

# Simple X-ray versus ultrasonography examination in blunt chest trauma: effective tools of accurate diagnosis and considerations for rib fractures

Eun Gu Hwang<sup>1</sup>, Yunjung Lee<sup>2,\*</sup>

<sup>1</sup>Department of Thoracic and Cardiovascular Surgery, Gunpo G Sam General Hospital, Gunpo, Korea

<sup>2</sup>Department of Computer Science and Statistics, Jeju National University, Jeju, Korea

Simple radiography is the best diagnostic tool for rib fractures caused by chest trauma, but it has some limitations. Thus, other tools are also being used. The aims of this study were to investigate the effectiveness of ultrasonography (US) for identifying rib fractures and to identify influencing factors of its effectiveness. Between October 2003 and August 2007, 201 patients with blunt chest trauma were available to undergo chest radiographic and US examinations for diagnosis of rib fractures. The two modalities were compared in terms of effectiveness based on simple radiographic readings and US examination results. We also investigated the factors that influenced the effectiveness of US examination. Rib fractures were detected on radiography in 69 patients (34.3%) but not in 132 patients. Rib fractures were diagnosed by using US examination in 160 patients (84.6%). Of the 132 patients who showed no rib fractures on radiography, 92 showed rib fractures on US. Among the 69 patients of rib fracture detected on radiography, 33 had additional rib

fractures detected on US. Of the patients, 76 (37.8%) had identical radiographic and US results, and 125 (62.2%) had fractures detected on US that were previously undetected on radiography or additional fractures detected on US. Age, duration until US examination, and fracture location were not significant influencing factors. However, in the group without detected fractures on radiography, US showed a more significant effectiveness than in the group with detected fractures on radiography ( $P=0.003$ ). US examination could detect unnoticed rib fractures on simple radiography. US examination is especially more effective in the group without detected fractures on radiography. More attention should be paid to patients with chest trauma who have no detected fractures on radiography.

**Keywords:** Blunt chest trauma, Ultrasound examination, Rib fracture

## INTRODUCTION

Chest trauma is the third most common type of traumatic injury. Blunt chest trauma, in particular, is typically caused by motor vehicle accidents, falls, dropping from a great height, direct blow to the chest during physical confrontations among others, and it shows a wide range of clinical presentations. Rib fracture is the most common injury (25%) (Hurley et al., 2004) sustained following a blunt chest trauma, accounting for 67% of all such injuries. The major symptom of rib fracture is pain at the injury site with or without movement (Mayberry and Trunkey, 1997). De-

pending on the patient's chief complaints, a primary care physician will inquire regarding the pain, perform a physical examination, and most likely check a plain chest radiograph (Hurley et al., 2004). Unfortunately, plain chest radiography presents various limitations. A simple chest radiograph seldom immediately discloses fracture displacement unless it is definite. Similarly, damage to the cartilage is hardly detected in the absence of severe calcification (Malghem et al., 2001). In addition, obesity and existing lung conditions can negatively affect radiograph quality, which poses a challenge for interpreting the image and making a diagnosis (Kara et al., 2003). Moreover, in cases of a suspected lower rib

\*Corresponding author: Yunjung Lee  <http://orcid.org/0000-0001-7394-1723>  
Department of Computer Science and Statistics, Jeju National University, Jeju National University, 102 Jejudaehak-ro, Jeju 63243, Korea  
Tel: +82-64-754-3597, Fax: +82-64-725-2579, E-mail: rheeeyj@jejunu.ac.kr  
Received: October 7, 2016 / Accepted: December 1, 2016

