American College of Radiology
ACR Appropriateness Criteria®
Rib Fractures

Variant: 1 Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
Radiography rib views	May Be Appropriate	☢☢☢
US chest	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢

Variant: 2 Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
Radiography rib views	May Be Appropriate	☢☢☢
CT chest without IV contrast	May Be Appropriate	☢☢☢
US chest	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

Variant: 3 Suspected pathologic rib fracture. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
Bone scan whole body	Usually Appropriate	☢☢☢
CT chest without IV contrast	Usually Appropriate	☢☢☢
Radiography rib views	May Be Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	May Be Appropriate	☢☢☢☢
US chest	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

Panel Members

Travis S. Henry, MD[a]; Edwin F. Donnelly, MD, PhD[b]; Phillip M. Boiselle, MD[c]; Traves D. Crabtree, MD[d]; Mark D. Iannettoni, MD[e]; Geoffrey B. Johnson, MD, PhD[f]; Ella A. Kazerooni, MD[g]; Archana T. Laroia, MD[h]; Fabien Maldonado, MD[i]; Kathryn M. Olsen, MD[j]; Carlos S. Restrepo, MD[k]; Kyungran Shim, MD[l]; Arlene Sirajuddin, MD[m]; Carol C. Wu, MD[n]; Jeffrey P. Kanne, MD.[o]

Summary of Literature Review

Introduction/Background

Rib fracture is the most common thoracic injury and is present in 10% of all traumatic injuries and in almost 40% of patients who sustain severe nonpenetrating trauma [1,2]. Rib fractures typically affect the fifth through ninth ribs. This may be due to the fact that the shoulder girdle affords relative protection to the upper ribs, and the lower ribs are relatively mobile and may deflect before fracturing [1].

Although rib fractures can produce significant morbidity, the diagnosis of associated complications (such as pneumothorax, hemothorax, pulmonary contusion, atelectasis, flail chest, cardiovascular injury, and injuries to solid and hollow abdominal organs) is arguably more important as these complications are likely to have the most significant clinical impact [1,2]. When isolated, rib fractures have a relatively low morbidity and mortality [2,3].

Treatment of rib fractures is generally aimed at pain control and avoidance of respiratory distress and intubation, but the presence of multiple rib fractures, underlying organ injury, or in an elderly patient especially, may warrant transfer from a community hospital to tertiary care center [2,4-6].

Discussion of Procedures by Variant

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.

This variant refers to rib fractures resulting from minor blunt trauma. For severe cases of trauma, please refer to the ACR Appropriateness Criteria® topic on "Blunt Chest Trauma" [7] and the ACR Appropriateness Criteria® topic on "Major Blunt Trauma," which will be made available on the ACR website when completed. For suspected stress fractures, please refer to the ACR Appropriateness Criteria® topic on "Stress (Fatigue/Insufficiency) Fracture, Including Sacrum, Excluding Other Vertebrae" [8].

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.
A. Radiography Chest

In combination with the physical examination, a standard posteroanterior (PA) chest radiograph should be the initial diagnostic test for detection of rib fractures. Despite the low sensitivity of the chest radiograph, which may miss 50% of rib fractures [2], studies suggest that failure to detect fractures does not necessarily alter patient management or outcome in uncomplicated cases. A review of 271 patients who presented to a community hospital emergency department after minor trauma showed no difference in treatment (use of pain medications, etc) between patients who did and did not have rib fractures diagnosed on physical examination or radiographs [3]. In a study of 552 patients who had blunt chest trauma and resultant rib fracture (diagnosed on clinical or radiographic grounds), 93% of affected patients ultimately resumed daily activities without significant disability [2]. The chest radiograph may detect complications that are more important than the rib fractures themselves, such as pneumothorax, hemothorax, flail chest, or contusion

[1,2]. Although a flail chest can usually be diagnosed at physical examination, it is conceivable that in a heavy patient a flail chest could be missed by clinical examination, but a chest radiograph almost always shows the displaced fragments.

Dual-energy chest radiography with bone subtraction imaging has failed to show improved detection when compared with standard radiographs. A review of 39 patients with a total of 204 rib fractures showed no statistically significant difference in sensitivity, specificity, or level of confidence between standard images and dual-energy subtraction images [9].

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.

