Missed rib fractures on evaluation of initial chest CT for trauma patients: pattern analysis and diagnostic value of coronal multiplanar reconstruction images with multidetector row CT

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Objective: The objective of this study was to review the prevalence and radiological features of rib fractures missed on initial chest CT evaluation, and to examine the diagnostic value of additional coronal images in a large series of trauma patients.

Methods: 130 patients who presented to an emergency room for blunt chest trauma underwent multidetector row CT of the thorax within the first hour during their stay, and had follow-up CT or bone scans as diagnostic gold standards. Images were evaluated on two separate occasions: once with axial images and once with both axial and coronal images. The detection rates of missed rib fractures were compared between readings using a non-parametric method of clustered data. In the cases of missed rib fractures, the shapes, locations and associated fractures were evaluated.

Results: 58 rib fractures were missed with axial images only and 52 were missed with both axial and coronal images ($p=0.088$). The most common shape of missed rib fractures was buckled (56.9%), and the anterior arc (55.2%) was most commonly involved. 21 (36.2%) missed rib fractures had combined fractures on the same ribs, and 38 (65.5%) were accompanied by fracture on neighbouring ribs.

Conclusion: Missed rib fractures are not uncommon, and radiologists should be familiar with buckle fractures, which are frequently missed. Additional coronal images can be helpful in the diagnosis of rib fractures that are not seen on axial images.

Rib fractures are the most common skeletal injury in patients with blunt chest trauma, and occur in approximately 50% of these individuals [1]. The rib fracture itself mostly requires only conservative treatment, so the seriousness of the rib fractures is often overlooked. However, rib fractures are an indicator of severe injury from which 12% of patients will die. Additionally, more than 90% of these patients will have associated injuries, half will require operation and intensive care unit admission, one-third will develop pulmonary complications and one-third will require discharge to an extended care facility [2]. The middle ribs are the ones most commonly fractured [3]. The first rib is rarely fractured because of its protected position behind the clavicle, so fractures of the first and second ribs usually signify severe trauma that can cause damage to the brachial plexus and subclavian vessels [4]. In particular, first rib fractures are accompanied by mortality as high as 36.3% [5]. Fractures of the lower ribs may result in laceration of the spleen, liver or kidneys, and need prompt and careful evaluation [1, 4].

Conventionally, chest radiographs have been widely performed to investigate suspected rib fracture as the first diagnostic modality, but have shown sensitivity as low as 15% [6–8]. It has been noted that sonography reveals more fractures than radiography, but this modality depends on the operator’s skill and is inaccessible to most emergency rooms [7, 9, 10]. Omert et al [11] reported that CT detected chest injuries in 39% of patients with an initial normal chest radiograph who were thought to have severe mechanism of injury. Major recent developments have led to the introduction of multidetector row CT (MDCT) as a widely used and versatile imaging modality for emergency management of trauma patients [12]. The nearly isotropic matching of in-plane resolution and section thickness on MDCT means that multiplanar evaluation of transaxial imaging is feasible [13].

To our knowledge, there have been few reports analysing the prevalence and patterns of rib fractures missed on initial CT evaluation in emergency rooms. Furthermore, we do not know whether additional images on the coronal plane help increase diagnostic accuracy for detection of missed rib fractures on the axial plane. Thus, the purpose of our study was to review the prevalence and radiological features of rib fractures missed on initial chest CT evaluation, and to determine the value of additional coronal images in a large series of trauma patients.
Methods and materials

Study population

The institutional review board approved this study and waived informed consent for this retrospective study. Written informed consent was obtained from patients who participated in the enhanced CT study. From July 2007 to December 2009, 518 consecutive patients visited our institution with blunt chest trauma and underwent CT of the thorax. All initial CT scans were performed within the first hour during their stay in the emergency room. Of these 518 patients, 130 had follow-up CT scans of the thorax (n = 79) or bone scans (n = 51) as the primary diagnostic determinant for the presence of rib fractures, and these patients formed the study population. This population consisted of 102 male and 28 female patients, with a mean age of 49.3 years (range 17–88 years). The mean follow-up period between the initial CT scan and follow-up study was 24.4 days (range 1–219 days).

CT acquisition

CT scans were obtained with the helical technique using 16-detector (Sensation 16; Siemens, Forchheim, Germany) scanners. Scanning was performed from the level of the thoracic inlet to the level of the middle portion of the kidneys. Post-enhancement images were obtained within 30–40 s after the start of a 90 ml injection of a non-ionic iodinated contrast agent (Ultravist® 370; Bayer Schering Pharma, Berlin, Germany) administered through the antecubital vein at a rate of 3–4 ml s⁻¹. For all patients, the scanning parameters were 120 kVp and 170–200 mA, and both axial (2.5 mm collimation) and coronal (3.0 mm collimation) reformatted images were sent to picture archiving and communication system monitors. On the monitors, mediastinal (width, 400 HU; level, 20 HU), lung (width, 1500 HU; level, −700 HU) and bone (width, 4000 HU; level, 500 HU) window images were evaluated.

Image assessment and statistical analysis

Two radiologists (one with 8 years of experience of CT analysis and the other with 5 years of experience) reviewed all the initial CT examinations in consensus. Observers were allowed to adjust image brightness and contrast for simulating the routine clinical interpretation environment. The diagnostic criteria for rib fractures included visualisation of the fracture line with or without displacement. Two review sessions were performed: with axial images only and with both axial and coronal images. To limit learning bias, the interval between the two sessions was at least 6 weeks. During each session, the observers recorded their findings for the presence or absence of fracture, number of involved ribs from the 1st to 12th and location of fracture (anterior, lateral and posterior arc by dividing the rib length into three equal parts). The primary diagnostic determinant for the presence of rib fractures was achieved by one of two conditions: definite fracture line or callus formation on follow-up CT scans or increased trace uptake on follow-up bone scans that were reviewed by one radiologist who did not take part in the initial CT analysis. After comparing the observations in each session to the established diagnostic standard, fractures missed in each session were identified. In the cases of missed rib fractures, the shapes (normal, buckle and radiolucent line), presence or absence of combined fractures on the same ribs, presence or absence of fractures on the neighbouring ribs and accompanying fractures in other thoracic bones (sternum, clavicles, scapulae or spines) were described by consensus.

The presence or absence of missed rib fractures was compared between the axial images only and combined axial and coronal images by using a non-parametric method of clustered data [14].

Results

According to the established diagnostic standard, 58 rib fractures were missed in 25 (19.2%) of 130 patients by examining only axial images. Among the 58 missed rib fractures, the shapes (normal, buckle and radiolucent line), presence or absence of combined fractures on the same ribs, presence or absence of fractures on the neighbouring ribs and accompanying fractures in other thoracic bones (sternum, clavicles, scapulae or spines) were described by consensus.

The presence or absence of missed rib fractures was compared between the axial images only and combined axial and coronal images by using a non-parametric method of clustered data [14].

Figure 1. A 71-year-old male with blunt chest trauma from a motor vehicle accident. (a) The fracture of the right seventh rib (arrow) is missed on the initial CT scan. It is located at the lateral arc and shows buckle in shape. (b) The follow-up CT image after 2 days shows callus formation (arrow) at the same site.
fractures, 51 fractures from 22 patients were found on follow-up CT (Figure 1) and 7 fractures from 3 patients were identified on follow-up bone scans (Figure 2). The mean age of the patients with missed rib fractures was 52.0 years (range 20–87 years), with a mean follow-up period of 18.4 days (range 2–94 days). Upon reviewing both axial and coronal images, 52 rib fractures were missed on the initial CT scans. However, the difference between the detection rates of missed fractures by examining only axial images and review of both axial and coronal images was not significant ($p=0.088$).

The location of missed fractures identified with axial images only and with axial plus coronal images is summarised in Table 1. The anterior arc was the most commonly involved site for missed fractures [32 (55.2%) of the 58], followed by the posterior arc (14 fractures, 24.1%) and the lateral arc (12 fractures, 20.7%). The frequencies of right or left rib fractures were similar (27 on the right vs 31 on the left). The shape of the missed rib fractures on axial images was normal in 22 (37.9%), buckle in 33 (56.9%; Figures 1 and 2) and radiolucent line in 3 (5.2%; Figure 3) cases. None of these cases showed apparent signs of fracture on the axial images, but the coronal images revealed fracture lines in six cases (Figure 4), which were normal ($n=1$) or buckle ($n=5$) in shape on axial images and located in the anterior ($n=5$) or lateral arc ($n=1$).

All 25 patients with missed rib fractures had combined rib fractures, and a total of 280 rib fracture sites were found. The number of rib fracture sites per patient ranged from 1 to 35, with a mean of 11.2. 21 (36.2%) missed rib fractures were associated with combined

Table 1. Number of missed rib fractures accounting for location on the evaluation of initial chest CT with axial images only and with axial plus coronal images in parentheses

<table>
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<th>Lateral</th>
<th>Posterior</th>
<th>Left</th>
<th>Anterior</th>
<th>Lateral</th>
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No., number
fractures on the same ribs, and 38 (65.5%) appeared along with fractures on the neighbouring ribs. Accompanying fractures in other thoracic bones were seen in 12 (48%) patients: on the sternum (one patient), clavicles (five patients), scapulae (one patient), spines (three patients), clavicles and scapulae (one patient), and scapulae and spines (one patient).

Discussion

Simple rib fractures are the most common injury sustained following blunt chest trauma, accounting for more than half of the thoracic injuries from non-penetrating trauma [1, 12]. These fractures are rarely life threatening by themselves, but can be an external indicator of more severe visceral injury inside the abdomen and chest [2, 4, 5, 15]. The most common mechanism of injury for rib fractures in the elderly is a fall from a height or standing. In adults, motor vehicle accident is the most common mechanism [16]. Youths sustain rib fractures most often from recreational and athletic activities [17].

When the fracture ends are substantially displaced, diagnosis is usually possible based on standard radiographs of the ribs or chest radiographs. If fractures are subtle and non-displaced, standard radiography may appear to show normal findings, despite the presence of clinical symptoms and increased uptake on bone scintigraphy [8, 18]. Sonography has been known to detect rib fractures with greater accuracy than conventional radiography, but it is operator dependent and is not practical for use in an emergency setting [7, 9, 10]. Recently, CT has been considered to be the first choice modality for evaluation of trauma patients, including ones with thoracic trauma [12]. This technique requires a short time for scanning and enables accurate diagnosis of injuries. Despite higher sensitivity and specificity associated with CT for diagnosing rib fractures compared with other radiological modalities, missed rib fractures are still common problems in the hospital [11].

Figure 3. A 32-year-old male with blunt chest trauma from a motor vehicle accident. (a) A radiolucent line (arrow) in the left eighth rib is missed on the initial CT evaluation. (b) The follow-up CT image shows a definite fracture line with displacement (arrow).

Figure 4. A 59-year-old female with blunt chest trauma from a motor vehicle accident. The fracture (arrow) of the left eighth rib is missed on the (a) axial image alone, but a definite fracture line (arrow) is noted on the (b) coronal reformed image. (c) The follow-up CT image after 23 days shows callus formation (arrow) at the same site.
Pattern analysis of missed rib fractures with multidetector row CT

With the dissemination and technical development of MDCT, multiplanar reconstruction images are popular and available in most hospitals. The nearly isotropic matching of in-plane resolution and section thickness in MDCT images means that reviewing multiplanar reformats from transaxial imaging is standard practice [13]. The value of multiplanar reformatted images, including coronal images, has been proven in multiple studies [15, 16, 19–22]. In our study, additional coronal images revealed definite fractures in six cases that showed no distinguishable signs of fractures on axial images. Although there was no statistically significant difference, coronal reconstruction images can provide more information for more accurate diagnosis of rib fractures. A potential explanation for superior detection rate of rib fractures on coronal images is that vertically oriented lesions may be more easily detected on coronal images than on axial images. Additionally, coronal images can be used to increase accuracy by enabling more confident evaluation of questionable findings detected on axial images.

The cause of missed rib fractures can be attributed to the fact that most show no or few fracture signs on the scanning images. The anterior arc was the most commonly involved site for missed rib fractures in our study, and oblique orientation of the anterior arc may preclude detection of fractures on axial images. The most common shape of missed fractures in our study was buckle. Buckle fractures result from an injury insufficient in force to create a complete discontinuity of bone, but sufficient to produce buckling of the cortex. This type of fracture occurs most often in children because their bones are generally more flexible and elastic than those of adults [23]. Although many studies have reported on paediatric buckle fractures, few reports on this type of fracture in adults have been published to our knowledge. Love and Symes [24] reported a relatively high incidence of subtle patterns of rib fractures (e.g. incomplete and buckle fractures) in adults aged 21–76 years. Daegling et al [25] performed an experiment in vitro to examine whether rib fracture patterns are consistent under controlled loading conditions despite idiosyncratic variation in rib morphology. They found that the patterns of rib fractures such as transverse, spiral, butterfly and buckle shapes are remarkably variable and unpredictable, and buckling was expected in cases where a load is imposed on a very thin-walled structure. There were a few limitations to our study. First, this study was limited by a retrospective design and included patients who had follow-up chest CT or bone scans. Therefore, the proportion of severely injured patients may be larger than that of patients with minor injuries. Missed rib fractures may be found more frequently in cases of minor injuries. Second, the severity or mechanisms of injury were not considered during image analysis. Characteristic findings of rib fractures may happen according to the axis of the force. Third, the time differences for reporting on two separate occasions (once with axial images and once with axial and coronal images) were not measured.

In summary, missed rib fractures are not uncommon, and radiologists should be familiar with buckle fractures that are frequently missed on imaging scans. Additional coronal images can be helpful in the diagnosis of missed rib fractures that are not viewed on axial images.

References