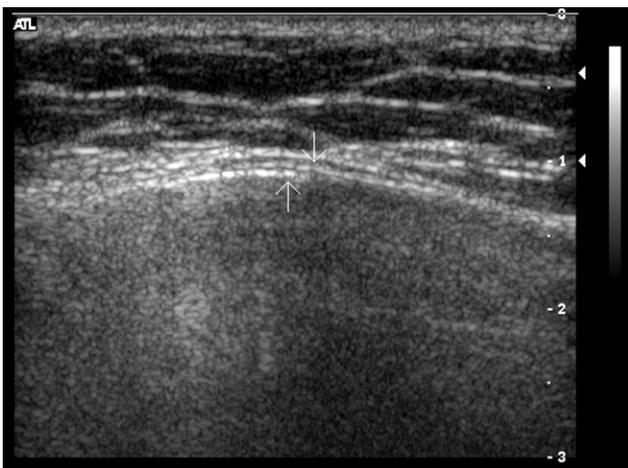
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

fracture, radiograph interpretation is particularly difficult because the area is closely located near the abdominal soft tissues. Furthermore, radiography is only able to detect fluid shifting if trauma-related hemothorax is above a certain level. A delay in diagnosing rib fracture-related lung complications, hemothorax (or pneumothorax), myocardial contusion, and damaged heart valve can become life-threatening and result in emergency surgeries. Moreover, additional diagnostic methods are necessary when legal problem exists or insurance companies require a definite diagnosis.

In addressing the above issues, whole body bone scan using radioactive isotope, chest computed tomography (CT) with three-dimensional chest reconstruction imaging have been made available to be used as supplementary diagnostic tools. However, they also present limitations, which include low specificity, high levels of radiation exposure, and high costs. Ultrasound examination has become popular in recent years as an efficient and non-invasive diagnostic tool. The present study investigate the efficacy of



**Fig. 1.** Chest wall tender point mapping.

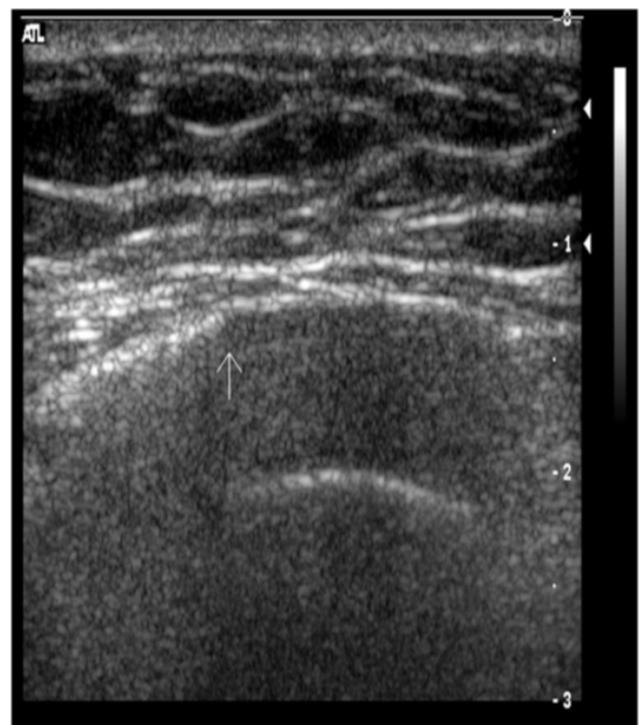


**Fig. 2.** Cortical disruption on ultrasound examination (arrows).

ultrasound examination in the early and accurate detection of musculoskeletal abnormalities in patients with blunt chest trauma by measuring and comparing the accuracy of chest radiographs and ultrasound examination and identify the influencing factors.

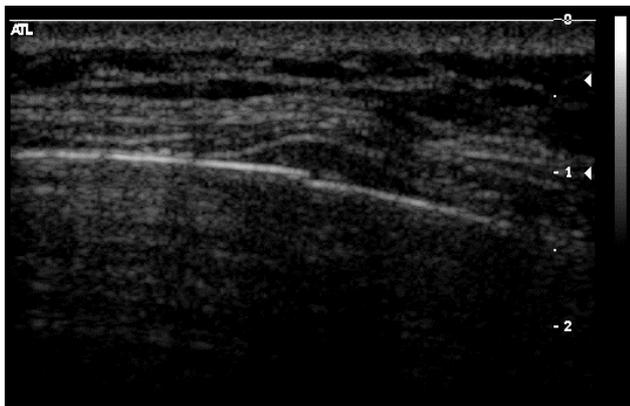
## MATERIALS AND METHODS

Study subjects consisted of patients with blunt chest trauma who visited the Konkuk University Chungju Hospital between October 2003 and August 2007. Medical interviews and physical examinations were performed followed by chest radiography for these patients. Subsequently, an imaging area was mapped out to include the pain site based on the patient's complaint, as well as the site of tenderness noted during the physical examination, plus one additional rib each from the top and bottom of the pain site (Fig. 1). Based on the ultrasound image obtained (HDI 5000, ATL, Bothell, WA, USA; high-spatial resolution transducer 12 MHz), fracture was confirmed if rib cortical defect (Fig. 2), costal cartilage disruption (Fig. 3), subperiosteal hematoma (Fig. 4) and sternal cortical defect were verified (Koh et al., 2002). In addition, the presence/absence of pneumothorax and hemothorax was examined. The results of ultrasound examination and plain radiography were compared to examine the efficacy of the former and to ascer-



**Fig. 3.** Costo-chondral junction disruption on ultrasound examination (arrow).

tain whether the results were identical or whether ultrasound examination detected rib or sternal fractures that were unnoticed upon radiography. The subjects were grouped based on sex, age, and injured rib location (upper, 1–4; mid, 5–7; lower, 8–12). The duration between the time of initial injury and ultrasound examination, and the presence/absence of rib fracture based on chest radiograph were statistically analyzed with SPSS ver. 13.0 (SPSS Inc., Chicago, IL, USA) with chi-square test, Fisher exact test. *P*-value less than 0.05 was regarded as statistically significant factors influencing the efficacy of ultrasound examination.



**Fig. 4.** Subperiosteal hematoma and cortical disruption on ultrasound examination.

**Table 1.** Patients characteristics (n=201)

Characteristic	Value
Sex, male:female	118: 83
Age (yr), mean ± SD (range)	48.18 ± 15.82 (3–91)
Vector	
Traffic accident	98
In car	78
Pedestrian	20
Direct trauma	28
Slip down	26
Fall down	20
Cultivator	11
Others	18
Location	
Left	95
Right	67
Both	12
Sternal area	27
Duration until US examination, mean ± SD (range)	6.84 ± 11.29 (0–138)

SD, standard deviation; US, ultrasound.

## RESULTS

The 201 patients with blunt chest trauma (n = 201) consisted of 118 men and 83 women whose mean age was 48.18 ± 15.82 years (range, 3–91 years). Causes of injury included motor vehicle accidents (98 cases; 78 drivers/passengers, 20 pedestrians), direct blows (28 cases), falls (26 cases), drops from a great height (20 cases), accidents involving a cultivator (11 cases), and others (18 cases). Locations of injury included left 95 cases, right 67 cases, both 12 cases, and sternum 26 cases. The mean duration between the time of initial injury and ultrasound examination was 6.84 ± 11.29 days (range, 0–138 days) (Table 1). Plain chest radiography detected 132 cases of nonfractures and 69 cases of fracture (upper, 9 cases; mid, 42 cases; lower, 18 cases), with the latter accounting for 34.3% of the total cases. Ultrasound examination detected 41 cases of nonfractures and 160 cases of fractures (upper, 23 cases; mid, 69 cases; lower, 68 cases), with the latter accounting for 84.6% of the total cases (Table 2). The results of the two imaging methods matched as identical for 76 cases. Of the 132 nonfracture cases determined upon radiography, 92 cases were later determined to be fractures upon ultrasound examination. In addition to the 69 fracture cases initially determined upon radiography, 32 cases of additional fracture were detected upon ultrasound examination, which were unnoticed upon plain chest radiography, resulting in a total of 125 fracture cases (62.1%) (Table 3). With regard to factors influencing the efficacy of ultrasound examination, the age of the

**Table 2.** Results of simple X-ray and US examinations

	Fracture (-)	Fracture (+)
Simple X-ray	132 (65.7%)	69 (34.3%)
		Upper 9
		Mid 42
		Lower 18
US examination	41 (15.4%)	160 (84.6%)
		Upper 23
		Mid 69
		Lower 68

US, ultrasound.

**Table 3.** Comparison of the results of simple X-ray and US examinations

Simple X-ray	US examination
No fracture on X-ray (n = 132)	Same result on US (n = 40)
	Unnoticed rib fracture on US (n = 92)
Fracture (+) on X-ray (n = 69)	Unnoticed another rib fracture on US (n = 33)
	Same result on US (n = 36)

US, ultrasound.

**Table 4.** Factors influencing on the effectiveness of ultrasound examinations

Factor	P-value
Age, 50 yr	1.000
Duration until ultrasound examinations (7 days)	0.639
Location, nonlower vs. lower	0.176
Fracture on simple X-ray, (-) vs. (+)	0.003

subjects (cutoff age, 50 years) did not appear to have a statistically significant effect ( $P = 1.000$ ). No statistical significance was found between the group of subjects who waited 7 days or longer before ultrasound examination and those who had the imaging performed within 7 days from the initial injury ( $P = 0.639$ ). The location of the injury was regrouped into nonlower (upper, mid) and lower to examine whether it influenced the efficacy of ultrasound examination. No significant difference was still found between the two groups ( $P = 0.176$ ). However, the efficacy of ultrasound imaging in the group of patients without fractures on plain chest radiography was found to be significantly greater ( $P = 0.003$ ) than that in the group of subjects with fractures (Table 4).

## DISCUSSION

Plain chest radiography is typically the first examination performed for patients with blunt chest trauma. When conservative treatment fails to improve the symptoms or the symptoms worsen over time, or when other symptoms and signs develop later on, clinicians will consider the idea that the initial diagnosis may have been incorrect (Turk et al., 2010). In such cases, another round of plain chest radiography may be checked, or other diagnostic methods may be considered. Occasionally, rib fracture previously undetected with plain chest radiography is detected during the second round of plain chest radiography. This is attributed to the fact that chest muscles around the injury site initially contract in response to the injury, but they relax over time, making the fracture appear definite during the second plain chest radiography.

Ultrasound examination is a diagnostic imaging technique widely used due to its noninvasiveness and efficiency. Images of chest wall structure and muscle layers are typically obtained, with a focus on the pain site. Ultrasound examination can detect 50%–88% of sternal cortical defect, rib cartilage disruption, minute cortical defect in rib, hemothorax (Ma and Mateer, 1997), pneumothorax (Bitschnau et al., 1997), myocardial contusion, and damage to the heart valve initially undetected by chest radiography. In the present study, additional 125 rib fracture cases were found with ultrasound imaging technique, accounting for approx-

imately 27.8% diagnostic efficacy. Rib cartilage fracture is seldom detected with plain chest radiography in the absence of severe calcification. In such cases, the patient would still complain of constant pain, which would lead the clinician to suspect malingering or would give cause for further confusion. Ultrasound examination is known to be more sensitive than plain chest radiography or CT in detecting such cartilage fractures (Lee et al., 2012). Furthermore, although plain chest radiography typically detects hemothorax at approximately 150 mL, ultrasound imaging can detect the condition with a volume as low as 40 mL, making it a highly sensitive diagnostic tool (Röthlin et al., 1993).

As review of previous study for rib fractures and ultrasound examination, Kara et al. (2003) aiming to identify the predictors, performed chest wall ultrasound examination for 37 cases of blunt chest trauma wherein initial plain chest radiography did not detect fractured ribs. Although the predictors of undetected rib fracture could not be identified, pain from a rib bone fracture has been found to last longer than the pain from a rib cartilage fracture. Hendrich et al. (1995) suggested indications for ultrasound examination for sternal fracture. (a) Ultrasound imaging is appropriate for detecting the presence of sternal fracture. Plain chest radiograph is superior to ultrasound examination for detecting fracture severity. (b) Ultrasound examination may be used to distinguish the initial old fracture from the newly developed fracture. (c) Ultrasound examination can provide more data without exposing the patient to additional radiation in cases of sternal fractures that do not appear definite on a plain chest radiograph. However, determining the accuracy of ultrasound examination was difficult because of the group of subjects consisting 45 patients, only one case of sternal fracture that was previously undetected by plain chest radiography was later detected with ultrasound examination.

In supporting the superior efficacy of ultrasound examination, Turk et al. (2010) reported that ultrasound examination was effective for the group of patients who still had unexplained pain after plain chest radiography could not detect a fracture. The finding is consistent with what the present study found. Lee et al. (2012) reported that ultrasound examination was effective in detecting costal cartilage fractures previously undetected with plain chest radiography or CT. Griffith et al. (1999) reported that, whereas the diagnostic sensitivity of plain chest radiography for sternal fracture was 15%, that of the ultrasound was 90%. Furthermore, the specificity was 100% when both techniques were used.

In addition, there is a suggestion that ultrasound examination allows identification of the precise fracture location to help determine the site for surgical incision before rib fixation surgery,

which eliminates the potential for having to extend the incision. In contrast, Hurley et al. (2004), in their study comparing the efficacies of plain chest radiography and ultrasound examination, found that the two imaging techniques' results match identically when displacement is definite, and that ultrasound examination presents its own limitations because it requires more time, and can be painful for the patient depending on the fracture location. And Griffith et al. (1999) identified three disadvantages of ultrasound examination. First is time-consuming, second is retroscapular and infraclavicular portion of the first rib is inaccessible, and third is difficulty to exam in dyspneic, unconscious, uncooperative or severely traumatized patients. Large breast and obesity may also limit rib fracture detection by ultrasound examination.

In conclusion, ultrasound examination seems to be an effective method for diagnosing rib fracture in patients with blunt chest trauma. Particularly, if patients with blunt chest trauma without rib fractures determined upon plain chest radiography continue to complain of pain or if symptoms do not improve, or a definite diagnosis is required for legal and insurance-related purposes, ultrasound imaging appears to be a supplementary diagnostic tool that offers greater accuracy. Nevertheless, because the present study is a retrospective study, along with many other existing studies also retrospective and small sample size, concluding that ultrasound examination has superior efficacy is difficult. On this note, a large-scale, randomized controlled study in the future would be beneficial for verifying the imaging technique's efficacy for diagnosing rib fractures in patients with blunt chest trauma.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

## REFERENCES

- Bitschnau R, Gehmacher O, Kopf A, Scheier M, Mathis G. Ultrasound diagnosis of rib and sternum fractures. *Ultraschall Med* 1997;18:158-161.
- 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* 1999;173:1603-1609.
- Hendrich C, Finkewitz U, Berner W. Diagnostic value of ultrasonography and conventional radiography for the assessment of sternal fractures. *Injury* 1995;26:601-604.
- Hurley ME, Keye GD, Hamilton S. Is ultrasound really helpful in the detection of rib fractures? *Injury* 2004;35:562-566.
- 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;24:608-613.
- Koh DM, Burke S, Davies N, Padley SP. Transthoracic US of the chest: clinical uses and applications. *Radiographics* 2002;22:e1.
- Lee WS, Kim YH, Chee HK, Lee SA. Ultrasonographic evaluation of costal cartilage fractures unnoticed by the conventional radiographic study and multidetector computed tomography. *Eur J Trauma Emerg Surg* 2012;38:37-42.
- Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med* 1997;29:312-315.
- Malghem J, Vande Berg B, Lecouvet F, Maldague B. Costal cartilage fractures as revealed on CT and sonography. *AJR Am J Roentgenol* 2001;176:429-432.
- Mayberry JC, Trunkey DD. The fractured rib in chest wall trauma. *Chest Surg Clin N Am* 1997;7:239-261.
- Röthlin MA, Näf R, Amgwerd M, Candinas D, Frick T, Trentz O. Ultrasound in blunt abdominal and thoracic trauma. *J Trauma* 1993;34:488-495.
- Turk F, Kurt AB, Saglam S. Evaluation by ultrasound of traumatic rib fractures missed by radiography. *Emerg Radiol* 2010;17:473-477.