B. Radiography Rib Views

While still performed in many practices, rib detail radiograph series rarely add additional information to the PA film that would change treatment as has been shown in two retrospective studies. In a review of 422 patients presenting to a university-affiliated emergency department for suspected rib fracture, Shuaib et al [10] found that rib series resulted in a change of management in only one patient (0.23%). Moreover, these authors found that, compared to standard PA radiographs, rib series negatively impacted patient care by prolonging report turnaround time [10].

Hoffstetter et al [11] retrospectively reviewed 609 patients that underwent rib series in the emergency department and found that while diagnosing a higher number of rib fractures as compared to PA radiographs alone, there was no statistically significant difference in the number of patients who received medical treatment. If rib series are to be performed, Park et al [12] showed that interpreting images with both conventional grayscale and inverted grayscale views may improve detection of rib fractures, although this study did not assess if the improved detection had an effect on outcomes.

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.

C. CT Chest

The increased sensitivity of CT for the detection of rib fractures does not necessarily alter the management or clinical outcomes of patients without associated injuries. Kea et al [13] reported that CT detected rib fractures in 66 of 589 patients (11%) who had initial chest radiographs interpreted as normal at a level I trauma center, but none of the rib fractures were considered of major clinical significance.

The presence and number of rib fractures, and the degree of displacement of the fractures, may carry prognostic significance. Thus, detection of rib fractures by CT may be indicated under certain circumstances (especially if severe injury is suspected). Bugaev et al [14] retrospectively reviewed 245 patients that presented to a level 1 trauma center for a number of rib fractures and degree of displacement. They found that the number of rib fractures and the degree of fracture fragment displacement accurately predicted subsequent opioid requirements.

In contrast, an outcomes analysis by Livingston et al [15] reviewed 388 patients with rib fractures who underwent both chest radiography (anteroposterior, supine) and chest CT and correlated the presence of rib fractures with pulmonary morbidity and mortality. They reported that although rib fractures were detected on only 46% of patients' initial chest radiographs, the presence of rib fractures or underlying parenchymal abnormality on radiography was associated with increased

pulmonary morbidity (odds ratio, 3.8) compared with fractures only detected by CT.

Rib fractures are associated with pulmonary complications, including atelectasis, impaired clearance of secretions, pneumonia, and adult respiratory distress syndrome [2,5,6]. Increased number of rib fractures has been shown to directly correlate with increasing morbidity and mortality, and this effect is greater in patients 65 years of age or older, many of whom have additional comorbid conditions that contribute to poor cardiopulmonary reserve [2,4-6]. Chapman et al [16] recently proposed a "RibScore" using 6 different CT variables: (1) ≥6 rib fractures, (2) bilateral fractures, (3) flail chest, (4) ≥3 severely displaced fractures, (5) first rib fracture, or (6) at least 1 fracture in all 3 anatomic areas (anterior, lateral, and posterior), where higher scores predicted adverse pulmonary outcomes.

Patients with rib fractures from a high-energy mechanism or with a high clinical suspicion of intrathoracic or intra-abdominal injury may warrant further evaluation with contrast-enhanced CT, whereas a low-energy injury or normal physical examination may obviate further testing. Dubinsky and Low [17] studied 69 patients with nonthreatening trauma (stable vital signs with no evidence of cardiac injury, solid or hollow viscus rupture, or fractures associated with significant blood loss) and found that neither rib studies nor chest radiographs were of clinical benefit in this scenario, but they concluded that clinical evidence of a complicated injury, such as pneumothorax, hemothorax, or flail chest, may warrant further evaluation.

Similarly, Schurink et al [18] studied patients with lower rib fractures (ribs 7 through 12) and found that the negative predictive value of a negative physical examination for abdominal injury that is due to low-energy impact was 100%, but in patients with multiple injuries, lower rib fractures were associated with abdominal organ injury in 67% of patients. Matthes et al [19] found no association between right-sided lower rib fractures in 55 trauma patients with hepatic injury when matched with 55 trauma patients without hepatic injury (there was a slight negative association of hepatic laceration with left-sided fractures) but ultimately concluded that the absence of rib fractures could not rule out hepatic injury. Thus, in patients with multiple injuries and lower rib fractures, contrast-enhanced CT might be indicated even in the setting of a normal clinical examination.

