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Review

Thoracic cage injuries

Kimia Khalatbari Kani[a,*], Hyojeong Mulcahy[b], Jack A. Porrino[c], Felix S. Chew[b]

[a] Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland School of Medicine, Baltimore, MD, USA
[b] Department of Radiology, University of Washington, 4245 Roosevelt Way NE, Box 354755, Seattle, WA, 98105, USA
[c] Radiology and Biomedical Imaging, Yale School of Medicine, New Haven, CT, 06520-8042, USA

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ABSTRACT

Rib fractures are the most common form of blunt thoracic injury. Multiple rib fractures are an important indicator of trauma severity, with increased morbidity and mortality occurring with increasing numbers of rib fractures, especially in the elderly. Thoracic cage injuries may be associated with concomitant and potentially life-threating injuries. In the acute setting, correct recognition of the pattern, extent and severity of thoracic cage injuries, may aid in more accurate delineation of concomitant injuries.

1. Introduction

The thoracic cage (rib cage) is formed by the sternum and the twelve pairs of ribs with their associated costal cartilages. Rib fractures are the most common form of blunt thoracic injury and occur in approximately 50% of patients [1]. Multiple rib fractures are an important indicator of trauma severity, with increased morbidity and mortality occurring with increasing numbers of rib fractures, especially in the elderly [2]. Thoracic cage injuries may be associated with concomitant and potentially life-threating injuries, such as aortic rupture or pneumothorax [3,4]. Therefore, a diligent search for associated injuries should be performed in patients with traumatic thoracic cage injuries.

The goals of this article are to review the anatomy, mechanisms of injuries, classification, imaging evaluation, treatment and long-term complications of osseocartilaginous injuries of the thoracic cage.

2. Rib anatomy

The ribs are classified as true, false or floating, based on the anterior attachments of their respective costal cartilages [5] (Fig. 1). Ribs 1–7 are true ribs, with each rib attaching directly to the sternum through its own costal cartilage. The costal cartilages of the first ribs attach to the manubrium by synchondroses, while the second to seventh costal cartilages form synovial joints with the manubrium or body of the sternum [6]. Slight gliding movements occur at the sternocostal joints to allow for ventilation [7]. Ribs 8, 9 and usually 10 are false ribs. The costal cartilage of a false rib forms a synchondrosis with the costal cartilage of the next superior rib, thus its attachment to the sternum is indirect [6]. Floating ribs (ribs 11, 12 and sometimes 10) do not attach to the sternum, and the rudimentary cartilages of these ribs end in the abdominal musculature [5]. Laterally, each costal cartilage, attaches to a cup-like depression on the sternal end of the same level rib (Fig. 1). No motion occurs at the costochondral synchondroses [7].

Morphologically, the ribs are classified as either typical or atypical. Typical ribs (ribs 3–9) are composed of a head, neck, tubercle and body (Fig. 2). The head is composed of two articular facets for articulation with the numerically corresponding vertebral body and the next superior vertebral body (Fig. 2), and thus forms the costocorporeal (or costocentral) joint [8]. The tubercle is located at the junction of the neck and body and articulates with the numerically corresponding vertebral transverse process (Fig. 2), forming the costotransverse joint. The body of the rib is curved (most markedly at the costal angle) and contains a costal groove along its inferomedial aspect (Fig. 2). The costal groove accommodates the intercostal vessels and nerve. Ribs 1, 2 and 10–12 are atypical [5]. The first rib has a single facet on its head for articulation with the T1 vertebral body along with two grooves on its superior surface for the subclavian vessels (the grooves are separated by the scalene tubercle and ridge, to which the anterior scalene muscle is attached) [5]. The main atypical feature of the second rib is the superiorly located "tuberosity for serratus anterior" from which the serratus anterior muscle partially originates [5]. Ribs 10–12 have only a single articular facet on their heads. In addition, the eleventh and twelfth ribs do not have a neck and tubercle [5]. Slight gliding movements occur at the level of the costocorporeal and costotransverse joints [7].

* Corresponding author.
E-mail addresses: kimia.kani@umm.edu (K.K. Kani), hyomul@uw.edu (H. Mulcahy), rhees27@yahoo.com (J.A. Porrino), fchew@uw.edu (F.S. Chew).

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Fig. 1. Rib anatomy. Modified three-dimensional reconstructed CT image of the thoracic cage in a 56-year-old male. True ribs (ribs 1–7) attach directly to the sternum through their own costal cartilages. False ribs (ribs 8–10) attach to the costal cartilage of the next superior rib, thus their attachment to the sternum is indirect. The floating ribs -ribs 11 and 12 (not shown)- do not attach to the sternum. Observe that the first costal cartilage is completely ossified in this patient and forms a synostosis both at its manubriosternal and costochondral junctions. Laterally, each costal cartilage, attaches to a cup-like depression (marked by a white arrow at the sixth rib level) on the sternal end of the same level rib.

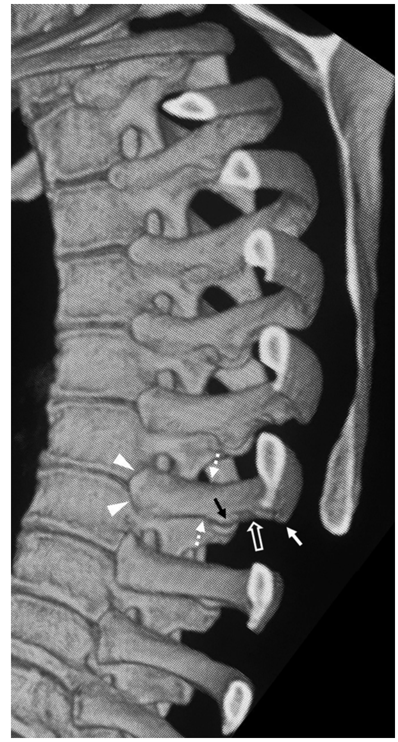

Fig. 2. Typical rib anatomy. Three-dimensional reconstructed CT image of the left costovertebral junctions in a 35-year-old female. Typical ribs are composed of a head, neck (dashed arrows), tubercle (black arrow) and body. The head is composed of two articular facets (arrowheads) for articulation with the numerically corresponding vertebral body and the next superior vertebral body, thus forming the costocorporeal joint. The tubercle (black arrow) is located at the junction of the neck and body and articulates with the numerically corresponding vertebral transverse process, forming the costotransverse joint. The body of the rib is curved most markedly at the costal angle (white arrow) and contains a costal groove (open arrow) along its inferomedial aspect.

3. Rib fractures (excluding stress fractures, fragility fractures and pathologic rib fractures)

Rib fractures are common injuries and occur most commonly in the context of blunt thoracic trauma. Rib fractures resulting from severe coughing, athletic activities, and minor injuries (especially in osteoporotic elderly individuals or with an underlying focal rib lesion) will be discussed separately [3,9]. Discussion of rib fractures resulting from nonaccidental trauma (child abuse) is beyond the scope of this article.

Rib fractures are the most common form of blunt thoracic injury and occur in approximately 50% of patients [1]. Associated injuries and complications range from mild discomfort to potentially life-threatening conditions, such as aortic rupture or pneumothorax. Multiple rib fractures are an important indicator of trauma severity, with increased morbidity and mortality occurring with increasing numbers of rib fractures, especially in the elderly [2].

The ribs can be divided into three zones based upon the degree of trauma required for producing a fracture and the associated injuries [3] (Fig. 3). Fractures of the upper four ribs typically require high-energy trauma. Given the severity of injury required to fracture the upper ribs, concomitant injuries to other ribs and organ systems (including vascular or brachial plexus injuries) are not uncommon [10]. Vascular injuries are usually limited to the thoracic aorta and subclavian arteries and have been well described in the literature especially in the context of first rib fractures. Isolated first rib fractures have a 3% incidence of vascular injury, while first rib fractures associated with multiple rib fractures have a 24% incidence of vascular injuries [10]. Angiography (typically CT angiography) is recommended in patients with first rib fractures and any of the following findings: widened mediastinum on chest radiography, upper extremity pulse deficit or acute disparity of upper extremity pulses, posteriorly displaced first rib fracture, subclavian groove fracture, brachial plexus injury, expanding hematoma and equivocal clinical or radiographic findings (e.g., equivocal mediastinal widening) [10,11]. Upper rib fractures may also occur in patients with no or minimal history of trauma (incidental first rib fractures have been described in soldiers possibly from carrying heavy military equipment) [10,12].

Fractures of the middle zone ribs (ribs 5–9) are most commonly associated with pulmonary, pleural and extrapleural complications (e.g., lung contusion and laceration, hemothorax, pneumothorax and extrapleural hematoma). Fractures of the lower three ribs are most frequently associated with liver, splenic and renal injuries [1,3].

3.1. Classification

Rib fractures can be broadly categorized as “incomplete” or “complete” and “displaced” or “nondisplaced” fractures (Fig. 4). Incomplete fractures involve either the inner or the outer rib cortex, while complete fractures demonstrate opposing outer and inner cortical rib disruptions. The elasticity of ribs relative to other long bones, predisposes them to a specific type of incomplete fracture known as a “buckle fracture.” Buckle is an engineering term that has been used to describe the occurrence of a fracture on the compression (inner) side of a linear structure prior to tensile (outer) surface fracture [13]. Buckle rib fractures are strictly defined as bending or kinking of the inner rib cortex without associated disruption of the outer rib cortex (Fig. 4c). Reverse buckle fractures demonstrate the same morphology but involve the outer rib cortex, without concomitant inner cortical rib involvement [14]. Bending of both inner and outer rib cortices may also occur

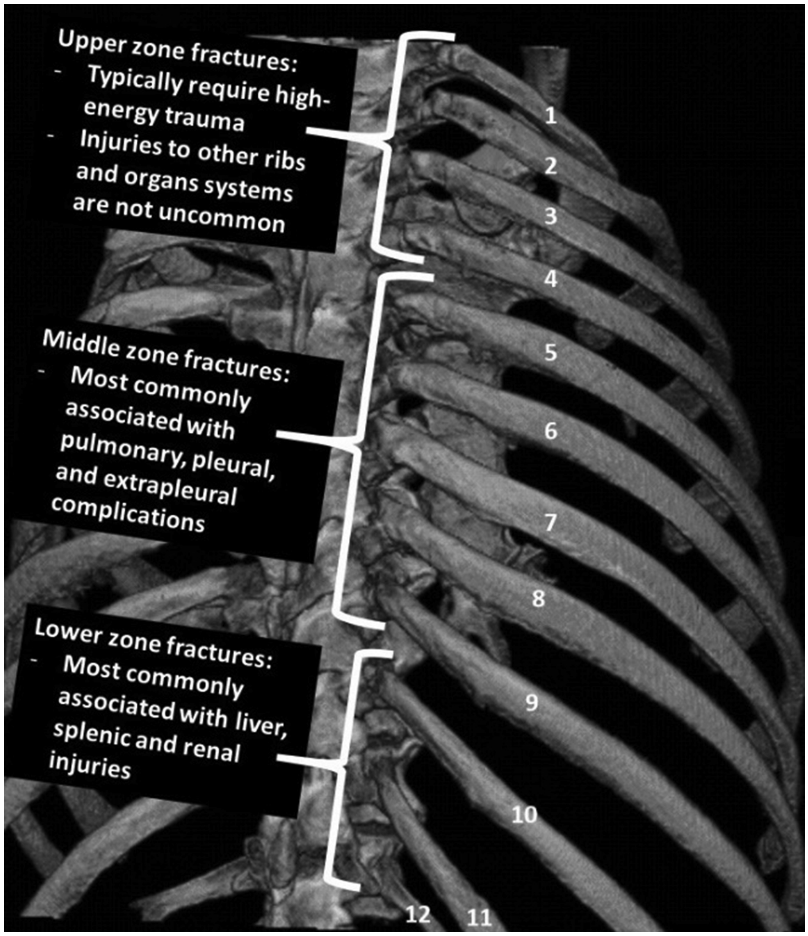

Fig. 3. Zonal rib division. Zonal division of the ribs according to the degree of trauma required for producing a fracture and the associated injuries.

without an obvious fracture line [14]. Buckle rib fractures may occur with cardiopulmonary resuscitations. Rib fractures following cardiopulmonary resuscitations, typically demonstrate a symmetric and continuous pattern of involvement of mostly the second to sixth or seventh ribs along the midclavicular line [14].

3.2. Segmental rib fractures; flail chest

Segmental fracture (Fig. 5) is a fracture composed of at least two complete fracture lines that together separate a segment of bone. Segmental fractures may be nondisplaced or more frequently displaced and are usually associated with high-energy trauma [3]. Segmental fractures may demonstrate a “butterfly” morphology in individuals who have experienced blast injury [15].

Flail chest is a clinical diagnosis and occurs when a portion of the thoracic cage loses contiguity with the rest of the thoracic cage and moves paradoxically during spontaneous respiration (i.e., the unstable segment retracts inward with inspiration and balloons out with expiration) (Fig. 6). It is the result of high-energy blunt trauma (typically from a motor vehicle accident or fall) that impacts on the anterior and lateral aspects of the thoracic cage [16]. There is an increased risk of flail chest with segmental fractures involving three or more contiguous ribs (Fig. 5). Variations to this classical description include combined sternal and rib fractures, combined costal cartilage and rib fractures, and bilateral costochondral separations with a free-floating sternal segment affecting 3 or more consecutive rib levels [16–18].

Flail chest itself is an independent predictor of poor outcomes in patients with blunt chest trauma with reported mortalities ranging from 5% to 36% [16]. Associated intrathoracic and extrathoracic injuries along with an increased risk of superimposed complications (such as pneumonia, acute respiratory distress syndrome and sepsis) may contribute to the detrimental course of some of the affected patients [19]. Prolonged mechanical ventilation and surgical chest wall fixation may be required in some of these patients [19].

3.3. Imaging

A standard posteroanterior (PA) chest radiograph usually suffices for evaluation of patients with suspected rib fractures after minor trauma [20]. The sensitivity of PA chest radiographs for detection of rib fractures is low [21]. Nevertheless, since isolated rib fractures have a relatively low morbidity and mortality, further evaluation with dedicated rib radiographs or other imaging tests -such as computed tomography (CT) or ultrasound (ultrasound may detect rib fractures that are not seen on conventional radiographs, but has limited utility in routine clinical practice) - is usually not necessary as it will typically not affect patient management or outcome [20]. Nonetheless, in daily clinical practice, rib radiographs are not infrequently obtained in patients with chest wall pain to rule out rib fractures.

Chest radiography and chest CT scan (contrast enhanced chest CT or ideally chest CT angiography) are usually the recommended first line imaging for high-energy blunt chest trauma patients [22]. Rib fractures are well depicted and characterized on multidetector CT images (some rib fractures that are missed on axial images, can be identified on coronal reconstructed CT images). Three-dimensional (3D) reconstruction of CT images is recommended for surgical planning of rib fractures [23].

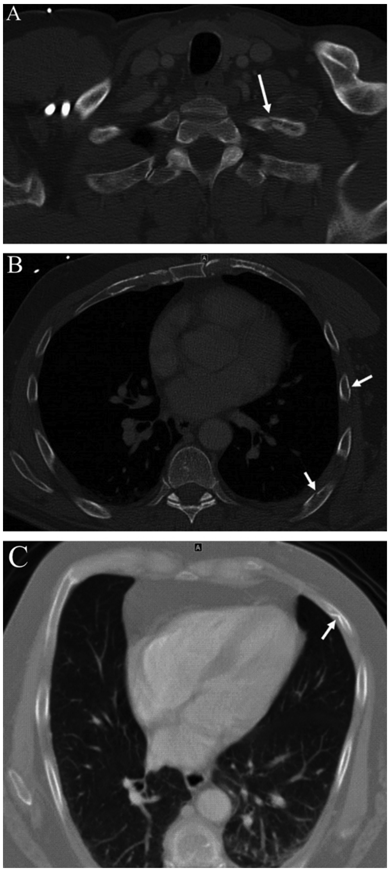

Fig. 4. Rib fractures (different patients). (A and B) Axial CT images of the chest in a 44-year-old male show a nondisplaced complete fracture of the left first rib (long arrow) and incomplete fractures of the left fifth and eight ribs (short arrows). (C) Axial CT image of the chest in a 62-year-old male shows a buckle fracture (arrow) of the anterior aspect of the left sixth rib.

Fig. 5. Segmental rib fractures. Three-dimensional reconstructed CT image of the ribs in a 69-year-old male shows segmental fractures of the first to fifth ribs (clinically, patient had a flail chest). There is severe displacement and depression of the second to sixth rib fractures, and mild displacement of the 7th rib fracture.

3.4. Treatment

Rib fractures are typically treated conservatively. Surgical fixation of rib fractures may be indicated in the following conditions: flail chest, patients requiring ventilation when thoracotomy is otherwise indicated, reduction of pain and disability, chest deformity, and symptomatic nonunion [2]. Rib fractures may be stabilized using a variety of fixation devices [2,23]. Currently, the most popular method of rib fixation employs a locking plate system designed for placement on the outer cortex of the rib (Fig. 7) [24]. Locking plates are manufactured in various forms, may be precontoured or malleable and are made from permanent or absorbable materials [23]. A distinctive locking plate is the U-shaped, U-plate that is placed along the superior aspect of the rib and secured by locking screws placed through the midsubstance of the rib [25]. Postsurgical complications include hardware failure and migration, intercostal nerve impingement by the implanted hardware, infection, hematoma or persistent effusion [2].

4. Stress fractures, fragility fractures and pathologic rib fractures

4.1. Terminology

Stress fracture is an overuse injury caused by repetitive stress. Stress fractures can result from either abnormal repetitive stress on normal bone (fatigue fractures) or normal repetitive stress on abnormal bone (insufficiency fractures). Fatigue fractures typically occur in young active individuals, while insufficiency fractures are usually seen in elderly patients. It is important to realize that stress injuries encompass a spectrum of abnormalities, that progress from periosteal edema to progressive bone marrow edema, and ultimately to a discrete stress fracture [26]. The progressive stages of stress injuries can be accurately depicted with MRI [26].

Osteoporosis associated fractures that occur after a single episode of minor trauma are referred to as fragility fractures. The World Health Organization has quantified this low-energy trauma as forces equivalent to a fall from a standing height or less [27]. The term “pathologic” fracture is reserved for insufficiency fractures that occur at sites of focal osseous abnormalities (Fig. 8).

4.2. Stress fractures: fatigue fractures

Fatigue fractures are rare rib injuries that are typically seen in athletes, manual laborers or patients with severe or chronic cough. Rib fatigue fractures usually result from repetitive tensile muscular forces, rather than the axial compressive forces that are typically responsible for the lower extremity stress injuries. Patients typically present with pain and the diagnosis is often missed or delayed [28]. Stress injuries occur along a continuum from periosteal edema, to progressive bone marrow edema, microfractures and ultimately complete fractures. Rib stress fractures are typically treated conservatively [29].

First rib fatigue fractures are associated with athletic activities that involve repetitive overhead positioning of the arm (such as the dominant arm of baseball pitchers, tennis and lacrosse players) [29]. The fracture is typically seen in the anterolateral aspect of the first rib (at or near the groove for the subclavian artery) due to the repetitive opposing

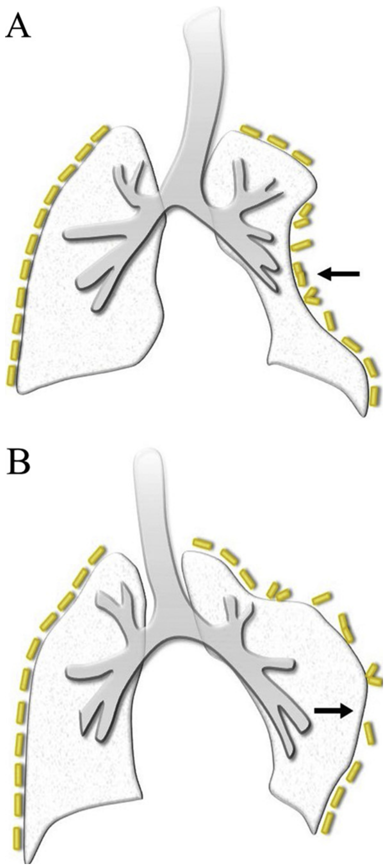

Fig. 6. Flail chest. Illustrations show the paradoxical motion of the flail segment with respiration. The flail segment collapses with inspiration (A) and balloons out with expiration (B).

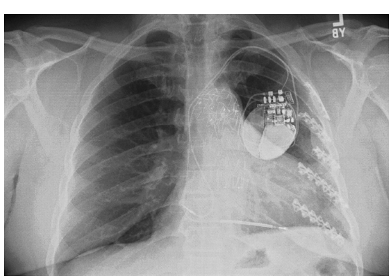

Fig. 7. Locking plate fixation of rib fractures. 54-year-old male with history of left thoracic crush injury and significantly displaced left rib fractures. Anteroposterior chest radiograph shows locking plates (KLS martin rib plates) at level of the left third and fifth to eight ribs.

actions of the scalenus anterior muscle (which elevates the rib) and the serratus anterior and intercostal muscles that depress it [28].

Fatigue injuries of the middle ribs are usually a consequence of repetitive torso action, and can be seen in rowers, swimmers and golfers [28]. In rowers, fatigue injuries are most commonly seen in the anterolateral or lateral aspects of the fifth to ninth ribs, due to the repetitive opposing serratus anterior and external oblique muscle contractions [3,28]. Rib fatigue injuries in golfers typically involve the posterolateral aspects of the fourth to sixth ribs of the leading arm side of the trunk [29]. Fatigue injuries of the floating ribs may be seen in baseball players consequent to repetitive opposing latissimus dorsi and external oblique muscular forces. Rib fatigue fractures may also occur in individuals with severe or chronic cough. Due to similar underlying biomechanics, these fractures usually demonstrate a similar distribution to the typical fatigue fractures that are seen in rowers [28].

Fig. 8. Pathologic rib fracture. Axial CT image in a 75-year-old male with metastatic prostate cancer. There is a lytic metastatis (arrow) in the lateral asepct of the left sixth rib with a superimposed nondisplaced pathologic fracture.

4.2.1. Imaging of rib stress injuries

Radiographs (PA chest radiograph without or with dedicated rib x-rays) are typically the initial imaging study performed for suspected stress injuries. Early radiographic findings are subtle (e.g., subtle periosteal reaction or subtle ill-defined cortex) or nonexistent (the sensitivity of radiography is 15–35% in the early stages of stress injuries) [30]. Follow-up radiographs have increased sensitivity to stress fractures compared to initial radiographs, with 30%–70% of follow-up radiographs being positive secondary to healing and callus formation [26,29,30].

Repeat radiography in 10–14 days, MRI, CT, and bone scintigraphy may be used for further evaluation of patients, especially after negative initial radiography (Fig. 9) [30]. MRI has the highest sensitivity and specificity for evaluation of bone stress injuries, with the additional benefit of identifying soft tissue injuries. Bone scintigraphy is highly sensitive (100%) for the early detection of stress injuries but demonstrates lower specificity compared to MRI [29]. Uptake on bone scans often lags behind the resolution of clinical symptoms and may require 12–18 months to normalize (Fig. 9) [31]. Therefore, bone scans are less helpful for guiding return to activity and sport participation.

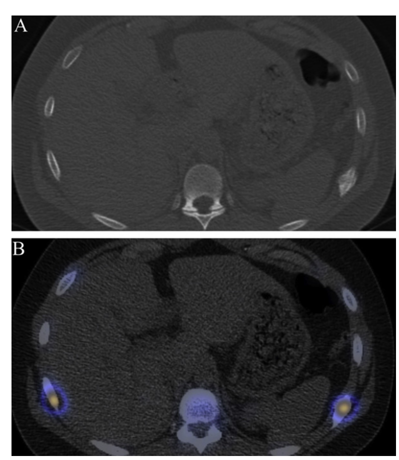

Fig. 9. Stress injury. (A) Axial CT and (B) fused single photon emission computed tomography/ CT images of the thoracic cage in a 21-year-old female softball pitcher with acute exacerbation of right midaxillary pain, during her last game. There is focal radiotracer uptake in the posterolateral aspect of the right ninth rib without associated abnormality on the corresponding CT image, suggestive of stress injury. There is callus formation and increased radiotracer uptake at site of healing fatigue fracture of the posterolateral aspect of the left ninth rib (patient was asymptomatic at this level).

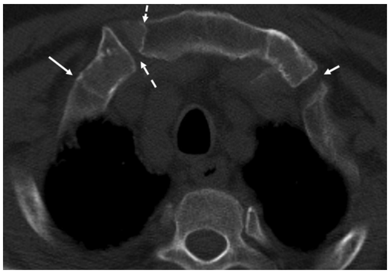

Fig. 10. Costochondral separation. Axial CT image of the chest in a 62-year-old male with a remote history of blunt chest trauma. There is costochondral separation of the first left rib (short arrow) and an old nonunited fracture of the medial aspect of the ossified right first costal cartilage demarcated with the long dashed arrow. Additional multilevel healed bilateral rib fractures were seen more distally (not shown). Long arrow: Right first costochondral synostosis. Short dashed arrow: Right first manubriosternal synostosis.

4.3. Fragility fractures

Rib fractures are the most common clinically evident fractures in individuals who are 65 years of age or older [9]. The most common mechanism for rib fractures in the elderly is a fall either from the standing position (fragility fractures) or a height. Rib fractures may be a marker for low bone mass in postmenopausal females and older men (≥65 years old), and therefore likely to predict an increased future fracture risk of the rib, hip or wrist. Targeted treatment for osteoporosis is recommended in such patients to prevent future fractures [9,32].

5. Costal cartilage (CC) injuries

Injuries to the costal cartilages and their attachments (costochondral separations and chondrosternal junction disruptions) (Fig. 10) may occur with blunt chest trauma or sports. CC fractures are common in high-energy blunt chest trauma [33]. Costal cartilage fractures may also be seen in collision sports (e.g., hockey and rugby) as a result of direct blows, while sports that involve twisting maneuvers (e.g., wrestling) may predispose athletes to costochondral separations typically at the level of the relatively immobile first and second ribs [33,34].

Injuries to the costal cartilages and their attachments usually involve the middle ribs and the attachments of the first and second ribs. In the setting of high-energy trauma, CC fractures often occur with multiple consecutive rib fractures, and affected patients are at higher risk of associated intrathoracic and liver injuries [33].

CC fractures are not visible on radiographs, unless the costal cartilage is strongly calcified or ossified [34]. These fractures are often overlooked in the acute setting and patients may present weeks or months after the initial trauma either with parasternal pain that is unexplained by radiographic findings or with a painful parasternal mass [33]. CC injuries may be diagnosed with CT, MRI or ultrasound. Associated soft-tissue injuries (including hematoma) may also be noted on these modalities. On CT, a nondisplaced CC fracture is seen as a hypoattenuating fracture line (Fig. 11), while a displaced fracture is seen as a step-off of the cartilage surface or overlap of the fracture fragments [33]. Coronal reformatted CT images are especially useful for detection of CC fractures (Fig. 11). Single or even multiple clefts are commonly noted in calcified and ossified first costal cartilages and should not be mistaken for a fracture (Fig. 12) [35]. On MRI, costal cartilage fractures are best seen on coronal fluid sensitive sequences with a focused field of view, typically as a linear high signal intensity line with surrounding edema [36]. On ultrasound, normal CC is typically seen as a hypoechoic band-like structure that is demarcated by parallel, thin echogenic lines that represent the interfaces between the cartilage and adjacent soft-tissues [37]. On color Doppler, no vascularity is seen at the level of normal costal cartilages [37]. A CC fracture is seen as focal discontinuity of the hypoechoic cartilage and its echogenic margins, with variable degrees of displacement [37]. Costochondral injuries are usually treated conservatively. Athletes are restricted from sports for 3 weeks or longer and encouraged to use protective padding when resuming sports activities [36].

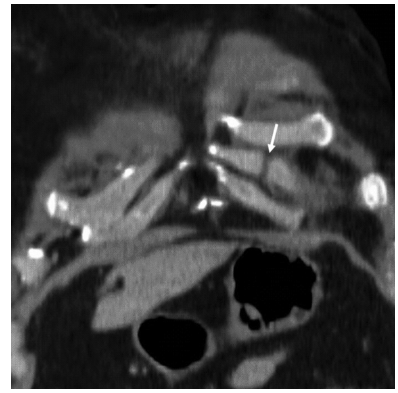

Fig. 11. Costal cartilage fracture. Coronal reconstructed CT image of the chest in a 55-year-old male shows a nondisplaced fracture of the left sixth costal cartilage (arrow).

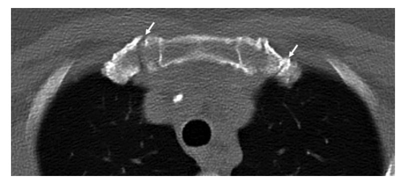

Fig. 12. First costal cartilage clefts. Axial CT image of the chest in a 67-year-old female shows bilateral first costal cartilage clefts (arrows). The first costal cartilages are partially ossified.

6. Costovertebral injuries

The costovertebral joint is comprised of the costocorporeal and costotransverse joints (Fig. 2). Costovertebral injuries are uncommon injuries that usually occur with major trauma. The sternal-rib complex, particularly the costovertebral joints contribute to thoracic spine stability [8]. Costovertebral injuries may be associated with other injuries especially lower thoracic spinal and sternal fractures [8]. On radiographs, costovertebral injuries may demonstrate only subtle findings and be overlooked. These injuries can be reliably diagnosed on CT.

7. Long term complications of rib fractures

Rib fractures, especially when occurring in the context of substantial chest wall trauma may be associated with long term morbidity [24]. Chronic complications of rib fractures include: infection, chest wall deformity, nonunion, chronic pain, clicking, subjective dyspnea, long-standing disability and poor quality of life [3,24].

8. Sternal fractures

8.1. Anatomy

The sternum forms the anterior central aspect of the thoracic cage and is composed of three parts: the manubrium, body and xiphoid process. The manubrium, is the most proximal and broadest part of the sternum and articulates laterally with the clavicles and first ribs, and distally with the body of the sternum via the manubriosternal joint. In adults the manubriosternal joint is typically a fibrocartilaginous articulation. In 30% of cases, the fibrocartilaginous disk within this joint may be partially or completely absorbed and replaced by synovial

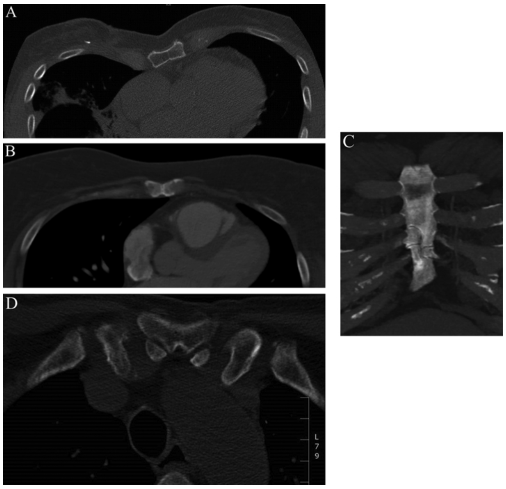

Fig. 13. Normal sternal variants (different patients). (A) Axial CT image in a 75-year-old male demonstrates a tilted sternum. Axial (B) and coronal reconstructed (C) CT images of the sternum in a 53-year-old female, show a well-corticated vertically oriented cleft in the distal sternal body, with adjacent unfused sternal body ossification centers. (D) Axial CT image of the sternum in a 69-year-old male demonstrates bilateral retromanubrial accessory ossicles.

tissue. In 14% of cases the disk may become variably ossified (especially with increasing age), thus forming a synostosis [38]. Laterally, the manubriosternal joint articulates with the second ribs. More distally, the body of the sternum articulates with the second through seventh costal cartilages laterally, and distally with the xiphoid process.

The xiphisternal joint is cartilaginous in young individuals but tends to ossify during middle to late adulthood [5]. The xiphoid process is the smallest and most variable part of the sternum.

8.2. Pertinent normal variants

The sternum is subject to several normal variations that have the potential to mimic fractures or post-traumatic deformities. Posterior displacement, anterior protrusion and oblique orientation of the sternum are seen in pectus excavatum, pectus carinatum and tilted sternum (Fig. 13a), respectively. Tilting of the sternum may also occur in the context of sternoclavicular joint dislocation [4].

Vertically oriented midline sclerotic bands and clefts (Fig. 13b and c) may be seen at the junction of the sternal bars (a pair of mesenchymal bands that fuse at the midline during normal development) [4]. Failure of fusion of the sternal body ossification centers (fusion is usually complete by 25 years of age) results in transversely oriented sternal body clefts (Fig. 13c). A notch or focal defect of the sternal cortex may be evident, most commonly in the posterior cortex of the inferior sternal body [39]. Episternal ossicles (Fig. 13c) are retro- or supramanubrial accessory ossicles that are found in 1.5% of the population. These supernumerary ossification centers may be uni- or bilateral and measure up to 15 mm[4]. Fusion of a suprasternal ossicle to the manubrium results in a suprasternal tubercle [39].

8.3. Sternal fractures

Sternal fractures are relatively uncommon injuries. These fractures are usually the result of blunt anterior chest trauma, although stress and pathologic sternal fractures may also occur. Sternal fractures are most commonly sustained in automobile accidents involving restrained passengers [4]. Contact sports, vehicle to pedestrian collisions, falls, and assaults form the majority of the remining cases [40].

Sternal fractures may be displaced or nondisplaced (Fig. 14) and usually involve the sternal body. These fractures may be isolated or associated with other injuries. Isolated sternal fractures have an excellent prognosis. The importance of sternal fractures is due to the high frequency of concomitant injuries, especially with displaced or unstable sternal fractures. Associated injuries are seen in two-thirds of sternal fractures and may include other types of chest wall injuries along with cardiac, pulmonary, pleural, abdominal, craniocerebral, spinal, and extremity injuries [4,40].

Fig. 14. Sternal fracture. Lateral reconstructed CT image of the sternum in a 36-year-old male demonstrates a nondisplaced fracture of the posterior cortex of the manubrium.

Although sternal fractures are frequently depicted on lateral chest radiographs, this examination is usually not practical in the acute trauma setting [4]. Chest CT (usually performed for evaluation of associated injuries) or MRI can provide detailed characterization of sternal fractures.

Most sternal fractures are treated conservatively. Indications for surgical fixation include nonunion, severe pain, respiratory insufficiency, deformity, a displaced fracture that cannot be corrected by closed reduction and sternal instability [41,42]. Surgical fixation is usually achieved with wiring or plates [41].

8.4. Manubriosternal joint injuries

Disruption of the manubriosternal joint may be associated with subluxation or dislocation of the joint (Fig. 15). Depending on the mechanism of injury, manubriosternal dislocations are classified into two types. Type I injury (more common type) is a posterior dislocation of the sternal body that typically occurs with direct impact injuries. Type II injury is an anterior dislocation of the sternal body relative to the manubrium (Fig. 15b) which follows an indirect hyperflexion injury (e.g., upper thoracic spine flexion-compression injuries or marked thoracic kyphosis) [4,7].

Manubriosternal dislocations may be treated conservatively or with surgery. Conservative treatment may lead to ankylosis and chest wall deformity, with impaired mechanical and respiratory functions [43]. Currently the surgical indications for this rare injury have not been clearly defined [43].

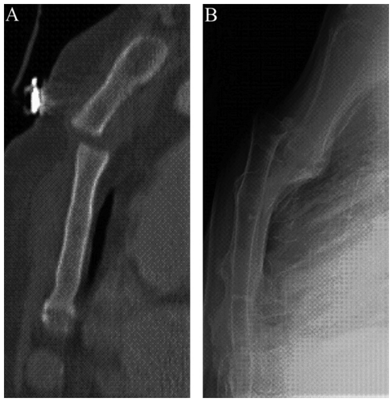

Fig. 15. Manubriosternal joint injuries (different patients). (A) Lateral reconstructed CT image of the sternum in a 56-year-old male shows posterior subluxation of the manubriosternal joint. (B) Lateral sternal radiograph in a 66-year-old female demonstrates anterior dislocation of the sternal body relative to the manubrium (type II injury).

9. Conclusion

Rib fractures are the most common form of blunt thoracic injury. Multiple rib fractures are an important indicator of trauma severity, with increased morbidity and mortality occurring with increasing numbers of rib fractures, especially in the elderly. In the acute setting, correct recognition of the pattern, extent and severity of thoracic cage injuries, may aid in more accurate delineation of concomitant injuries.

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Conflicts of interest

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