American College of Radiology
ACR Appropriateness Criteria®
Blunt Chest Trauma-Suspected Cardiac Injury

Variant: 1 Suspected cardiac injury following blunt trauma, hemodynamically stable patient.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	O
Radiography chest	Usually Appropriate	☢
CT chest with IV contrast	Usually Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Appropriate	☢☢☢
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CTA chest without and with IV contrast	Usually Appropriate	☢☢☢
US echocardiography transesophageal	May Be Appropriate	O
CT chest without IV contrast	May Be Appropriate	☢☢☢
CT heart function and morphology with IV contrast	May Be Appropriate	☢☢☢☢
US echocardiography transthoracic stress	Usually Not Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Not Appropriate	O
MRI heart function and morphology without IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without and with IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without IV contrast	Usually Not Appropriate	O
MRI heart with function and vasodilator stress perfusion without and with IV contrast	Usually Not Appropriate	O
CTA coronary arteries with IV contrast	Usually Not Appropriate	☢☢☢
SPECT or SPECT/CT MPI rest only	Usually Not Appropriate	☢☢☢
FDG-PET/CT heart	Usually Not Appropriate	☢☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

Variant: 2 Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transthoracic resting	Usually Appropriate	O
Radiography chest	Usually Appropriate	☢
CT chest with IV contrast	Usually Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Appropriate	☢☢☢
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CTA chest without and with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
US echocardiography transesophageal	May Be Appropriate	O
CT chest without IV contrast	May Be Appropriate	☢☢☢
CTA coronary arteries with IV contrast	May Be Appropriate	☢☢☢
US echocardiography transthoracic stress	Usually Not Appropriate	O

MRI heart function and morphology without and with IV contrast	Usually Not Appropriate	O
MRI heart function and morphology without IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without and with IV contrast	Usually Not Appropriate	O
MRI heart with function and inotropic stress without IV contrast	Usually Not Appropriate	O
MRI heart with function and vasodilator stress perfusion without and with IV contrast	Usually Not Appropriate	O
SPECT or SPECT/CT MPI rest only	Usually Not Appropriate	☢☢☢
FDG-PET/CT heart	Usually Not Appropriate	☢☢☢☢
SPECT or SPECT/CT MPI rest and stress	Usually Not Appropriate	☢☢☢☢

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Summary of Literature Review

Introduction/Background

Blunt trauma is a significant cause of death. In 2016, 1.4 million of the 56.9 million deaths worldwide were due to road injuries. In the United States, blunt injuries to the thorax are responsible for one-quarter of traumatic deaths [1] caused by high-energy mechanisms, such as motor vehicle accidents (MVAs), motorcycle collisions, and falls [2]. The most devastating fatal injuries to the thorax are from blunt trauma, causing acute cardiac injury and aortic injury or transection [3]. The majority of these patients do not survive long enough to receive care at a hospital and expire before definitive diagnoses and treatments can be implemented [4]. For patients with suspected polytrauma (injury to at least 2 body parts), please refer to the ACR Appropriateness Criteria® topic on "Major Blunt Trauma" [5] for imaging guidelines. Blunt cardiac injuries range from myocardial concussion (commotio cordis) leading to fatal ventricular arrhythmias to myocardial contusion, cardiac chamber rupture, septal rupture, pericardial rupture, and valvular injuries [6,7]. Some patients may present with posttraumatic coronary dissection and subsequent myocardial infarction that may mimic myocardial contusion [6]. Cardiac chamber rupture, even though rare, is associated with a high mortality rate. This is usually caused by rapid direct impact to the anterior chest in end-diastole when the ventricles are maximally distended leading to laceration or tear in the walls of the ventricles and/or atria [8].

Other mechanisms of blunt cardiac trauma include indirect impact caused by a large force to the abdominal or upper extremity veins that increase the preload and intracardiac pressure, bidirectional forces compressing the heart between the sternum and the spine, acceleration and deceleration forces allowing the heart to freely move in the anterior–posterior direction, blunt forces, concussive forces, and penetration by displaced rib fractures [7,9]. Patients with cardiac chamber rupture usually do not survive long enough to reach the hospital [10]. However, for

patients with suspected cardiac injuries who present to the emergency department after an MVA with chest pain, hemodynamic instability, and electrocardiographic (ECG) abnormalities, early diagnosis and life-saving management strategies are paramount to improve the likelihood of a favorable outcome [10-12]. This ACR Appropriateness Criteria document will discuss the role of different imaging modalities that are appropriate for initial assessment of possible cardiac injury.

Special Imaging Considerations

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the [ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA)](#) [13]:

> "*CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric data set is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings.*"

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and recons/reformats. Only in CTA, however, is 3-D rendering a **required** element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

CTA can also be performed with or without ECG gating. The ECG gating is usually prospective and allows for better assessment of cardiac injuries as well as concomitant aortic injuries in patients with blunt chest trauma and concomitant cardiac injuries.

The role of focused assessment with sonography for trauma (FAST) (or extended-FAST or chest abdominal-FAST in evaluating chest injury) is primarily one of triage; a positive FAST and signs of hemodynamic instability may lead to immediate surgical intervention rather than CT [14,15]. Ultrasound (US) may be able to diagnose certain thoracic and abdominal injuries, but it is an insufficient test to fully exclude injuries to these areas because it has a relatively lower specificity compared with CT [16]. Hemodynamic instability and findings such as abnormal ECG and increased level of high-sensitivity troponin in hemodynamically stable patients should raise the suspicion of cardiac injuries, and these patients should undergo rapid cardiac assessment by echocardiography [7,10].

An initial FAST examination can detect pericardial effusion and wall motion abnormality. Hall et al [11] analyzed the cardiac component of the FAST examination in hypotensive (systolic blood pressure <90 mm Hg) and normotensive trauma patients. The authors concluded that performing echocardiography in hypotensive blunt trauma patients is effective in evaluating myocardial rupture with limited evaluation of the right ventricle, valvular injuries such as valvular or perivalvular regurgitation, hemopericardium, tamponade, pneumopericardium, and myocardial infarction. The authors have also stressed that a cardiac FAST examination may not be an effective use of resources for normotensive blunt trauma patients.

Discussion of Procedures by Variant

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient.

Clinical assessment of a patient's hemodynamic stability is the paramount first step in patients with

blunt chest trauma and suspected cardiac injury. Hemodynamically unstable patients are defined as persistent hypotension (systolic blood pressure <90 mm Hg or mean blood pressure <65 mm Hg) despite fluid resuscitation [17].

In general, hemodynamically stable patients should be either monitored or evaluated by cardiac imaging if the abnormal ECG findings persist or cardiac troponin levels are rising [7]. Patients with normal ECG and cardiac troponin levels are usually considered low probability for cardiac blunt trauma and therefore can be safely discharged [7,18,19].

CT chest has been accepted as an imaging modality of choice in patients with blunt chest trauma [20-23]. The superior spatial resolution combined with the ability of contrast enhancement to display the anatomic structures and 3-D reconstructions allows for accurate assessment of cardiovascular anatomy and the associated detection of pathology. Ideally, CT chest in patients with suspected cardiac injuries as part of the blunt trauma evaluation should be performed with intravenous (IV) contrast. However, in some instances, CT chest could be performed either without or with and without IV contrast, as described in the CT chest sections below.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. A. CT Chest Without IV Contrast

In patients with suspected cardiac injury, CT chest studies without IV contrast can easily identify hemothorax or hemopericardium from pleural and pericardial effusion by measuring the attenuation within the pleural or pericardial space. CT chest without IV contrast can also accurately detect sternal fractures by evaluating the sagittal and 3-D reconstructions. Even though a sternal fracture in the setting of trauma is considered a benign condition, myocardial contusion and myocardial concussion leading to malignant ventricular arrhythmias can be encountered with this finding only if there are ECG changes and cardiac troponin levels are rising. It is difficult to predict which patients with a sternal fracture will develop cardiac complications. In a cohort of 54 patients with a suspected sternal fracture by emergency physicians in a multicenter descriptive retrospective study, only 72% of the patients had ECG performed at baseline, 33% had follow-up ECG, and 30% had troponin I assessment; in this group, 6% of the patients were diagnosed with arrhythmias and myocardial contusion. The authors also showed that only 38 (70%) of the patients with suspected sternal fractures were confirmed by imaging [24]. This study shows the importance of diagnosing sternal fractures in conjunction with ECG monitoring and troponin assessment to evaluate cardiac injury in the setting of blunt trauma. However, it is noteworthy that echocardiography is not recommended in isolated sternal fractures in the presence of a normal ECG and cardiac troponins to evaluate for myocardial contusion [25]. The use of CT chest without IV contrast is of paramount importance in patients with prior chest surgery or retained metal fragments for accurate diagnosis of cardiac trauma and concomitant vascular injuries.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. B. CT Chest With IV Contrast

CT chest with IV contrast has the ability to identify the source of bleeding in patients with blunt chest trauma and is complementary to chest radiography and transthoracic echocardiography (TTE) in the workup of blunt chest trauma with suspected cardiac injuries. For example, a case report described a hemothorax that resulted from right atrium rupture at the junction with inferior vena cava and an associated pleuropericardial laceration [26]. It is worth noting that the right ventricle is most commonly affected because of its anterior location in the chest, followed by the left ventricle and right atrium [27]. However, in some trauma cases, the pericardium remains intact

and the hemorrhage from the myocardial rupture accumulates in the pericardium, causing hemopericardium and cardiac tamponade that requires immediate intervention [7,28]. Therefore, both hemothorax and hemopericardium warrant immediate further assessment with IV contrast to rule out concomitant cardiovascular injury [28,29]. In addition, the triad of high-attenuation pericardial effusion, periportal low attenuation, and distention of the inferior vena cava, renal, superior vena cava, and azygos veins at CT should raise the suspicion for cardiac tamponade [30]. In rare cases of an isolated pericardial tear, a heart herniation and strangulation can occur. In another study, 5 out of 10 cases with pericardial rupture identified at autopsy were complicated with strangulation of the heart [31]. It is important to note that heart strangulation is a serious complication associated with a high mortality rate. CT findings of heart herniation/strangulation include empty pericardial sac, "collar sign" (defined as constriction of the cardiac contour by a pericardial tear), and malposition of the heart to the left or right hemithorax [32,33]. CT findings of traumatic pericardial rupture without cardiac herniation/strangulation are focal pericardial discontinuity or pneumopericardium [30,34].

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. C. CT Chest Without and With IV Contrast

CT chest with and without IV contrast is the most effective routine imaging modality for detecting thoracic injuries caused by blunt trauma. It accurately detects hemorrhage within the chest followed by identification of concomitant cardiovascular injuries as a source of bleeding.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. D. CT Heart Function and Morphology

ECG-gated cardiac CT with IV contrast can be used in the trauma setting to evaluate the cardiac structure and can detect cardiac chamber rupture and pericardial rupture [35]. A case report has described various entities such as rupture of the right ventricle with contained contrast extravasation [36], left atrial appendage tear, rupture of the atria at the junction with pulmonary veins, and inferior vena cava. The existing literature focuses on clinical decision scores along with a chest radiograph, ECG, and troponin assessment [37] as a screening algorithm to triage patients in whom cardiac CT has the potential to guide life-saving interventions. Cardiac CT has been demonstrated to be highly accurate for the detection of cardiac structural abnormalities in the nontrauma setting.

A case report described the right ventricular pseudoaneurysm following an MVA diagnosed with cardiac CT and missed with echocardiography [36]. Another case report described contrast extravasation from the apical portion of the right ventricle into the pericardial space compatible with contained ventricular rupture in addition to multiple chest injuries detected at CT [38]. Other case reports have described the ability of contrast-enhanced CT chest to detect enhancement defects in the myocardium suggestive of myocardial infarction in the setting of trauma. These findings triggered further imaging and subsequent intervention [21] to treat coronary artery dissection following blunt trauma [39]. In addition, another case report described a patient with a hemothorax caused by a left atrial appendage rupture, pleuropericardial tear, and cardiac herniation through the pericardium [40]. Moreover, case reports have described the ability of CT chest with IV contrast to detect enhancement defect in the myocardium suggestive of myocardial infarction and ventricular septal defect in the setting of trauma that triggered further imaging and intervention [6,21,41].

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. E. CTA Chest

Although this document excludes the discussion of vascular injuries, CTA chest without and with IV contrast is useful in a patient with blunt chest trauma and suspected cardiac injury. This is because CT chest can identify the extent of cardiac injury as well as other concomitant injuries in the chest and, most importantly, can be used for surgical planning.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. F. CTA Coronary Arteries

Coronary CTA evaluates for potential posttraumatic coronary arterial dissection or occlusion resulting in myocardial infarction. There are limited data on the coronary CTA in patients with suspected myocardial infarction in the trauma setting. A case report has described various entities such as intramural hematomas or atypical dissection of the coronary artery [42] and enhancement defects in the myocardium suggestive of myocardial infarction in the setting of trauma. These findings triggered further imaging and subsequent intervention [21] to treat coronary artery dissection following blunt trauma [39]. Several case reports have described the use of coronary angiography as a diagnostic and therapeutic modality [40,43-46] to not only detect coronary artery dissection and thrombosis in patients with ECG abnormalities, or increased serum troponin level, but also treat with angioplasty or coronary artery stent placement. More recently, high-sensitivity cardiac troponins have become the mainstays in an emergency evaluation [7].

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. G. FDG-PET/CT Heart

Cardiac fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT may be used to assess myocardial function, perfusion, and viability in the trauma setting.[37,47]. There are no data regarding the use of FDG-PET/CT heart in the setting of blunt chest trauma and suspected cardiac injury.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. H. MRI Heart Function and Morphology

There are no data regarding the use of MRI heart in the setting of blunt chest trauma and suspected cardiac injury. A few case reports describe the use of cardiac MR (CMR) in detecting viable myocardium using late gadolinium enhancement because of myocardial infarction in trauma patients [41,46] and a case report describing a heart herniation [48]. CMR is also useful for detecting cardiac injuries, particularly right ventricular injury and pericardial injury, quantifying valvular regurgitation, and detecting typical or atypical aortic dissection in patients. In many instances, the CMR protocol may be shortened to address the clinical question; however, it is still a longer examination than a CT scan. However, CMR may be helpful in selected patients with suspected cardiac trauma and equivocal echo findings.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. I. MRI Heart with Function and Inotropic Stress

There is no relevant literature regarding the use of CMR with function and inotropic stress in a hemodynamically stable patient with blunt trauma to evaluate suspected cardiac injuries.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. J. MRI Heart With Function and Vasodilator Stress Perfusion

There is no relevant literature regarding the use of CMR with function and inotropic stress in a hemodynamically stable patient with blunt trauma to evaluate suspected cardiac injuries.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. K. Radiography Chest

In any trauma setting, chest radiography is the first imaging modality to identify indirect findings that infer cardiac or pericardial injuries. However, the role of chest radiography in blunt cardiac trauma is often limited in quality because of motion artifacts and overlying devices and garments. Longitudinal prospective studies examining the diagnostic yield of imaging in a blunt cardiac trauma have not been possible because identification of indirect findings that infer cardiac injury are rare and often missed and are mainly discussed in case reports. Chest radiography alone has limited ability to detect traumatic cardiac injuries.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. L. SPECT/CT MPI Rest and Stress

Single-photon emission computed tomography (SPECT) may be used to assess myocardial function, perfusion, and viability in the trauma setting. The literature for use of SPECT is contradictory. In a prospective study involving 125 patients that evaluated the use of T1-201 thallous chloride SPECT in blunt chest trauma [49], the authors found that 11 out of 75 patients who screened positive and 3 out of 48 patients who screened negative developed serious arrhythmias such as premature ventricular beats and atrial fibrillation. They concluded that SPECT is useful to evaluate myocardial contusion in patients with blunt chest trauma. A meta-analysis study showed that radionuclide results did not correlate with cardiac complications whereas ECG abnormalities and cardiac troponins did in patients with blunt chest trauma [37]. This could be explained by the fact that SPECT better detects left ventricular abnormalities than right ventricular abnormalities, which are more common in blunt cardiac trauma.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. M. SPECT/CT MPI Rest Only

There is no relevant literature regarding the use of SPECT/CT MPI rest only to evaluate suspected cardiac injuries.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. N. US Echocardiography Transesophageal

Transesophageal echocardiography (TEE) can be used in the trauma setting; however, it is often time limited because of the hemodynamic instability of the patients, need for sedation, and concern about esophageal injury. TEE is of value when the TTE findings are equivocal and aortic injury is suspected [50]. In a prospective study of 105 patients with severe blunt chest trauma, 20 patients underwent TEE because of suboptimal TTE findings, 9 of whom were diagnosed with a myocardial contusion and 5 with acute aortic injury [50]. TEE is also useful in evaluating right heart and tricuspid valve [51]. There is no evidence to support the use of TEE in the trauma setting for isolated cardiac injury.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. O. US Echocardiography Transthoracic Resting

TTE resting is a first-line imaging modality in the evaluation of patients with suspected blunt cardiac trauma presenting with abnormal ECG and elevated cardiac troponin level. TTE can easily assess the biventricular systolic function, pericardial effusion with suspected tamponade, myocardial rupture, wall motion abnormality, septal injuries, and valvular injuries in the setting of blunt chest trauma. The initial detection of hemothorax with pericardial tear or hemopericardium in intact pericardium by echocardiography should raise the suspicion of concomitant myocardial rupture. If echocardiography findings are suboptimal for evaluation of myocardial rupture, further evaluation with cardiac CT or TEE is warranted. Septal defects, which can be caused by either

mechanical rupture or delayed postinflammatory rupture 2 to 3 days following septal contusion, should be evaluated by Doppler echocardiography and echocardiography with agitated saline [52]. The diagnosis of ventricular septal defect was made in 85% of the cases reviewed in the literature [53]. Ventricular septal ruptures, which are likely to occur during late diastole when the ventricles are filled and valves are closed, are more common than atrial septal ruptures, which occur during late systole when the atria are filled and the valves are closed [7]. The ventricular septal injuries most commonly affect the muscular portion of the septum near the ventricular apex because of rapid anterior–posterior compression of the heart between the spine and the sternum [32].

Valvular injuries are also rare but have been reported in the literature. Aortic and mitral valves are the most commonly affected, followed by tricuspid and pulmonic valves, because the mural pressure is higher on the left side of the heart [54]. Valvular injuries can present as perivalvular leak, dehiscence because of papillary muscle or chordae tendineae rupture, tearing of valve leaflets, or papillary muscle contusion leading to necrosis. Aortic and pulmonic valves are vulnerable to injury during early diastole and atrioventricular valves are prone to injury during early systole when the intraventricular pressure is increased [7]. All valvular injuries present with signs and symptoms of regurgitation, therefore, it is prudent to perform echocardiography and assess the severity of regurgitation to guide further management with surgical repair in severe cases. Several case reports describe posttraumatic severe mitral regurgitation requiring surgical repair following MVAs [55-57].

A few case reports have described the use of echocardiography for diagnosing wall motion abnormality in the setting of myocardial infarction and coronary artery dissection after blunt chest trauma, especially when myocardial contusion mimics myocardial infarction with elevated cardiac troponins [42,58]. Prompt identification of wall motion abnormality in coronary artery distribution following blunt chest trauma is important for the identification and treatment of coronary artery dissection. Additionally, when a wall motion abnormality is present in the absence of elevated high-sensitivity cardiac troponins, a diagnosis of myocardial concussion can be made. Myocardial concussion does not cause myocardial anatomic injuries that lead to necrosis and elevated high-sensitivity cardiac troponins but instead stretches the cell membrane, leading to activation of ion channels through mechanical-electrical coupling that trigger ventricular arrhythmias [59]. In summary, TTE is the first-line imaging modality used in evaluation of blunt cardiac trauma in patients with abnormal ECG and elevated cardiac troponins.

Variant 1: Suspected cardiac injury following blunt trauma, hemodynamically stable patient. P. US Echocardiography Transthoracic Stress

There is no relevant literature regarding the use of TTE stress in suspected myocardial infarction in the trauma setting.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.

Hemodynamically unstable patients are defined as persistent hypotension (systolic blood pressure <90 mm Hg or mean blood pressure <65 mm Hg) despite fluid resuscitation [17]. Hemodynamically unstable patients with ECG changes and elevated cardiac troponins worrisome for cardiac trauma are usually managed with advanced cardiac life support followed by echocardiography evaluation [7]. On the contrary, hemodynamically unstable patients with normal ECG and cardiac troponins are usually admitted for monitoring and echocardiography is only indicated for unstable patients with rising troponin levels [7].

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
A. CT Chest

CT chest plays a complementary role in defining the extent of blunt cardiac trauma and is typically reserved for surgical planning in patients with ongoing symptoms and unclear clinical etiology [7]. For this purpose, CT in a hemodynamically unstable patient with blunt trauma is useful despite the lack of relevant literature to support this statement.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
B. CT Heart Function and Morphology

CT heart in a hemodynamically unstable patient with blunt trauma and possible cardiac injury is useful in clinically indicated scenarios despite the lack of direct evidence.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
C. CTA Chest

The use of CTA chest is helpful in a hemodynamically unstable patient with blunt trauma and possible cardiac injury if clinically indicated to define the extent of blunt chest trauma and identify concomitant thoracic injuries; it is also helpful for surgical planning. However, there is no relevant literature to support the use of CTA chest in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
D. CTA Coronary Arteries

The lack of evidence does not support the use of CTA coronary in a hemodynamically unstable patient with blunt trauma and possible cardiac injury, but it could be done if clinically indicated.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
E. FDG-PET/CT Heart

There is no relevant literature to support the use of FDG-PET/CT in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
F. MRI Heart Function and Morphology

There is no relevant literature to support the use of CMR function and morphology in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
G. MRI Heart With Function and Inotropic Stress

There is no relevant literature regarding the use of CMR stress in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
H. MRI Heart With Function and Vasodilator Stress Perfusion

There is no relevant literature regarding the use of CMR stress in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
I. Radiography Chest

Bedside anteroposterior (AP) chest radiographs are commonly used as a first-line imaging modality in the evaluation of blunt thoracic trauma at most level I trauma centers in the United States, especially in hemodynamically unstable patients [26,60]. AP chest radiographs have limited ability to identify the direct findings of blunt cardiac injuries such as cardiac rupture, coronary artery dissection, pericardial tear, and valvular injuries. However, radiographs have the potential to identify indirect findings that infer cardiac or pericardial injuries. These indirect findings include hemothorax, widened mediastinum, enlarged cardiomediastinal silhouette, abnormal cardiac silhouette contour, changing cardiac position after tube thoracotomy, pneumopericardium, and displaced rib fractures, especially between the third and ninth ribs. These findings coupled with the appropriate clinical presentation should trigger a further evaluation of potential life-threatening cardiac and pericardial injuries [61-63]. Attention should be paid in patients with cardiac implantable electronic devices for possible device header fracture, lead fracture, or lead migration [64]. A case report of chest trauma that resulted in device malfunction showed an abnormal angulation between the device header and the body of the generator on a lateral chest radiograph [65].

Although an AP chest radiograph is the first-line imaging in trauma patients, it is often limited in quality because of motion artifacts and overlying devices and garments. The evaluation of the mediastinum is also limited with only an AP projection image. Several studies have evaluated the diagnostic yield of the chest radiograph in the assessment of blunt thoracic injuries and have shown the value of using chest radiographs, especially when coupled with abdominal CT, chest CT, or a clinical decision score [23,66-73]. AP chest radiograph has a lower diagnostic yield for occult blunt traumatic injuries than chest CT, missing 80% of cases of hemothorax and 50% of vertebral and rib fractures compared with CT [68,69,72,73]. Hemothorax or hemopericardium can result from cardiac rupture and pericardial tamponade; sternal fracture can result in cardiac contusion or even rupture. Overall, chest radiography alone has limited ability to detect traumatic cardiac injuries.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
J. SPECT/CT MPI Rest and Stress

There is no relevant literature regarding the use of Tc-99m SPECT/CT MPI rest and stress in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
K. SPECT/CT MPI Rest Only

There is no relevant literature regarding the use of Tc-99m SPECT/CT MPI rest only in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
L. US Echocardiography Transesophageal

TEE is more sensitive than TTE and is often recommended when TTE is not diagnostic and the suspicion of cardiac causes remains high. Even though there is no relevant literature regarding the use of TEE rest in a hemodynamically unstable patient with blunt trauma and possible cardiac injury, TEE rest is useful if clinically indicated.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
M. US Echocardiography Transthoracic Resting

TTE resting is a first-line imaging modality in the evaluation of suspected cardiac trauma in the setting of blunt chest trauma. TTE can easily assess the biventricular systolic function, pericardial effusion with suspected tamponade, myocardial rupture, wall motion abnormality, septal injuries, and valvular injuries in the setting of blunt chest trauma. The diagnostic yield of TTE is greater in patients who present with chest pain, abnormal ECG findings, rising troponin values, new arrhythmia, or clinical heart failure. Hemodynamically unstable patients with normal ECG and cardiac troponins should be monitored and TTE should be performed if the cardiac troponins are rising or if there is a new onset of arrhythmia or abnormal ECG changes.

Variant 2: Suspected cardiac injury following blunt trauma, hemodynamically unstable patient.
N. US Echocardiography Transthoracic Stress

There is no relevant literature regarding the use of TTE stress in a hemodynamically unstable patient with blunt trauma and possible cardiac injury.

Summary of Recommendations

- **Variant 1:** Radiography chest, US echocardiography transthoracic resting, and CT chest (with IV contrast or without and with IV contrast) or CTA chest (with IV contrast or without and with IV contrast) are complementary first-line imaging modalities and are usually appropriate in the workup of a hemodynamically stable patient with suspected cardiac injury following blunt trauma.

- **Variant 2:** Radiography chest, US echocardiography transthoracic resting, CT chest (with IV contrast or without and with IV contrast), CTA chest (with IV contrast or without and with IV contrast), and CT cardiac function and morphology with IV contrast are complementary imaging modalities and are usually appropriate in the workup of a hemodynamically unstable patient with suspected cardiac injury following blunt trauma.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria[®] [Radiation Dose Assessment Introduction](#) document [74].

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria[®] [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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