Several studies have demonstrated a high prevalence of radiographically detected rib fractures in patients with aortic injury, although the positive predictive value is low. In a large prospective multicenter trial involving 50 trauma centers in North America, Fabian et al [20] reported multiple rib fractures in 46% of 274 patients with blunt aortic injury. Mirvis et al [21] found fractures of ribs 1 through 4 in 18% of 41 patients with traumatic aortic injury proved by angiography but with a positive predictive value of only about 21%. Lee et al [22] studied 548 patients who underwent angiography to evaluate for aortic injury and concluded that rib fractures were the only type of thoracic skeletal injury that had a higher incidence in patients with aortic injury (58%) versus those without aortic injury (43%), but the positive predictive value was only 14.8%. This has also been shown at autopsy, where Williams et al [23] retrospectively reviewed 530 motor vehicle fatalities. In 90 victims, 105 aortic injuries were found, and 78% had multiple rib fractures, including 42% with fractures of the first rib.

In contrast, there is some evidence that rib fractures detected with CT (given the increased sensitivity) may not be associated with an increased risk of aortic injury. A review of 185 patients with rib fractures detected on spine CT found no association between presence of first-rib or

second-rib fracture and the incidence of aortic injury on subsequent CT [24]; however, ribs 3 through 12 were not assessed. Increased likelihood of injury to the adjacent subclavian and innominate vessels has been reported with displaced first-rib and second-rib fractures, but this injury can usually be suspected on clinical grounds or from a chest radiograph [25].

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.
D. US Chest

Several articles have noted that ultrasound (US) can detect fractures not seen on conventional radiographs [26-28]. Griffith et al [28] compared US and radiography (chest radiography plus one oblique rib radiograph) in 50 patients and found that radiographs detected only 8 of 83 (10%) sonographically detected rib fractures and were positive in only 6 of the 39 patients who had demonstrated fractures. In this study, US allowed evaluation of the costochondral junction, the costal cartilage, and the ribs and was able to show nondisplaced fractures.

Kara et al [26] found rib fractures in 40.5% of 37 patients with minor blunt chest trauma and negative radiographs by using US; osseous fractures were more common in the elderly, and duration of pain was significantly longer in these patients compared to those with chondral injuries [26-28]. However, Hurley et al [29] found US to be only marginally superior to conventional radiographs, and its routine use was not indicated because of the lengthy time of the examination, averaging 13 minutes in this series, and patient discomfort from the pressure of the US probe, particularly since identification of the fracture was unlikely to impact patient care.

Variant 1: Suspected rib fractures from minor blunt trauma (injury confined to ribs). Initial imaging.
E. Bone Scan Whole Body

Nuclear medicine bone scans are sensitive but not specific for detection of rib fracture [30]. Bone scans are most commonly used for detection of osseous involvement in systemic processes (eg, metastatic disease) and may result in false-positive diagnosis of malignancy in a patient with rib fractures, although the pattern of tracer uptake can often help differentiate the two processes [30]. Bone scans have limited use in distinguishing acute and subacute or chronic rib fractures as they will usually be positive within 24 hours after an injury, but the return to normal can be slow (79% by 1 year, 93% by 2 years, and 100% in 3 years) [31]. Furthermore, patients with known malignancy and benign rib fractures may exhibit false-positive findings on PET using the tracer fluorine-18-2-fluoro-2-deoxy-D- glucose (FDG) studies performed 17 days to 8 weeks after injury [32].

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging.

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging.
A. Radiography Chest

Multiple studies [33-35] have shown that rib fractures are under-reported on radiography performed following cardiopulmonary resuscitation (CPR). In a retrospective analysis of 40 patients who survived CPR, Kim et al [33] reported that CT detected rib fractures in 26 patients (65%); whereas, anteroposterior chest radiography detected fractures in only 10 of the patients. Lederer et al [34] found that radiography detected only 14% of rib fractures compared to autopsy in 19 patients.

Rib fractures from CPR are more commonly anterior, on the left side, and are more numerous in

the elderly [34]. The diagnosis of such fractures in CPR survivors may be important since approximately half of CPR survivors with rib fractures experience complications, and the presence of rib fractures in these patients may impair ventilation and compromise recovery. It should be noted that many of these patients are examined with portable supine radiography, which may contribute to underdiagnosis.

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging. B. Radiography Rib Views

There is no strong indication in the literature that radiography rib series serves any significant use as an initial imaging modality to detect rib fractures after CPR.

