Ultrasonographic Diagnosis of Suspected Hemopneumothorax in Trauma Patients

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Background: Bleeding and trapped air in the pleural space are called hemothorax and pneumothorax, respectively. In cases where there are delays in diagnosis and treatment, the mortality rates due to hemopneumothorax can be significant. Hemopneumothorax is characterized by decreased lung sounds or chest percussion and subcutaneous emphysema. Diagnosis of pneumothorax and hemothorax can be achieved by portable chest X-ray (CXR), computed tomography (CT) scan, or ultrasonography. Portable CXR and CT-scans have their individual drawbacks. CXR creates a high percentage of false negative results, and a CT-scan is time consuming and less cost-effective; in addition, both modalities expose patients to radiation. Therefore, the introduction of ultrasonography as an easily available and highly accurate diagnostic modality has particular importance.

Objectives: The aim of this study was to evaluate the sensitivity and specificity of ultrasonography in the diagnosis of pneumothorax and hemothorax in comparison with the other two methods, namely portable CXR and CT-scan.

Patients and Methods: Patients (163) with multiple trauma who were suspected of having chest injuries, and who had indications for a chest CT-scan according to ATLS algorithms, were included in the study. All patients underwent portable CXR, CT-scan, and ultrasonography.

Results: In total, 163 patients were included in this study; 29 patients had a pneumothorax, 24 patients had a hemothorax, and 23 patients had a hemopneumothorax confirmed. The study revealed that ultrasonography had a sensitivity of 96.15%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 98%, in the diagnosis of pneumothorax. The sensitivity for ultrasonography in the diagnosis of a hemothorax was 82.97%, with a specificity of 98.05%, a positive predictive value of 90%, and a negative predictive value of 92.66%. Portable CXR for pneumothorax detection had a sensitivity of 34.61%, a specificity of 97.95%, a positive predictive value of 90%, and a negative predictive value of 73.84%. In the detection of hemothorax, CXR had a sensitivity of 25.53%, a specificity of 95.14%, a positive predictive value of 70.58%, and a negative predictive value of 73.68%.

Conclusions: Ultrasonography sensitivity and specificity for diagnosis of hemopneumothorax was high. The sensitivity of portable CXR was low despite its high specificity for the detection of hemothorax and pneumothorax.

Keywords: Pneumothorax; Hemothorax; Trauma

1. Background

Bleeding and trapped air in the pleural space called hemothorax and pneumothorax, respectively are among the most common clinical conditions that are seen in patients with multiple trauma. After airway obstruction, pneumothorax and hemothorax are the most common causes of ventilator failure (1). These are characterized by decreased lung sounds, chest percussion, and asymmetrical chest wall movements (2). Its incidence among patients with blunt trauma is 20% (3), while in patients with penetrating trauma, the incidence is 40% (4). In patients who have spontaneous breathing, a pneumothorax of a small or average amount is not life threatening. However, if the patient is under positive pressure ventilation, it can lead to tension pneumothorax, which is lethal.

Diagnosis of pneumothorax and hemothorax can be achieved by portable chest radiography (CXR), computed tomography (CT-scan), or ultrasonography (5). According to ATLS guidelines, a portable CXR is the first step necessary for a diagnosis of hemopneumothorax; however, the drawbacks of this method, which include low sensitivity (false negative results) and the patient's exposure to radiation, are considerable. Although a CT-scan is currently the gold standard for hemopneumothorax diagnosis (6), this apparatus is not available everywhere and in addition is costly as well. Recently, ultrasonography has been developed and used for the detection of hemopneumothorax (7). In addition, ultrasound has high levels of sensitivity and specificity, as well as being fast and cost-effective in comparison with the other two diagnostic methods (portable CXR and CT-scan).

