American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Blunt Chest Trauma**

Variant 1: **First-line evaluation. High-energy mechanism.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9	Chest x-ray and CT/CTA are complementary examinations.	☢
CT chest with IV contrast	9	Ideally, this procedure should be performed with CTA. Chest x-ray and CT/CTA are complementary examinations.	☢☢☢
CTA chest with IV contrast	9	Chest x-ray and CT/CTA are complementary examinations.	☢☢☢
CT chest without IV contrast	5		☢☢☢
US chest	5		O
CT chest without and with IV contrast	2		☢☢☢
MRI chest without and with IV contrast	2		O
MRI chest without IV contrast	1		O
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Variant 2: **Normal anteroposterior (AP) chest radiograph, normal examination, and normal mental status. No high-energy mechanism.**

Radiologic Procedure	Rating	Comments	RRL*
CTA chest with IV contrast	5		☢☢☢
CT chest with IV contrast	5		☢☢☢
CT chest without IV contrast	4		☢☢☢
MRI chest without and with IV contrast	2		O
CT chest without and with IV contrast	1		☢☢☢
US chest	1		O
MRI chest without IV contrast	1		O
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Blunt Chest Trauma**

Variant 3: **Clinically suspected cardiac injury after initial imaging and clinical evaluation.**

Radiologic Procedure	Rating	Comments	RRL*
US echocardiography transthoracic resting	8		O
CTA coronary arteries with IV contrast	5	Use this procedure if looking for coronary artery injury.	☢☢☢☢
US echocardiography transesophageal	5	Use of this procedure depends on TTE findings.	O
MRI heart function and morphology without and with IV contrast	4	Use this procedure as a problem-solving tool.	O
MRI heart function and morphology without IV contrast	4	Use this procedure as a problem-solving tool.	O
Thallium-201 SPECT heart	3		☢☢☢☢
Tc-99m sestamibi SPECT heart	3		☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

BLUNT CHEST TRAUMA

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Summary of Literature Review

Introduction/Background

Blunt trauma is very common in the United States and is a significant cause of mortality in younger adults; most cases are related to high-energy mechanisms, such as motor vehicle accidents, motor cycle collisions, and falls [1]. According to the World Health Organization data, 1.21 million people world-wide died from car accidents [2]. In the United States, it is estimated that trauma is responsible for approximately 100,000 deaths annually. Accidents (unintentional injuries) are the fifth most common cause of death after heart disease, cancer, chronic lower respiratory diseases, and cerebrovascular accidents. In the United States, accidents (including motor vehicle accidents) continue to be the most common cause of death among people ages 15–44 accounting for approximately 40,000 deaths in 2010. Among people ages 15–24, motor vehicle accidents are by far the most common cause of death [3].

Approximately 25% of deaths from blunt trauma arise from chest injuries, although up to 50% of deaths are at least partially related to thoracic injuries [4]. It is essential to diagnose and treat emergent thoracic injuries quickly, and imaging plays an essential role in diagnosing these injuries. The imaging manifestations of thoracic trauma are diverse and include musculoskeletal, pleural, pulmonary, and mediastinal findings. The most devastating injury to the thorax from blunt trauma is acute aortic injury or transection, and the most common thoracic injury is a rib fracture; see previous ACR Appropriateness Criteria® for these specific indications. This set of guidelines will discuss imaging in blunt thoracic trauma in the broadest sense.

Chest Radiography

The anteroposterior (AP) chest radiograph is a standard part of the trauma workup at most level I trauma centers across the United States [5]. This is often combined with an AP pelvic radiograph and a lateral horizontal-beam cervical spine radiograph to quickly assess the patient for emergent injuries and to triage patients. A multitude of injuries can be detected or inferred from chest radiography; these include acute aortic injury, pulmonary injury, pneumothorax, hemothorax, extrapleural hematoma, large airway rupture, hemidiaphragmatic rupture, or musculoskeletal injury [6-8]. The most devastating of these is acute aortic injury, and chest radiography continues to be an appropriate primary screening modality in its assessment, as noted in the ACR Appropriateness Criteria® topic on "Blunt Chest Trauma—Suspected Aortic Injury" [9]. In addition, patients with blunt trauma are often intubated and have other lines and tubes inserted as well. The AP chest radiograph is essential to quickly exclude obvious misplacement of lines and tubes that may be difficult to detect in the setting of multitrauma.

Although they seem to be essential to the care of critically ill blunt trauma patients, AP chest radiographs in the trauma setting are often of low quality. If patients are in severe pain or are unconscious, full inspiration is usually not possible. Overlying material is the rule rather than the exception, and motion artifact is common. The mediastinum may appear falsely enlarged due to AP projection. Given these shortcomings, many studies have shown that AP chest radiographs miss many injuries that are evident on computed tomography (CT) [10-18].

A single-center study evaluating occult pneumothoraces (identified on CT but not on AP chest radiography) in the setting of blunt trauma, showed that up to 55% of pneumothoraces detected on CT were occult on AP chest

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radiography. This was likely an underestimation, given that patients who had apparently normal AP chest radiographs were often not evaluated with chest CT, as is common in many trauma centers. The authors used the clinical radiology reports for the initial review of data but reassessed radiographs with occult pneumothoraces to ensure that the pneumothorax was not simply missed on the initial review [17]. Another study found that occult pneumothoraces were actually visible on AP chest radiography in 12%–24% of cases in a blinded retrospective review [19]. The agreement between radiologists for detecting subtle pneumothoraces was fair (kappa scores: 0.55–0.56), which was not surprising given the low quality and low contrast resolution of AP chest radiography in the trauma setting.

Another study also showed the modest sensitivity of AP chest radiography for thoracic injuries [20]. In this study of 374 patients with blunt trauma, approximately half of all pneumothoraces, rib fractures, and pulmonary contusions were not apparent on AP chest radiography. Nearly three-fourths of all hemothoraces were also not identified on AP chest radiography. The authors focused on the ability of combined chest radiography and abdominal CT to detect most pertinent chest injuries. Even with the combined AP radiograph and abdominal CT, one-fifth of all pneumothoraces, rib fractures, and pulmonary contusions were still missed. Moreover, all 5 cases of aortic injury were not evident on chest radiograph or CT abdomen, which argues against over-reliance on chest radiography in the setting of high-energy mechanism blunt trauma.

The authors of a prospective comparative study showed that chest CT revealed an acute injury (most often pulmonary contusion and pneumothoraces) in 39% of patients with no thoracic symptoms or signs, a negative chest radiograph, and recent high-energy mechanism blunt trauma (MECH group). This was in contrast to patients with clinical chest symptoms or abnormal chest radiographs (CTL group) in which 66% had injuries noted with chest CT but not radiography [13]. Furthermore, additional data from chest CT scans led to alterations in management in 5% of the MECH group and 20% of the CTL group, leading the authors to conclude that chest radiography is inadequate in the setting of high-mechanism blunt trauma.

Using chest CT as a gold standard, a retrospective study evaluated the accuracy of portable chest radiographs in the setting of stable patients who had suffered recent blunt trauma [18]. Stable patients were defined as those who were not intubated, normotensive, and nonhypoxic. In 95 patients with “normal” chest radiographs, CT showed that 38 had traumatic injuries. Furthermore, in 63 patients with “abnormal” radiographs, CT showed no evidence of acute injuries in 18 of those patients. In 32 patients, CT led to changes in patient management. Given chest radiography’s relatively poor sensitivity and specificity for blunt injuries, the authors suggested that routine chest radiography may not be necessary in stable patients with blunt trauma.

In summary, AP chest radiography has lower accuracy for blunt traumatic injuries than CT. Reliance on radiography as the sole means to detect traumatic thoracic injuries is, therefore, likely not prudent. However, the ability to acquire a radiograph in the trauma bay with little interruption in clinical survey, monitoring, and treatment (especially important in severely injured patients) as well as radiography’s accepted role in screening for traumatic aortic injury and rapid evaluation of line and tube placement supports the routine use of chest radiography in the setting of blunt trauma.

Computed Tomography

As previously noted, chest CT is much more accurate than a chest radiograph in evaluating blunt thoracic trauma. It is such a trusted modality in detecting thoracic trauma that much of the literature treats contrast-enhanced chest CT as a gold standard [16,20-22]. However, given the increased cost and radiation dose from chest CT, some have questioned the routine use of chest CT in all cases of blunt trauma [10-12,16,20,23-26]. Unfortunately, there are conflicting data on whether routine chest CT is necessary in the setting of blunt trauma.

In a prospective study of 464 consecutive patients with severe blunt trauma, all were scanned with contrast-enhanced CT of the chest—routine multidetector CT (MDCT) algorithm [11]. A selective MDCT algorithm subgroup of 164 patients was identified. This group was defined as patients in whom clinical or radiographic findings suggested a possible thoracic injury. Additional diagnoses (compared to radiography) were found more often in the selective group than in the routine group (59% compared with 43%, respectively). However, the routine MDCT algorithm resulted in 104 extra patients in whom radiographically occult findings were identified. In 34 of these 104 patients, there was a change in management, usually from additional pulmonary and mediastinal injures.

In a small retrospective study of 93 patients with blunt trauma who were evaluated with AP chest radiography and chest CT, the authors identified 25 patients with normal chest radiographs [25]. In 13 of these 25 patients, CT scans showed multiple injuries, including 2 aortic lacerations. The authors concluded that the routine use of chest CT is prudent to detect rare but important thoracic injuries.

Other studies, however, have found that routine use of chest CT may not be necessary in the setting of blunt trauma [24]. In a retrospective study of 542 patients with a history of motorized blunt trauma who underwent full body CT, the researchers identified 108 patients who experienced no tenderness, deformity, or bruising over the chest, abdomen, or pelvis and no hemodynamic compromise. CT identified acute thoracic injuries in 11 of those 108 patients, but none required direct and immediate intervention. Eight of the 11 patients were either intoxicated or had distracting injuries. Based on their findings, the authors suggested that CT use is likely of low yield in patients with normal examinations, with no distracting injuries, and with normal mental status.

Another group created a predictor of chest injury using chest CT based on a logistic regression analysis of 9 clinical and radiographic variables in 1,047 patients who suffered high-energy blunt trauma [26]. They found that chest CT identified chest injuries in 13% of patients who would not have been predicted to have chest injuries, and only 2% had injuries that were considered clinically relevant. The authors concluded that a selective model of chest CT use in the setting of blunt trauma is acceptable, given the low rate of clinically significant injuries detected by using their model, in addition to the low morbidity and mortality that arises from most chest injuries (small pneumothoraces, pulmonary contusions, and rib fractures). A similar study supported use of a predictive model based on radiographic, clinical, and demographic data to select patients in whom chest CT would be more likely to identify injuries [22].

A recent ACR Appropriateness Criteria® topic on "Blunt Chest Trauma—Suspected Aortic Injury" [9], supports the use of chest CT angiography (CTA) in combination with chest radiography without reservation. The authors reported evidence that CTA is highly sensitive (with a high negative predictive value) in evaluating suspected traumatic aortic injury when there are no signs of direct aortic injury. CTA is also highly specific for aortic injury, such that most centers have now abandoned invasive aortography in the initial assessment of patients with suspected aortic injury from trauma.

CT is the imaging modality of choice in suspected thoracic spinal injury [27]. In this setting, radiographs are of limited value and are considered "usually not appropriate."

In summary, chest CT is the gold standard routine imaging modality for detecting thoracic injuries caused by blunt trauma. Although wide use of chest CT has become standard, there is disagreement on whether routine chest CT is necessary in all patients with a history of blunt trauma. However, routine use of chest CT should be strongly considered in patients with high-mechanism, abnormal chest radiographs, altered mental status, distracting injuries, or clinically suspected thoracic injury. Ultimately, the frequency and timing of CT chest imaging should be site-specific and should depend on the local resources of the trauma center and patient status. CTA of the chest should be used routinely in patients with suspected acute aortic laceration, given the serious ramifications of missing such an injury.

Ultrasound

Ultrasound (US) in the setting of trauma has been most widely accepted in the form of the focused assessment with sonography for trauma (FAST), in which US is used to detect free fluid in the abdomen and pericardium [28]. At some centers, FAST is also extended into the thorax to detect a pneumothorax and hemothorax, although the significance and use of extended FAST has yet to be defined [29]. Multiple studies have shown that US is superior to radiography but inferior to CT in detecting a pneumothorax [30,31]. One small study of 27 patients showed that 11 had a pneumothorax detected by CT (gold standard), and all 11 pneumothoraces were detected by US [32]. Only 4 of the 11 pneumothoraces were detected by supine radiography. In a recent meta-analysis, a group found there was very good sensitivity and specificity of US for a pneumothorax detected by CT (86%–98% and 97%–100%, respectively); however, supine radiography had limited sensitivity in detecting a pneumothorax (28%–75%), although its specificity was high (100%) [33].

US can detect even a small hemothorax and is likely able to detect pleural fluid collections as small as 20 mL [34]. When compared with radiography, US has been shown to be as accurate or more accurate in detecting a hemothorax [29,35]. However, as in pneumothoraces, US may miss small hemothoraces.

There is limited literature on the use of US in the setting of other thoracic injuries, such as pulmonary injury and musculoskeletal trauma [36-39]. In the setting of suspected cardiac injury and hypotension, echocardiography is often helpful in excluding cardiac chamber rupture and acute valvular injury; routine screening of patients with blunt trauma to the chest is not universally accepted [40-42]. The role of US in the setting of blunt thoracic trauma will likely continue to evolve as we gain a better understanding of how to most rapidly, accurately, and safely image patients in this setting.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is not widely used in the trauma setting. As opposed to radiography, CT, and US, rapid image acquisition is not possible with MRI. Some studies may take up to 1 hour or more during which time patients cannot be monitored as closely as in the trauma bay. Furthermore, trauma patients are often not cooperative with breathing instructions and may require life support with devices that are not MRI-compatible. Some scattered publications (mainly case reports or small case series) describe the potential use of MRI in the setting of blunt thoracic trauma, specifically in the setting of cardiac or pericardial [43-46], musculoskeletal [47-49], or hemidiaphragmatic injuries [50]. However, MRI is likely most useful as a problem-solving tool and not as part of a standard trauma protocol, except in rare instances of significant thoracic spinal injury as detailed in the ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [27]. The authors of this publication suggested that "a myelopathy indicates the need for imaging the symptomatic levels of the spine and spinal cord with MRI"; however, "screening the thoracolumbar spine with MRI for detecting ligamentous disruption is not indicated when the CT is normal."

Nuclear Medicine

Currently, nuclear medicine studies (including positron emission tomography using fluorine-18-2-fluoro-2-deoxy-D-glucose) do not have any well-established uses in the setting of blunt thoracic trauma. However, there may be some use in specific cases, such as in the setting of blunt cardiac injury [51,52].

Summary

- Chest radiography and chest CT/CTA are complementary first-line imaging modalities in the workup of patients with high-mechanism blunt trauma.
- When initial trauma survey and mechanism of injury suggest a low probability of significant thoracic trauma (normal mental status, normal clinical examination, and normal chest radiograph), further assessment with chest CT/CTA may not be necessary. Inclusion or exclusion of CT in this setting should be site and/or case-specific.
- In suspected cardiac injury (based on initial imaging and clinical evaluation), transthoracic echocardiography is indicated. Cardiac CTA, cardiac MRI, and transesophageal echocardiography may be useful as problem-solving tools.

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, both because of 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 to 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 (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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