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging. C. US Chest

While focused US of the chest wall is more sensitive for detection of rib fractures than radiography in trauma patients [28], there is no direct evidence assessing the use of US in patients after CPR.

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging. D. Bone Scan Whole Body

There is no strong indication in the literature that bone scan serves any significant use as an initial imaging modality to detect rib fractures after CPR.

Variant 2: Suspected rib fractures after cardiopulmonary resuscitation (CPR). Initial imaging. E. CT Chest

As described above, chest CT is more sensitive than radiography for the detection of rib fractures after CPR. Moreover, CT may show fracture-related complications that are radiographically occult. Kim et al [33] reported that CT found fracture-related complications in 6 of 40 patients (15%) who received CPR, including 1 pneumothorax, 1 subclavian vein injury, and 4 chest wall hematomas. This study did not indicate whether intravenous (IV) contrast was used, nor did it indicate whether CT was performed specifically for evaluation of rib fractures, or if the rib fractures were an incidental finding on a CT performed for other means (eg, suspected pulmonary embolism).

Despite this evidence that CT is sensitive for detection of CPR-associated rib fractures, no data exists in the literature that shows that the increased rate of rib fracture diagnosis affects a patient's long-term management or prognosis.

Variant 3: Suspected pathologic rib fracture. Initial imaging.

Variant 3: Suspected pathologic rib fracture. Initial imaging. A. Radiography Chest

Pathologic fractures may result from metabolic disorders or neoplasm, including primary bone tumor, metastatic disease of intrathoracic or extrathoracic primary, hematologic malignancy (eg, multiple myeloma, lymphoma), or direct extension of a tumor in the thorax. A PA chest radiograph may be sufficient for diagnosis of a pathologic fracture (or provide clues to an underlying diagnosis), but further evaluation using such modalities as CT, bone scan, or FDG-PET may be necessary to further characterize a lesion detected on radiography or to search for radiographically occult lesions [36-38].

Variant 3: Suspected pathologic rib fracture. Initial imaging. B. Radiography Rib Views

There is no strong indication in the literature that radiography rib series serves any significant use as an initial imaging modality to detect suspected pathologic rib fractures.

Variant 3: Suspected pathologic rib fracture. Initial imaging.
C. US Chest

There is no strong indication in the literature that US serves any significant use as an initial imaging modality to detect rib fractures.

Variant 3: Suspected pathologic rib fracture. Initial imaging.
D. CT Chest

CT may be useful for characterizing a pathologic fracture, and some features may be helpful in differentiating a primary malignant tumor of bone from metastasis [36]. CT may also be helpful to search for a primary malignancy in patients with a suspected pathologic fracture; however, there is no strong indication that CT serves a significant use as the initial imaging modality to detect pathologic rib fractures.

Variant 3: Suspected pathologic rib fracture. Initial imaging.
E. Bone Scan Whole Body

Bone scans have a high sensitivity (>95%) but a low specificity for detection of pathologic rib fractures [30]. The distribution of abnormalities may serve as a useful clue in differentiating metastasis from post-traumatic fractures.

Variant 3: Suspected pathologic rib fracture. Initial imaging.
F. FDG-PET/CT Skull Base to Mid-Thigh

FDG-PET/CT may be useful to further characterize a lesion detected on radiography or to search for radiographically occult lesions [36,37]. There is no strong indication in the literature that FDG-PET/CT should be the initial imaging modality to detect suspected pathologic rib fractures.

Summary of Recommendations

- **Variant 1:** A radiograph of the chest is usually appropriate for the initial imaging of suspected rib fractures from minor blunt trauma (injury confined to ribs).
- **Variant 2:** A radiograph of the chest is usually appropriate for the initial imaging of suspected rib fractures after cardiopulmonary resuscitation.
- **Variant 3:** A radiograph of the chest is usually appropriate for suspected pathologic rib fracture with CT chest without IV contrast or Bone scan whole body as complimentary to the chest radiography.

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.

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."

References

1. Alkadhi H, Wildermuth S, Marincek B, Boehm T. Accuracy and time efficiency for the detection of thoracic cage fractures: volume rendering compared with transverse computed tomography images. J Comput Assist Tomogr. 2004;28(3):378-385.

2. Bansidhar BJ, Lagares-Garcia JA, Miller SL. Clinical rib fractures: are follow-up chest X-rays a waste of resources? Am Surg. 2002;68(5):449-453.