2. Objectives

Although ultrasound has previously been introduced as an accurate method to detect pneumothorax (8) and hemothorax (9), few published reports are available in Iran concerning evaluation of the sensitivity and specificity of ultrasonography in the diagnosis of pneumothorax and hemothorax in comparison with portable CXR and CT-Scan. Taking the limitations of portable CXR and CT-scans into account, the objectives of the present study were to determine the sensitivity and specificity of ultrasonography in detection of hemopneumothorax in patients with multiple trauma admitted to the emergency room. Moreover, we aimed to include this method in a focused assessment with sonography for trauma (FAST) protocol to assess suspected cases of chest trauma.

3. Patients and Methods

We enrolled all patients with severe multiple trauma at triage ESI 1 and 2 levels, who were admitted to the emergency ward of Imam Reza Hospital, Tabriz, Iran during winter 2013 based on the mechanism of injury, or their history and examination findings of suspected chest injuries, and chest CT-scan according to an Advanced Trauma Life Support algorithm. The mechanisms of injury included; car rollover, being thrown out of the vehicle, frontal impact, compression of the chest with the steering wheel or dashboard, severe side impact, fall, or acceleration-deceleration injury. The examination findings included: chest pain, tenderness over the ribs, decreased lung sounds or chest percussion, subcutaneous emphysema, or any sign of trauma such as abrasions and/or bruises. Patients who underwent a tube thoracostomy, before they had an opportunity to have an ultrasound due to their unstable clinical situation, or for any other reason, such as a lack of access to ultrasound at the time of admission, were excluded from the study. The patients were evaluated according to the ATLS algorithm, and examination findings were recorded following initial evaluations, an emergency medicine specialist performed chest ultrasonography to detect pneumothorax and hemothorax. We used a General Electric E200 ultrasound with two types of probes namely: a curve probe of 5 MHz frequency for hemothorax assessment and a linear probe of 6.5-9 MHz frequency for pneumothorax assessment. Sonography images of the lung are built with air artifacts as the air stops the beam; however, this artifact varies when it is in the pleural space. In a normal lung view, pleural movement along the parietal and visceral sides is called lung sliding, which can be easily seen with ultrasound. This characteristic is also known as the gliding sign. Moreover, sharp resonance appears during ventilation at the border of the pleura and lung, which is called a comet-tail artifact (Figure 1). Trapped air in the pleural space prevents visualization of lung sliding signs and comet-tail artifacts, therefore, based on these findings, pneumothorax can be detected with ultrasonography (5).

Ultrasound allows the detection of small amounts of loculated pleural fluid in amounts as small as 20 ml, which cannot be identified by X-rays, as it is only capable of detecting volumes above 50 mL. In contrast to the radiological method, ultrasonography allows an easy differentiation of loculated pleural liquid and thickened pleura and is efficient in pinpointing thoracocentesis, even in small fluid collections. The ultrasound image of pleural effusion is characterized by an echo-free space between the visceral and parietal pleura (Figure 2) (9). The disappearance of lung sliding and comet-tail artifacts in M-mode sonography used to detect pneumothorax and the hypo-echo area above the diaphragm and chest wall used to detect hemothorax were also considered.

It should be noted that the medical team responsible for the patient and the ER specialist who conducted the ultrasound were different. An independent medical team performed the necessary procedures based on ATLS algorithms and the research assessments did not interfere with the patient's care. Patients with ATLS guideline indications underwent a chest CT-scan. Assigned radiologists reported both CT-scan and portable CXR results, while ultrasonography was performed by an ER specialist. In fact, these two groups of examiners were not aware of each other's results. With regard to the clinical situation of the patients, if the medical team decided to employ a tube thoracostomy or chest tube after a sonography, then air or the existence of blood were considered as the gold standard of diagnosis.

SPSS version 17 (SPSS Inc., Chicago, Illinois, USA) was used for the statistical analysis. Data were reported as frequency and percentage. To compare qualitative variables, Chi-square and Fisher's exact test were employed. To compare the quantitative variables between the two methods of evaluation, independent samples t-test was used, a P value lower than 0.05 was considered as statistically significant level in all tests.

4. Results

Overall, 163 patients were assessed to participate in the study and the 150 patients who met the inclusion criteria were enrolled. The study participants were comprised of 124 (82.66%) males and 26 (17.33%) females. All portable CXR, CT-scan, and ultrasound findings are summarized in Table 1. Among the individuals with detected contusions and rib fractures by CT-scan, 13 (8.6%) patients had rib fractures and nine patients had contusions. In patients viewed by portable CXR, seven patients had contusions and 22 (14.66%) patients had rib fractures. Of the 52 patients with pneumothorax detected by CT-scan, 50 patients were diagnosed with ultrasonography, and all 98 patients who had negative results for pneumothorax were detected with ultrasonography (65.33%).

According to our results, a sensitivity of 96.15%, specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 98% for a diagnosis of
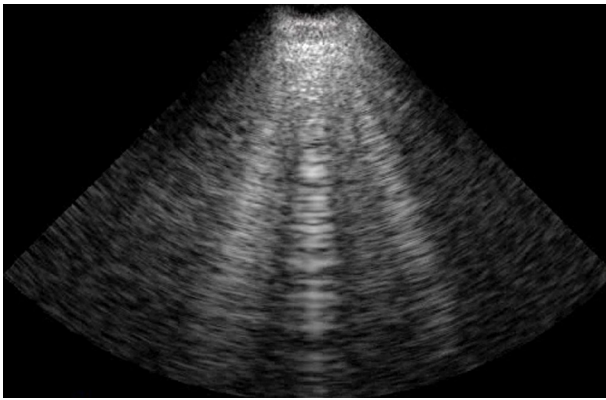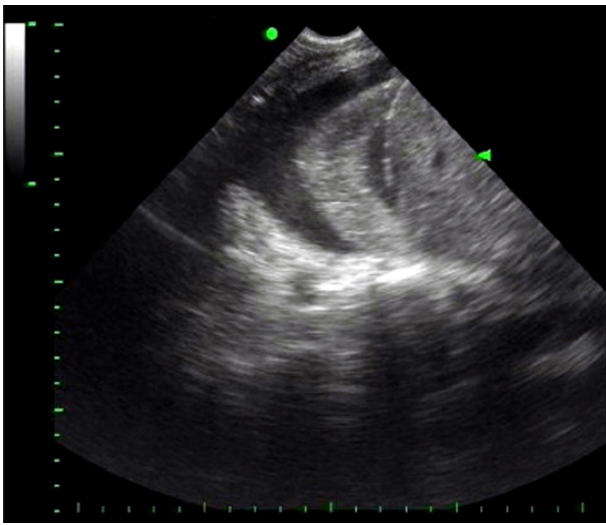
Figure 1. Comet-Tail Artifacts

Figure 2. Hemothorax

pneumothorax were achieved for ultrasound (Table 2). Of the 47 patients with a hemothorax detected by CT-scan, 39 patients were diagnosed and eight patients were missed on an ultrasonography. In addition, of the 103 total patients who were negative for a hemothorax by CT-scan, 101 patients were detected by ultrasonography. According to our results, a sensitivity of 82.97%, a specificity of 98.05%, a positive predictive value of 95.12%, and a negative predictive value of 92.66% for a diagnosis of hemothorax were obtained for ultrasonography (Table 3). It should be noted that all of the hemothorax cases that were not diagnosed by ultrasonography had a very low fluid volume, which did not actually involve any changes in patient management. Of the 52 patients with a pneumothorax detected on a CT-scan, 18 and 34 patients were diagnosed and missed with portable CXR, respectively. In addition, of the 98 patients negative for a pneumothorax on CT-scan, 96 cases were detected with a portable CXR. According to these results, a sensitivity of 34.61%, a specificity of 97.95%, a positive predictive value of 90%, and a negative predictive value of 73.84% in detecting pneumo-

thorax were obtained by portable CXR (Table 2). Of the 47 patients with a hemothorax detected on CT-scan, 12 cases were diagnosed by portable CXR and 35 were missed. Moreover, of the 103 negative results for a hemothorax on CT-scan, 98 cases were detected by portable CXR. According to our results, a sensitivity of 25.53%, a specificity of 95.14%, a positive predictive value of 70.58%, and a negative predictive value of 73.68% in detecting hemothorax were obtained via portable CXR (Table 3).

Table 1. Findings [a,b]

	CT-scan, Frequency	Portable CXR, Frequency	Bedside Ultrasonography, Frequency
Normal	63 (42)	90 (60)	71 (47.3)
Rib Fracture	46 (30.6)	14 (9.03)	-
Subcutaneous Emphysema	31 (20.6)	36 (24)	-
Contusion	33 (22)	21 (14)	-
Pneumothorax	29 (19.33)	14 (9.3)	38 (25.3)
Hemothorax	24 (16)	11 (7.03)	29 (19.33)
Hemopneumothorax	23 (15.33)	6 (4)	12 (8)

[a] Abbreviations: CT-Scan, computed tomography; CXR: chest X-ray.
[b] Data are presented as No. (%).

Table 2. Comparison of Ultrasound, Chest Radiography, and Computed Tomography in the Detection of Pneumothorax

	CT PTX [a]		Total
	+	-	
CXR PTX			
+	18	2	20
-	34	96	130
Total	52	98	150
Sonography PTX			
+	50	0	50
-	2	98	100
Total	52	98	150

[a] Abbreviations: CT, computed tomography; PTX, pneumothorax CXR, chest X-ray.

Table 3. Comparison of Ultrasonography, Chest Radiography, and Computed Tomography in the Detection of Hemothorax

	CT HTX [a]	
	+	-
CXR HTX		
+	12	5
-	35	98
Total	47	103
Sonography HTX		
+	39	2
-	8	101
Total	47	103

[a] Abbreviations: CT, computed tomography; HTX, hemothorax CXR, chest X-ray.

5. Discussion

In our study, the calculated sensitivity of ultrasound in the diagnosis of pneumothorax was in agreement with the studies of Nandipati et al. (10), Soldati et al. (4), Alrajhi et al. (6), Sartori et al. (5), Ku et al. (11), Blaivas et al. (8), and Rowan et al. (12). Moreover, the sensitivity, specificity, positive predictive value, and negative predictive value of CXR in the detection of pneumothorax was similar to the results found by Rowan et al. where they reported a sensitivity of 36%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 70% (12). However, in other studies such as Blaivas et al. (8) and Nandipati et al. (10), the sensitivity of portable CXR was reported to be higher than in our study. Possible causes for this difference may be the different quality of equipment, quality of graphics, or the skill of the radiologist who reported the findings. In the present study, the sensitivity, specificity, positive and negative predictive value of ultrasonography in the detection of hemothorax was also similar to the findings of Ma et al. (13), and Brooks et al. (9). All hemothorax cases which were not diagnosed by ultrasonography had very low fluid volumes, but they did not require any changes in patient management. However, the results of the present study were not similar to a study by Sisley et al., that reported a sensitivity and specificity of 92.5% and 99.7%, respectively, for portable CXR in the detection of hemothorax (14). In general, a supine CXR is conducted for diagnosis of hemothorax, which creates a decrease in sensitivity. On the other hand, small amounts of pleural fluid can be detected with an upright CXR. Ultrasound allows the detection of small amounts of loculated pleural fluid, with positive identification of amounts as little as 3 to 5 mL (15), which cannot be identified by CXR as it is only capable of detecting volumes above 50 mL of pleural fluid on an upright CXR, and a minimum of 175 mL on a supine CXR (16). Using this interpretation, we can state that this inconsistency was probably due to differences in fluid volumes in comparison to the studies of Ma et al. and Sisley et al. (13, 14).

To provide an accurate determination of the sensitivity of portable CXR in diagnosis of hemothorax, the volume of fluid in the plural space must be considered in future studies. Based on our results, we can conclude that the sensitivity and specificity of ultrasonography in a diagnosis of hemothorax and pneumothorax was very high, which was in accordance with other studies. However, despite the high specificity of portable CXR in the detection of hemothorax and pneumothorax, its sensitivity was low. Therefore, using ultrasonography in the diagnosis of hemopneumothorax would be a good substitute for a portable CXR or CT-scan due to its availability, accuracy, and rapid detection. Ultrasonography can be used for the primary evaluation of trauma patients as part of the FAST protocol, and this study has shown that ultrasound is a reliable, accurate, cost-benefit, and harmless method for evaluation of the lungs as well as the detection of hemopneumothorax.

Authors' Contributions

Study concept, design and supervision: Seyyed Hossein Ojaghi Haghighi and Samad Shams Vahdati; acquisition of data: Seyyed Hossein Ojaghi Haghighi; analysis and interpretation of data: Reza Sarkhoshi Khiavi and Ida Adimi; drafting of the manuscript, critical revision of the manuscript for important intellectual content, statistical analysis, and aadministrative, technical, and material support: Reza Sarkhoshi Khiavi.

References

1. Nakayama DK, Ramenofsky ML, Rowe MI. Chest injuries in childhood. *Ann Surg.* 1989;**210**(6):770–5.
2. Luh SP. Review: Diagnosis and treatment of primary spontaneous pneumothorax. *J Zhejiang Univ Sci B.* 2010;**11**(10):735–44.
3. Di Bartolomeo S, Sanson G, Nardi G, Scian F, Michelutto V, Lattuada L. A population-based study on pneumothorax in severely traumatized patients. *J Trauma.* 2001;**51**(4):677–82.
4. Soldati G, Testa A, Pignataro G, Portale G, Biasucci DG, Leone A, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. *Ultrasound Med Biol.* 2006;**32**(8):1157–63.
5. Sartori S, Tombesi P, Trevisani L, Nielsen I, Tassinari D, Abbasciano V. Accuracy of transthoracic sonography in detection of pneumothorax after sonographically guided lung biopsy: prospective comparison with chest radiography. *AJR Am J Roentgenol.* 2007;**188**(1):37–41.
6. Alrajhi K, Woo MY, Vaillancourt C. Test characteristics of ultrasonography for the detection of pneumothorax: a systematic review and meta-analysis. *Chest.* 2012;**141**(3):703–8.
7. Chan SS. Emergency bedside ultrasound to detect pneumothorax. *Acad Emerg Med.* 2003;**10**(1):91–4.
8. Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med.* 2005;**12**(9):844–9.
9. Brooks A, Davies B, Smethhurst M, Connolly J. Emergency ultrasound in the acute assessment of haemothorax. *Emerg Med J.* 2004;**21**(1):44–6.
10. Nandipati KC, Allamaneni S, Kakarla R, Wong A, Richards N, Satterfield J, et al. Extended focused assessment with sonography for trauma (EFAST) in the diagnosis of pneumothorax: experience at a community based level I trauma center. *Injury.* 2011;**42**(5):511–4.
11. Ku BS, Fields JM, Carr B, Everett WW, Gracias VH, Dean AJ. Clinician-performed Beside Ultrasound for the Diagnosis of Traumatic Pneumothorax. *West J Emerg Med.* 2013;**14**(2):103–8.
12. Rowan KR, Kirkpatrick AW, Liu D, Forkheim KE, Mayo JR, Nicolaou S. Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT–initial experience. *Radiology.* 2002;**225**(1):210–4.
13. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med.* 1997;**29**(3):312–5.
14. Sisley AC, Rozycki GS, Ballard RB, Namias N, Salomone JP, Feliciano DV. Rapid detection of traumatic effusion using surgeon-performed ultrasonography. *J Trauma.* 1998;**44**(2):291–6.
15. Rothlin MA, Naf R, Amgwerd M, Candinas D, Frick T, Trentz O. Ultrasound in blunt abdominal and thoracic trauma. *J Trauma.* 1993;**34**(4):488–95.
16. Juhl JH. Disease of the pleura, mediastinum and diaphragm. In: Juhl JH editor. *Essentials of radiologic imaging..* Philadelphia: Lippincott; 1993.