternatively, these patients may be unresponsive and in cardiorespiratory arrest.

Young, healthy patients with cardiac effusion/tamponade are much more likely to present clinically stable. Stable patients are also more likely to have either a small cardiac laceration causing only a slow leak of blood into the pericardium, a lesion that permits periodic decompression, or to have a low pressure tamponade in the presence of profound hypovolemia. Once the pericardial pressure reaches a critical value, however, these patients will ultimately progress to the severe distress and shock described above. Early detection of cardiac lesions, therefore, remains crucial, and the ED physician should remain vigilant.

When evaluating the unstable patient with penetrating chest trauma at risk for pericardial tamponade, it is important to recall that the differential diagnosis also includes tension pneumothorax. This should

Table 2. Performing a Thoracotomy

Do not waste time with other unnecessary procedures.

Immediately Recognize the Indication(s) for the Procedure

- Improved outcomes when performed rapidly
- Assemble the right team and call for surgical help

Prepare the Team

- Equipment includes thoracotomy tray, chest tube tray, resuscitation equipment.
- Roles — strong leadership and role clarity essential
- Protection — recognize that needle sticks are common and take precautions

Prepare the Patient

- Advance the endotracheal tube into the right main stem bronchus — left lung collapses improving exposure of the left chest.
- Place a folded towel under the left chest — this makes it easier to extend the incision and access the left chest.

Perform the Procedure

Step 1: Make a left curvilinear skin and soft tissue incision at the rib space just below the nipple line (between the 4th-5th ribs) from the sternum to the posterior axillary line.
Pitfalls:

- A straight incision crosses several rib spaces and makes it difficult to enter the thorax.
- The incision is not deep or long enough and time is wasted.

Step 2: Enter the pleural cavity with the edge of your Mayo scissors. The lung will collapse, allowing rapid surgical dissection to continue through the intercostal musculature and parietal pleura.

Step 3: Insert the rib spreaders with the handle facing the stretcher and open the intercostal space to gain access to the thorax.

Step 4: Immediately identify active bleeding and/or pericardial tamponade by opening the pericardium. Using tissue pick-ups with teeth, press hard against the pericardium to engage the tissue, then incise the pericardium vertically, avoiding the phrenic nerve.
Pitfalls:

- Delays in opening the pericardium
- Posterior pericardial clot not recognized

Step 5: "Deliver" the heart through the incised pericardium and inspect all surfaces for injuries. Remove clots of blood from the pericardial sac with your gloved hand or gauze pads.

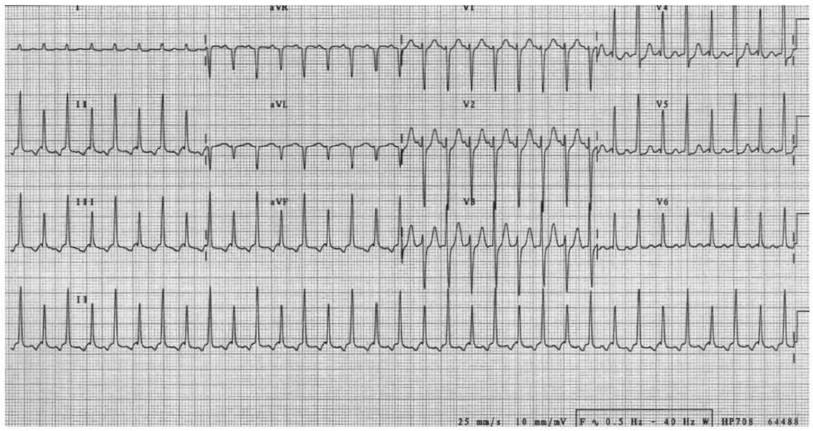
Step 6: Repair cardiac wounds if possible. There are several options:

- Direct pressure on the way to the OR, or
- Staples across the wound, or
- Two sutures parallel to the laceration tied across the wound, or
- Traditional surgical repair with pledgeted sutures

Dealing with the Aftermath

- Whose OR can the patient be in the fastest (keep vs. transfer)?
- If perfusion is restored (e.g., pericardial tamponade relieved) the patient may wake up.
- Team debriefing essential

Figure 5. ECG With Electrical Alternans



be rapidly excluded using physical examination primarily, and confirmed with bedside ultrasound and chest radiography as appropriate.

Management

Management of patients with penetrating cardiac injuries is initially indistinguishable from the management of other trauma patients. The focus is on managing the compromised airway, followed by managing pulmonary pathology and circulatory collapse. Often these patients need definitive care in the operating room, which may require the emergency physician to coordinate trauma surgery, cardiothoracic surgery, and intensivists in the care of the patient. Accompanying these stabilization efforts prior to transfer to the operating room, however, are two essential procedures that may be required of the emergency physician. These include pericardiocentesis and thoracotomy. (*See Tables 1 and 2.*)

The emergency physician treating a traumatic pericardial effusion should provide airway support as needed and aggressive fluid resuscitation. When preparing to intubate the patient, remember that with positive pressure ventilation, the patient's hemodynamics may worsen, as increased intrathoracic pressure further diminishes cardiac filling. Along with airway and circulatory support, clinical evidence of tamponade physiology ultimately requires pericardiocentesis as the only next therapeutic option. Often, symptoms and hemodynamics will improve dramatically following removal of hemopericardium. Even as little as 5-10 mL of blood can improve hypotension.[17] In other cases, such as ruptured myocardium and uncontained pericardium, the procedure serves only as a temporizing measure while the patient is prepared for the more definitive management of surgical pericardiectomy or thoracotomy.

Pericardiocentesis is best performed with ultrasound guidance to increase chances of successful fluid removal and to minimize complications. Multiple studies have demonstrated improved safety and outcomes with ultrasound.[18-20] Greater success rates of 97-99% have also been reported with sonographic guidance.[18,20] The primary role of ultrasound is to guide proper placement of the needle and to confirm placement of the catheter. Still images allow for estimation of location and depth of the pericardium, while real-time images can guide needle placement dynamically. Hold the ultrasound probe on the chest wall immediately adjacent to the aspiration site and, once the pericardial space is entered, inject agitated saline to confirm needle placement. The saline appears sonographically as a brightly echogenic stream.

If ultrasound is unavailable, the procedure can be performed blindly with acceptable success and safety. The blinded method, however, may be associated with misleading results up to 25% of the time, with false positives from aspirating blood from the cardiac chamber and false negatives from the immediate clotting of aspirated blood from a rapidly bleeding laceration.[21]

In the case of active extravasation from a cardiac laceration into a ruptured pericardium, pericardiocentesis will fail to improve hemodynamics despite significant volume aspiration. These patients require ED thoracotomy. (*See Table 2.*)

Injuries resulting in cardiac arrest pose significant challenges for emergency care providers. Rapid decisions must be made about the wisdom of continuing resuscitation and, if that is the chosen course, accepting the need for heroic procedures. It is equally important to understand and confidently articulate when resuscitative efforts should cease. Superimposed upon this decision is the need to consider organ preservation when the patient has no meaningful chance of survival. Because most clinicians will (fortunately) not face this scenario often, it is useful to review several guiding principles.

Traumatic Arrest and Indications for Thoracotomy

1. The outcomes for traumatic arrest are similar in adults and children. Acknowledging the significant added stress of managing an injured child with no pulse, the general approach should be the same, no matter what the age.[22]

2. When patients are found without signs of life at the scene, outcomes are dismal for both adults[23-25] and children,[26-28] regardless of the mechanism of injury. Under these circumstances, resuscitation should be terminated.

3. When cardiopulmonary resuscitation (CPR) has been ongoing for 15 minutes or longer, survival approaches zero, regardless of the mechanism of injury.[29] This is another indication to cease resuscitation.

4. Patients who sustain blunt traumatic cardiac arrest within the 15-minute "resuscitative window" generally have a very poor prognosis. If the patient remains pulseless despite effective management of the airway, empiric treatment for tension pneumothorax (with bilateral needle chest decompression), and sonographic exclusion of pericardial tamponade, resuscitative efforts should stop. If a significant pericardial effusion is detected at the bedside and the arrest time is brief, emergency thoracotomy should be considered, resources and skill permitting.

5. Patients with penetrating chest trauma have the most meaningful chance of survival. In large case series, the overall survival for patients with penetrating trauma is approximately 10% ,and as high as 30% for patients with isolated cardiac wounds. Outcomes in patients who have sustained stab wounds are better than for those with gunshot wounds. The strongest evidence for resuscitation and emergency thoracotomy is in patients with penetrating chest trauma and brief arrest times.[30]

6. Although published guidelines state that emergency thoracotomy should be "considered" in arrested patients with isolated penetrating wounds to the abdomen, survival in this group is also exceedingly rare.[30]

Blunt Cardiac Trauma

Case 2. *A 26-year-old, unrestrained male driver is involved in a high-speed, single motor vehicle crash striking a tree. He is extricated by EMS; there is a large amount of intrusion into the front of the car. The patient is awake but combative at the scene, with a systolic blood pressure of 60 mmHg, heart rate 120, and decreased breath sounds on the left. He is intubated for airway protection, and his left chest is decompressed with a needle. En route to the ED, he is resuscitated with a total of 3 L of crystalloid solution, but arrives at the ED with a systolic blood pressure of 70 mmHg and continued sinus tachycardia. Primary and secondary surveys reveal full bilateral breath sounds, muffled heart sounds with JVD, a nondistended abdomen, and stable pelvis. A bedside FAST reveals pericardial fluid without intraperitoneal free fluid. While materials for a sterile pericardiocentesis are prepared, a bedside chest X-ray is performed, revealing a normal cardiac silhouette, small left pneumothorax, and opacification of the left mid-lung consistent with contusion. A subxiphoid catheter pericardiocentesis is performed with sonographic guidance and evacuates 100 mL of dark blood with immediate rise of his systolic blood pressure to 120 mmHg. He is taken immediately thereafter to the operating room, where a thoracotomy is performed revealing a 0.5 cm linear tear in the right atrial appendage, which is repaired with a single suture.*

Initial Assessment

All trauma patients should undergo immediate primary and secondary surveys, assessing initially for any airway, respiratory, or hemodynamic compromise. Dysfunction of any of the aforementioned should be intervened upon concurrently, including needle decompression, pericardiocentesis, or hemorrhage control. The secondary survey will follow. Patients with evidence of blunt chest trauma should have a screening electrocardiogram[31] and a bedside chest X-ray. This chest X-ray will not identify cardiac injury, but will identify other injuries associated with BCI, including but not limited to, aortic disruption, rib or sternal fractures, pulmonary contusions, hemothorax, and pneumothorax. Both the ECG and chest X-ray will direct further management and disposition decisions.

It is important to note that cardiac injury can often go unnoticed secondary to other coexistent bodily injuries that clinically mask the presentation of BCI. So, while other noncardiac injuries to the head, neck, chest, spine, abdomen, and pelvis should be appropriately managed, the ED physician should continue to maintain a high level of suspicion for BCI. Certainly, if hypotension or hemodynamic instability persist despite appropriate treatment of comorbid pathology, BCI should be investigated.

Clinical Presentation

When considering BCI, it is helpful to obtain a full history from EMS, the patient, and/or the family regarding the mechanism of injury, context of injury (restraints, steering wheel impact, ejection from the vehicle, etc.), and past medical history, including dysrhythmias and medications that may mask clinical signs of hypovolemia. This information will help guide patient management.

As the patient is evaluated, the ED physician will essentially need to differentiate cardiac from noncardiac injury. Patients with BCI may specifically complain of chest pain or dyspnea, but may also be asymptomatic. They may or may not present with signs of thoracic injury. Thoracic trauma that is suggestive of patients at high risk for BCI includes chest wall tenderness, ecchymosis, flail chest, crepitus, hemothorax, or new pulmonary edema. A detailed physical exam may reveal pulsus paradoxus, which is pathognomonic for pericardial tamponade. Muffled heart sounds, jugular venous distention, hypotension (Beck's triad), and electrical alternans are also prototypical findings of tamponade.

Management

Managing patients with BCI has been a subject of much discussion and still leaves room for a certain amount of independent judgment on the part of the ED physician. There is a general lack of diagnostic criteria for BCI, and it remains difficult to predict who will develop complications from a BCI. Mattox et al sought to clarify the diagnosis of BCI by describing it in terms of its sequelae. (*See Table 3.*) This remains a pertinent means of delineating BCI. Pasquale et al published Guidelines for the Screening of BCI based on studies and reviews published between 1986 and 1997 to identify patients with BCI at risk for developing adverse events.[31] Since these published guidelines, there

Table 3. Types of Blunt Cardiac Injury[1]

1) BCI with minor ECG or enzyme abnormality
2) BCI with complex dysrhythmia
3) BCI with coronary artery thrombosis
4) BCI with free wall rupture
5) BCI with septal rupture
6) BCI with cardiac failure

have been numerous studies and articles attempting to further delineate and update BCI management, yet no definitive guideline has emerged.

BCI should be suspected in any patient who arrives at the ED after a deceleration injury, direct precordial impact, or a crush injury. The ECG, although nonspecific, is the most sensitive study for alerting the ED physician to patients at risk for complications.[31-38] Interpretation of the ECG should occur after the exclusion or correction of hypoxemia, hypovolemia, acidosis, and electrolyte abnormalities. Dysrhythmias are then inclusive of any aberration from a patient's known baseline or from normal. Studies to date suggest that any patient with a dysrhythmia should be considered to have a plausibly dangerous BCI and should, therefore, also be considered for admission for telemetry monitoring and repeat ECG.[33,37,39]

The utility of cardiac biomarker testing in patients with suspected BCI is less clear. Cardiac injury caused by trauma can differ from acute myocardial infarction in that trauma may not always produce myocardial ischemia or infarction. This discrepancy contributes to the findings that not all trauma patients with BCI have significant alterations in their cardiac biomarkers. Similarly, not all patients with a rise in their cardiac biomarkers will have evidence of BCI. The release of CK-MB from other organs during trauma confounds the interpretation of the value and is not appropriate for use in the evaluation of the patient with BCI.[31,40] Cardiac-specific troponins were thought to pose an opportunity for improved diagnostics and risk stratification in BCI, but studies to date do not reveal consistent findings of sensitivity and specificity in either regard.[41-47] Further prospective studies are needed to clarify, but as of now, no definitive studies have proven the clinical value of cardiac biomarkers in either stable or unstable patients.[32,48]

Historically, management of patients with suspected BCI has been conservative. Retrospective and prospective data, however, have shown that otherwise uninjured, asymptomatic, hemodynamically stable patients with BCI and without initial dysrhythmia on ECG do not, in fact, go on to develop acute complications of cardiac dysrhythmia or cardiac failure. These studies have concluded that the patients meeting these parameters do not require admission or monitoring and are safe to be dispositioned home with a less than 0.1% incidence of cardiac complication.[33,35,38,49-53]

Those patients with hemodynamic compromise, on the other hand, such as the patient presented in case 2, are clearly not disposition quandaries and require immediate attention and vigilance. The diagnosis of chamber wall rupture usually relies on the prompt recognition of the clinical signs and symptoms of cardiac tamponade. Along with stabilization efforts with crystalloid and packed red blood cells, the patient with suspected BCI and hemodynamic instability requires an immediate bedside FAST to evaluate for intraperitoneal free fluid and for pericardial effusion/tamponade. ED physicians should be prepared to perform a pericardiocentesis using cardiac telemetry and sonographic guidance to temporarily relieve tamponade and temporize the situation until a thoracotomy can be performed.[54] (*See Table 1.*)

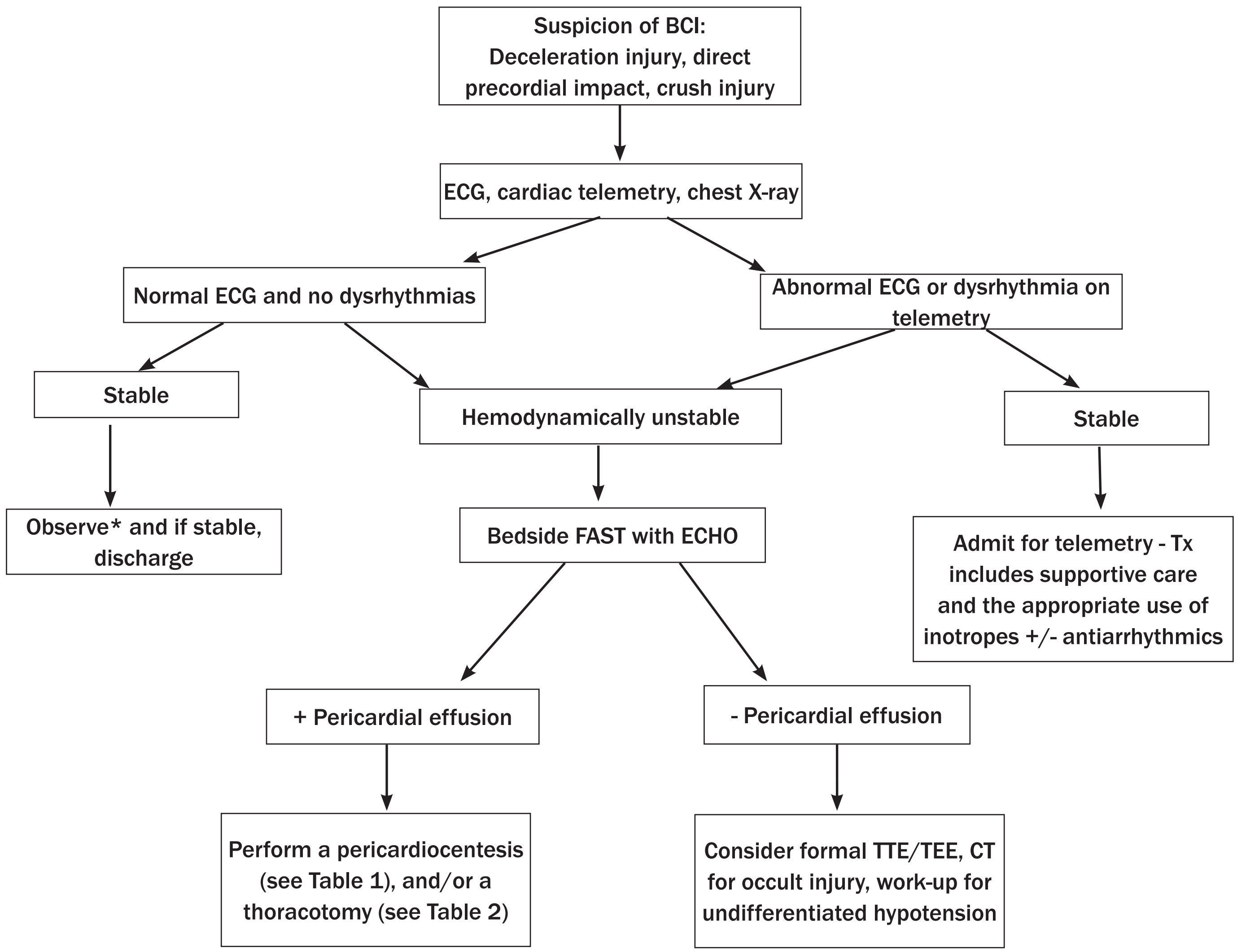
Septal or free wall rupture carries the highest mortality rate of the BCI categories. (*See Table 3.*) More than one chamber may be involved, with the right atrium allowing for the greatest survivability. Clinical characteristics and outcome depend on the chamber involved and the integrity of the pericardium. The combination of chamber wall and pericardial rupture results in rapid and abrupt hemodynamic demise, and the majority of these patients will die in the prehospital setting. There are case reports, however, documenting survival in transport and upon arrival to the ED after 30-90 minutes post-injury. It is for these patients that early diagnosis, pericardiocentesis, and emergent thoracotomy may be life-saving.[55-57]

Suspicion for cardiac failure secondary to valvular rupture or ventricular dysfunction is heightened in the setting of isolated BCI (other comorbid pathologies excluded) and refractory hypotension despite adequate resuscitation and negative FAST (including a lack of pericardial effusion). In these patients, the bedside FAST should be followed by a transthoracic echocardiogram (TTE), or if not adequate, then a transesophageal echocardiogram (TEE).[58,59] It is worth noting, however, that without such hemodynamic compromise, TTE or TEE is not practical in screening for clinically significant BCI.[34]

Lastly, a rare subset of patients with BCI present with signs of acute myocardial infarction (MI) secondary to contused myocardium, coronary artery thrombosis, or dissection. The exact mechanism of acute MI is unclear, as some patients have clean coronaries, others have underlying coronary artery disease, and some have underlying clotting abnormalities. Cardiac catheterization and potential treatment of the lesion with angioplasty and stenting is only possible when other injuries do not prevent the use of anticoagulation.[60-63]

BCI clearly presents both diagnostic and management challenges to the

Figure 6. Algorithm for Management of BCI



*No specific parameters exist for a period of observation. Some sources recommend 6 hours, some recommend no observation at all.

emergency physician. No single test or combination of tests has proven consistently reliable in detecting BCI, although using the ECG as a predictive tool has been shown to be the most sensitive. While the majority of cases require little workup, it is crucial to identify those cases that warrant more extensive evaluation. Cases of life-threatening BCI, while rare, require urgent stabilization. Unstable patients must be treated aggressively and efficiently, and specialist consultations should not be delayed. Established guidelines do not exist in the management of BCI; thus, each case should be managed with careful assessment of the history, physical examination findings, and use of bedside ultrasonography. Maintaining a high index of suspicion in BCI may prevent undesired outcomes in this somewhat unpredictable condition. The following algorithm, derived from the current pool of evidence in the management of BCI, should aid the ED physician in practice. (*See Figure 6.*)

Conclusion

Penetrating and blunt cardiac trauma may result in significant morbidity and mortality in the trauma patient. Early recognition and aggressive management may significantly improve the outcome for patients with these injuries.

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CME/CNE Questions

1. A subxiphoid pericardial window is the traditional gold standard for the diagnosis of pericardial effusion and tamponade.
   A. true
   B. false

2. Which of the following is true of ultrasound-guided pericardiocentesis?
   A. It is associated with more complications than the landmark approach.
   B. It is more difficult to perform than the landmark approach.
   C. It is associated with fewer complications and higher success rates than the landmark approach.
   D. The traditional landmark approach is the gold standard.

3. Which of the following should be considered in a patient with the combination of a penetrating chest wound, a left hemothorax on chest film and a negative FAST examination?
   A. blunt cardiac injury
   B. pericardial laceration through which blood decompresses into the chest
   C. pericardial effusion
   D. myocardial infarction

4. Diastolic collapse of the right ventricle and atria are the most frequently cited findings that indicate pericardial effusion with tamponade.
   A. true
   B. false

5. Which of the following statements is true?
   A. Patients with penetrating chest trauma have the most meaningful chance of survival.
   B. Outcomes in patients with stab wounds are better than for those with gunshot wounds.
   C. When CPR has been ongoing for 15 minutes or longer, survival approaches zero, regardless of the mechanism of injury.
   D. All of the above.

6. Which of the following statements is true regarding blunt cardiac trauma?
   A. There are several clear diagnostic criteria for BCI.
   B. It is easy to predict which patients will develop complications from BCI.
   C. No studies have been done to clarify the diagnosis of BCI.
   D. It is difficult to predict which patients will develop complications from BCI.

7. No definitive studies have proven the clinical value of cardiac biomarkers in either stable or unstable patients with BCI.
   A. true
   B. false

8. Any patient with a dysrhythmia should be considered to have a plausibly dangerous BCI and should be considered for which of the following?
   A. admission for telemetry monitoring and repeat ECG
   B. immediate discharge
   C. three hours of observation and discharge
   D. six hours of observation and discharge

9. Patients with isolated penetrating wounds to the abdomen have a very high survival rate following cardiopulmonary arrest.
   A. true
   B. false

10. Which of the following carries the highest mortality rate for BCI?
   A. BCI with minor ECG or enzyme abnormality
   B. BCI with complex dysrhythmia
   C. BCI with coronary artery thrombosis
   D. septal or free wall rupture

CNE/CME Objectives

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

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

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Customer Service E-Mail:
customerservice@ahcmedia.com

Editorial E-Mail:
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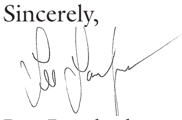

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