3. Davis S, Affatato A. Blunt chest trauma: utility of radiological evaluation and effect on treatment patterns. Am J Emerg Med. 2006; 24(4):482-486.

4. Sirmali M, Turut H, Topcu S, et al. A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. Eur J Cardiothorac Surg. 2003;24(1):133-138.

5. Stawicki SP, Grossman MD, Hoey BA, Miller DL, Reed JF, 3rd. Rib fractures in the elderly: a marker of injury severity. J Am Geriatr Soc. 2004;52(5):805-808.

6. Lee RB, Bass SM, Morris JA, Jr., MacKenzie EJ. Three or more rib fractures as an indicator for transfer to a Level I trauma center: a population-based study. J Trauma. 1990;30(6):689-694.

7. American College of Radiology. ACR Appropriateness Criteria®: Blunt Chest Trauma. Available at: https://acsearch.acr.org/docs/3082590/Narrative/.

8. Bencardino JT, Stone TJ, et al. ACR Appropriateness Criteria® Stress (Fatigue/Insufficiency) Fracture, Including Sacrum, Excluding Other Vertebrae. J Am Coll Radiol. 2017 May;14(5S):S1546-1440(17)30218-1.

9. Szucs-Farkas Z, Lautenschlager K, Flach PM, et al. Bone images from dual-energy subtraction chest radiography in the detection of rib fractures. Eur J Radiol. 2011;79(2):e28-32.

10. Shuaib W, Vijayasarathi A, Tiwana MH, Johnson JO, Maddu KK, Khosa F. The diagnostic utility of rib series in assessing rib fractures. EMERG. RADIOL.. 21(2):159-64, 2014 Apr.

11. Hoffstetter P, Dornia C, Wagner M, et al. Clinical significance of conventional rib series in patients with minor thoracic trauma. Rofo: Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin. 186(9):876-80, 2014 Sep.ROFO Fortschr Geb Rontgenstr Nuklearmed. 186(9):876-80, 2014 Sep.

12. Park JB, Cho YS, Choi HJ. Diagnostic accuracy of the inverted grayscale rib series for detection of rib fracture in minor chest trauma. American Journal of Emergency Medicine. 33(4):548-52, 2015 Apr.

13. Kea B, Gamarallage R, Vairamuthu H, et al. What is the clinical significance of chest CT when the chest x-ray result is normal in patients with blunt trauma?. American Journal of Emergency Medicine. 31(8):1268-73, 2013 Aug.

14. Bugaev N, Breeze JL, Alhazmi M, et al. Magnitude of rib fracture displacement predicts opioid requirements. J Trauma Acute Care Surg. 81(4):699-704, 2016 Oct.

15. Livingston DH, Shogan B, John P, Lavery RF. CT diagnosis of Rib fractures and the prediction of acute respiratory failure. J Trauma. 2008;64(4):905-911.

16. Chapman BC, Herbert B, Rodil M, et al. RibScore: A novel radiographic score based on fracture pattern that predicts pneumonia, respiratory failure, and tracheostomy. The Journal

of Trauma and Acute Care Surgery. 80(1):95-101, 2016 Jan.

17. Dubinsky I, Low A. Non-life-threatening blunt chest trauma: appropriate investigation and treatment. Am J Emerg Med. 1997;15(3):240-243.

18. Schurink GW, Bode PJ, van Luijt PA, van Vugt AB. The value of physical examination in the diagnosis of patients with blunt abdominal trauma: a retrospective study. Injury. 1997;28(4):261-265.

19. Matthes G, Stengel D, Bauwens K, et al. Predictive factors of liver injury in blunt multiple trauma. Langenbecks Arch Surg. 391(4):350-4, 2006 Aug.

20. Fabian TC, Richardson JD, Croce MA, et al. Prospective study of blunt aortic injury: Multicenter Trial of the American Association for the Surgery of Trauma. J Trauma. 1997;42(3):374-380; discussion 380-373.

21. Mirvis SE, Bidwell JK, Buddemeyer EU, et al. Value of chest radiography in excluding traumatic aortic rupture. Radiology. 1987;163(2):487-493.

22. Lee J, Harris JH Jr, Duke JH Jr, Williams JS. Noncorrelation between thoracic skeletal injuries and acute traumatic aortic tear. J Trauma. 43(3):400-4, 1997 Sep.

23. Williams JS, Graff JA, Uku JM, Steinig JP. Aortic injury in vehicular trauma. Ann Thorac Surg. 1994;57(3):726-730.

24. Khosla A, Ocel J, Rad AE, Kallmes DF. Correlating first- and second-rib fractures noted on spine computed tomography with major vessel injury. Emerg Radiol. 2010;17(6):461-464.

25. Poole GV. Fracture of the upper ribs and injury to the great vessels. Surg Gynecol Obstet. 1989;169(3):275-282.

26. Kara M, Dikmen E, Erdal HH, Simsir I, Kara SA. Disclosure of unnoticed rib fractures with the use of ultrasonography in minor blunt chest trauma. Eur J Cardiothorac Surg. 2003;24(4):608-613.

27. Malghem J, Vande Berg B, Lecouvet F, Maldague B. Costal cartilage fractures as revealed on CT and sonography. AJR Am J Roentgenol. 2001;176(2):429-432.

28. Griffith JF, Rainer TH, Ching AS, Law KL, Cocks RA, Metreweli C. Sonography compared with radiography in revealing acute rib fracture. AJR Am J Roentgenol. 2001;176(2):429-432.

29. Hurley ME, Keye GD, Hamilton S. Is ultrasound really helpful in the detection of rib fractures? Injury. 2004;35(6):562-566.

30. Harbert JC, George FH, Kerner ML. Differentiation of rib fractures from metastases by bone scanning. Clin Nucl Med. 1981;6(8):359-361.

31. Matin P. The appearance of bone scans following fractures, including immediate and long-term studies. J Nucl Med. 1979;20(12):1227-1231.

32. Shon IH, Fogelman I. F-18 FDG positron emission tomography and benign fractures. Clin Nucl Med. 2003;28(3):171-175.

33. Kim EY, Yang HJ, Sung YM, et al. Multidetector CT findings of skeletal chest injuries secondary to cardiopulmonary resuscitation. Resuscitation. 2011;82(10):1285-1288.

34. Lederer W, Mair D, Rabl W, Baubin M. Frequency of rib and sternum fractures associated with out-of-hospital cardiopulmonary resuscitation is underestimated by conventional chest X-ray. Resuscitation. 2004;60(2):157-162.

35. Miller AC, Rosati SF, Suffredini AF, Schrump DS. A systematic review and pooled analysis of CPR-associated cardiovascular and thoracic injuries. [Review]. Resuscitation. 85(6):724-31, 2014 Jun.

36. Soldatos T, Chalian M, Attar S, McCarthy EF, Carrino JA, Fayad LM. Imaging differentiation of pathologic fractures caused by primary and secondary bone tumors. Eur J Radiol. 82(1):e36-42, 2013 Jan.

37. Moog F, Kotzerke J, Reske SN. FDG PET can replace bone scintigraphy in primary staging of malignant lymphoma. J Nucl Med. 1999;40(9):1407-1413.

38. Harris SR.. Differentiating the Causes of Spontaneous Rib Fracture After Breast Cancer. Clin Breast Cancer. 16(6):431-436, 2016 12.

39. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

[a]University of California San Francisco, San Francisco, California. [b]Panel Chair, Vanderbilt University Medical Center, Nashville, Tennessee. [c]Schmidt College of Medicine, Florida Atlantic University, Boca Raton, Florida. [d]Southern Illinois University School of Medicine, Springfield, Illinois; The Society of Thoracic Surgeons. [e]University of Iowa, Iowa City, Iowa; The Society of Thoracic Surgeons. [f]Mayo Clinic, Rochester, Minnesota; Commission on Nuclear Medicine and Molecular Imaging. [g]University of Michigan Medical Center, Ann Arbor, Michigan. [h]University of Iowa Hospitals and Clinics, Iowa City, Iowa. [i]Vanderbilt University Medical Center, Nashville, Tennessee; American College of Chest Physicians. [j]Radiology Imaging Associates, Englewood, Colorado. [k]University of Texas Health Science Center at San Antonio, San Antonio, Texas. [l]John H. Stroger, Jr. Hospital of Cook County, Chicago, Illinois; American College of Physicians. [m]National Institutes of Health, Bethesda, Maryland. [n]The University of Texas MD Anderson Cancer Center, Houston, Texas. [o]Specialty Chair, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin.