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Diagnostic accuracy of ultrasound in the detection of hemothorax in comparison with Chest X-Ray in chest trauma patients with CT as the Gold Standard

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Abstract

Background: To study the diagnostic accuracy of ultrasound in the detection of hemothorax in comparison with Chest X-Ray in chest trauma patients with CT as the Gold Standard

Methods: The present study was conducted from 31th July 2018 to 30th July 2019. A total of 36 patients were enrolled in the study.

Results: The sensitivity of Chest X-Ray Supine AP view for the diagnosis of hemothorax was 62.07%, specificity was 85.71%, positive predictive value (PPV) was 94.74%, negative predictive value (NPV) was 35.29% and accuracy was 66.67%.The sensitivity of chest ultrasound for the diagnosis of hemothorax was 86.21%, specificity was 100%, positive predictive value (PPV) was 100%, negative predictive value (NPV) was 63.64% and accuracy was 88.89%.

Conclusion: Chest ultrasound can play an important role for bedside rapid and accurate diagnosis of hemothorax without interrupting the process of resuscitation and life-saving interventions and without transferring the patient to the radiology section. Ultrasound is readily available in the emergency department even at peripheral centres and chest ultrasound should be included as part of the basic survey in patients with major chest trauma which can rapidly and accurately diagnose haemothorax and other associated findings.

Keywords: Ultrasound, CT, Hemothorax

Introduction

Hemothorax is a very common finding in chest trauma patients and is a collection of blood in the pleural space, usually due to lesions of the lung parenchyma, pleura, chest wall, mediastinum, or abdomen (liver and splenic injuries with diaphragmatic rupture). Early diagnosis of hemothorax is important as excessive blood loss can lead to hypovolemic shock and collapse of the underlying lung which may lead to respiratory failure. The untreated hemothorax can also lead to empyema. Diagnosis of hemothorax can be achieved by Chest X-Ray, Computed Tomography (CT-Scan), or

Ultrasonography. Usually, when a clinician suspects a hemothorax, a Chest X-Ray is obtained. Chest radiographs are best at detecting hemothorax if obtained when patient is in upright position and in full inspiration as the radiographic appearance is dependent on gravity. Chest X-ray can diagnose only a large hemothorax however small hemothorax can be missed on Chest X-Ray especially on supine AP view. Obtaining upright inspiratory PA view in patients with multiple injuries with chest trauma is practically difficult due to conditions such as the stabilization of the spine, hemodynamic instability, immobilization in case of orthopedic injuries, continuing efforts of resuscitation or altered state of consciousness and such Chest X-Rays if done are usually suboptimal. Although CT-Scan is currently the gold standard for diagnosis of hemothorax, it is not available everywhere especially at the peripheral centers as compared to ultrasound. Also it is more time consuming which include patient's transportation to the scanner. In addition, it is costlier and high radiation exposure. Unlike radiographs or computerized tomography (CT) scans, ultrasonography can be done simultaneously along with resuscitation in trauma room to explore life-threatening injuries without any delay or even interruption in resuscitation. Ultrasound machines are also readily available even at the peripheral centres.

Material and methods

Study design: Comparative analysis of diagnostic accuracies.

Setting: Department of Radiodiagnosis, IGMC, Shimla, Himachal Pradesh, India.

Study period: 31st July 2018 to 30th July 2019

Methodology: This study was aimed to compare the diagnostic accuracy of ultrasound in comparison with Chest X-Ray for the diagnosis of hemothorax and correlation with CT Scan as the Gold Standard on patients being referred to the Department of Radiodiagnosis from various clinical departments in Emergency Section of Indira Gandhi Medical College and Hospital, Shimla.

Inclusion Criteria

1. Patients who presented with history of trauma to the chest.
2. Patients more than 10 years of age.

Exclusion Criteria

1. Patients treated with open and tube thoracostomy prior to imaging.
2. Patients who were not willing to participate in the study.
3. Pregnant patients.
4. Very sick Patients.

Results

Table 1: Demographic data of the patients (n = 36)

Age(Years)	Mean	43.56	
	Range	12-80	
Sex	Male	21	58.3%
	Female	15	41.7%
Cause of Trauma	Fall From Height	20	55.6%
	Road Traffic Accidents	16	44.4%

The age of patients in our study ranged from 12 years to 80 years. The mean age was 43.56 years. Most of the patients were in the range of 20-40 years (n=13) comprising 30.6% of total. Minimum number of patients were in the age group of <20 years (n=4).Out of the total 36 patients there were 21 male patients (58.3%) and female 15 patients (41.7%). Of the 36 patients, hemothorax was detected in 29 patients. Among the 29 patients, 20 patients had bilateral hemothorax. Final diagnosis of hemothorax were all made on CT scan.

On Chest X-Ray Supine AP view, hemothorax was detected in 18 of 29 patients. The sensitivity of Chest X-Ray Supine AP view for the diagnosis of hemothorax was 62.07%, specificity was 85.71%, positive predictive value (PPV) was 94.74%, negative predictive value (NPV) was 35.29% and accuracy was 66.67%.

Table 2: Accuracy of **Chest X-ray findings** in hemothorax, Gold Standard- CT (n=36)

Chest X-ray AP View Hemothorax	CT Scan Chest–Hemothorax				
	Disease				Total
	Present	n	Absent	n	
Positive	True Positive	a= 18	False Positive	c= 1	a+c= 19
Negative	False Negative	b= 11	True Negative	d= 6	b+d=17
Total	a+b= 29		c+d= 7		36
Statistic	Sensitivity	Specificity	PPV	NPV	Accuracy
	62.07%	85.71%	94.74%	35.29%	66.67%

Table 3: Accuracy of **Ultrasound findings** in hemothorax, Gold Standard- CT Scan (n=36)

Ultrasound Hemothorax	CT Scan Chest – Hemothorax				
	Disease				Total
	Present	n	Absent	n	
Positive	True Positive	a= 25	False Positive	c= 0	a+c= 25
Negative	False Negative	b= 4	True Negative	d=7	b+d= 11
Total	a+b= 29		c+d= 7		36
Statistic	Sensitivity	Specificity	PPV	NPV	Accuracy
	86.21%	100.00%	100.00%	63.64%	88.89%

By Chest Ultrasound, hemothorax was detected in 25 of 29 patients. The sensitivity of chest ultrasound for the diagnosis of hemothorax was 86.21%, specificity was 100%, positive predictive value (PPV) was 100%, negative predictive value (NPV) was 63.64% and accuracy was 88.89%.

Patient No 1: A 62 years old female with history of fall from height presents with chest pain.

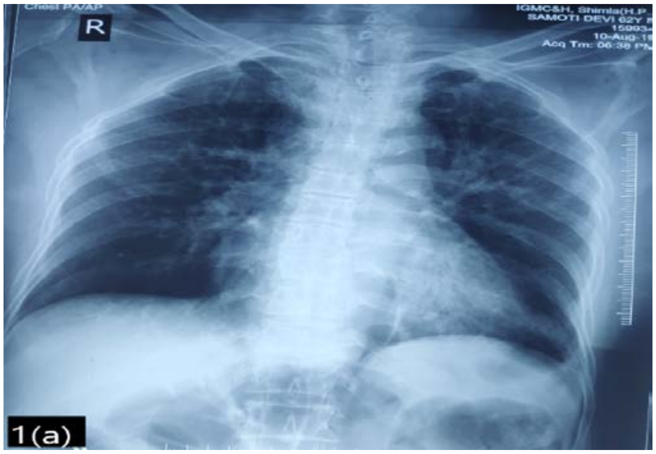


Fig. 1(a): Chest X-Ray Erect PA view of 62 years old female with history of fall showing blunting of left costophrenic angle

Fig. 1(b): USG – Minimal fluid in the Right Costo-phrenic angle

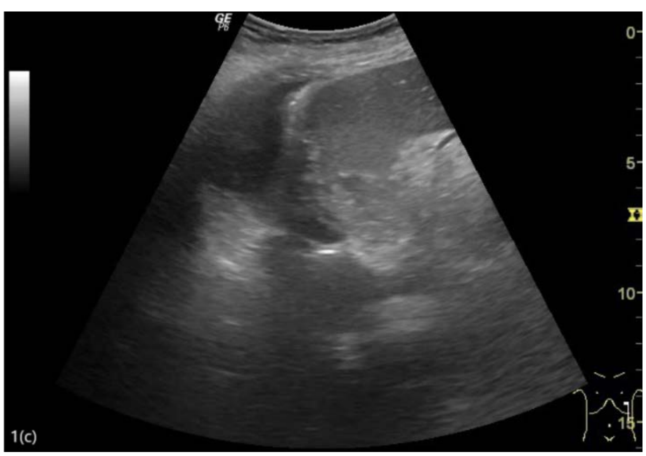


Fig. 1(c): USG- Fluid in the Left Costo-phrenic angle with internal echoes.

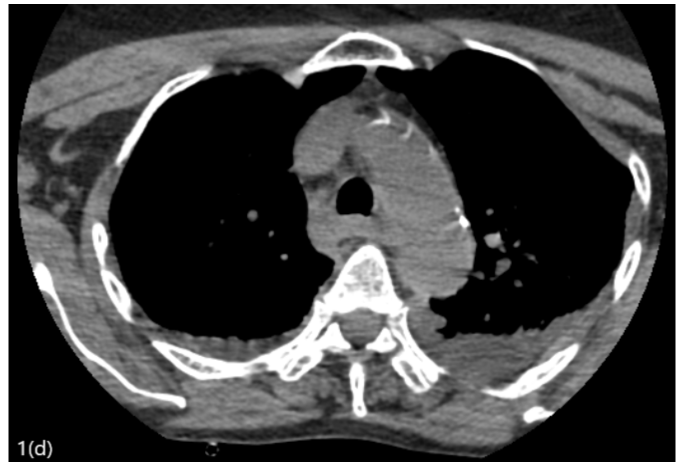


Fig. 1(d): Bilateral Pleural effusion (Left>Right) with Avg CT value of 35-45 HU – Hemothorax

Patient No 2: A 58 years old male patient with history of fall from height presents with pain in the left side of chest

Fig. 2(a): Chest X-Ray Supine AP view - Increased density of the left hemithorax with blunting of the left costo-phrenic angle.

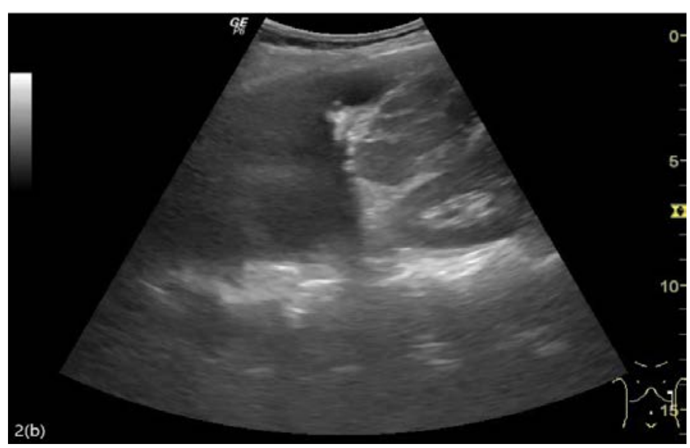


Fig. 2(b): USG showing Left sided pleural effusion with internal echoes

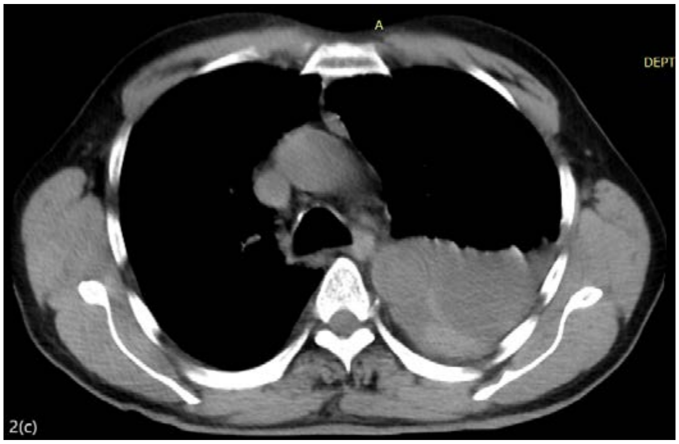
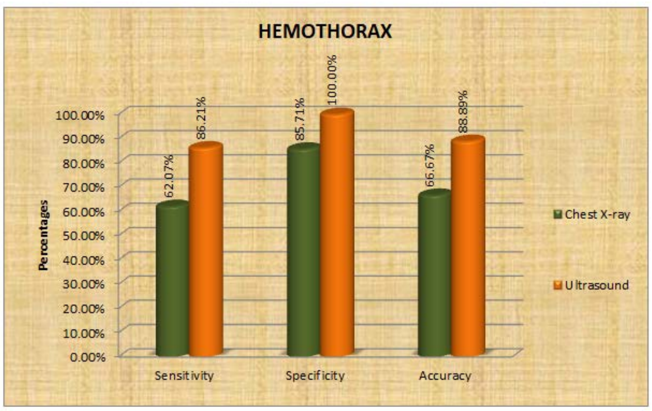


Fig. 2(c): CT Scan Chest- Fluid in the left Pleural cavity with CT value of 40-50 HU – Hemothorax; with collapsed of the underlying lung.



Discussion

Hemothorax occurs upto 50% of patients who suffer major blunt chest trauma[1,2].

On supine Chest X-Ray, unclotted blood usually settle posteriorly producing uniform increased density over the hemithorax. In the erect position however, due to gravity the unclotted blood will appear as increased density in the lower hemithorax giving a meniscus appearance. Depending on the amount of the hemothorax, there can be contralateral shift of the mediastinum. Clotted blood which is uncommon in an acute setting of trauma appear as lobulated density along the costal pleura or the diagphragmatic pleura[2].

On ultrasound, hemothorax can be identified using longitudinal scans along the posterior chest wall which is the dependent region of the chest. The fluid collection appears anechoic or hypoechoic with or without echogenic foci which is inferiorly lined by a hyperechoic line representing the diaphragm and can be visible both during inspiration and expiration.

On CT Scan, unclotted blood in the pleural space usually has a density between 30 to 45 Hounsfield unit, and clotted blood has a density between 50 to 90 Hounsfield unit [1,2].

O John Ma et al.(1997)[3] in their study of ultrasound versus chest X-Ray in the detection of hemothorax on 240 patients who sustained blunt trauma or penetrating trauma to the chest reported that both Chest X-ray AP view and chest ultrasound showed comparable sensitivity, specificity and accuracy of approximately 96%, 100% and 99% respectively in the detection of hemothorax.

A Brooks et al.(2004)[4] evaluated thoracic ultrasound for the detection of hemothorax in 61 patients with thoracic trauma. They performed thoracic ultrasound as an extension of the standard focused assessment with sonography for trauma (FAST) protocol for the detection of hemothorax. The findings were then compared against established investigations including intercostal drain, computed tomography, thoracotomy or supine chest radiography. The sensitivity of ultrasound was 92% and specificity 100% with a positive predictive value of 100% and negative predictive value 98% for the detection of hemothorax after trauma. They concluded that emergency ultrasound of the chest can rapidly and accurately diagnose hemothorax and is a valuable tool to augment the immediate clinical and radiological assessment of these patients.

Fusoon Liu et al.(2015)[5] performed a retrospective study to assess the applicability of the CT attenuation value in differentiating hemothorax from pleural effusions. They identified patients who underwent chest CT with definitive diagnoses of hemothorax, pleural effusion, and empyema. They measured the Hounsfield unit (HU) values of the pleural fluid, and those of the aortic blood. The HU value ratios of the pleural fluid over aortic blood (P/A) were also calculated. They compared the HU and P/A values between the patient groups. Receiver operating characteristic (ROC) curves were constructed to determine the validity and cut off values. They found that hemothorax had significantly higher attenuation values and P/A ratios than did pleural effusion or empyema. In differentiating hemothorax from pleural effusion, excellent accuracies were obtained with an area under the ROC curve (AUC) of 0.964 for HU values and 0.951 for P/A ratios. The optimal cut off values were 15.6 HU (sensitivity: 86.8%; specificity: 97.4%) and 30.0% (sensitivity: 94.7%; specificity: 83.3%). Also in distinguishing hemothorax from empyema, good accuracies were obtained with an AUC of 0.866 for HU values and 0.870 for P/A ratios. The optimal cut off values were 15.9 HU (sensitivity: 86.8%; specificity: 71.2%) and 56.0% (sensitivity: 76.3%; specificity: 90.4%). Their data suggested an excellent cut-off value to distinguish hemothorax from pleural effusion and hemothorax from empyema. In their study, they measured and calculated P/A values to correct the unwanted influence of anemia on blood density. However, no advantage in the P/A ratio was achieved over the HU value and measuring the attenuation value has sufficed to differentiate hemothorax from pleural effusions.

Nilam J Soni et al.(2015)[6] stated that based on its sonographic appearance, pleural effusions are categorized as simple or complex. Simple pleural effusions are anechoic, and usually transudative. Complex pleural effusions are subcategorized as homogeneously or heterogeneously echogenic, with or without septations, and are more often exudative. Effusions with heterogeneous echogenicity with swirling echoes suggest high cellular content that is often associated with malignancy. Fibrinous stranding, septations, and loculations also suggest an exudative effusion and are more readily identified and characterized on lung ultrasound than CT scan. Homogenously echogenic effusions are most often due to hemothorax or empyema. The high cell count of a hemothorax creates a layering effect in costophrenic recesses (“hematocrit sign”). Empyema develop from complex effusions that organize into collections of pus and usually have a homogeneously echogenic, speckled appearance. Sonographic evidence of septations in the presence of empyema predicts the need for intrapleural fibrinolytic therapy, longer duration of drainage, and possible surgical intervention.

Khaled Morsy Salama et al.(2017)[7] in their study on role of bedside sonography in the assessment of patients with chest trauma reported that the specificity and sensitivity of chest ultrasound in diagnosing hemothorax was 100% and 81% respectively, with Positive Predictive Value(PPV), Negative Predictive Value(NPV) and overall accuracy were 100%, 75% and 88% respectively; while supine chest X- Ray showed sensitivity and specificity were 75% and 88.9% respectively, with PPV, NPV and accuracy were 76%, 75% and 80% respectively.

A Hilendarov et al.(2018)[8] perform a study regarding the use of ultrasonography in the diagnosis, follow-up and therapy of free and encapsulated hemorrhagic collections in polytrauma patients. They used thoracic ultrasound, supine chest radiography, and CT in 107 patients (35 female and 72 male). Ultrasound findings were compared with CT findings as the reference standard for hemothorax detection. In 32(91.42%) of them a sufficient amount of liquid collections was obtained, favouring the diagnosis and planning following therapy. Only in 3(8.57%) cases of 35 patients with performed invasive manipulations they failed to obtain pleural fluid due to thickened pleura. They then concluded that ultrasound should be used as a primary method in diagnosis and monitoring of hemothorax in major trauma patients.

Thus the findings in our study is in concordance with the above mentioned studies with chest ultrasound being more sensitive, specific and accurate than Chest X-Ray in the diagnosis of hemothorax.

Ultrasound chest has shown to provide an accurate and rapid evaluation of hemothorax therefore augmenting clinical decision making. In our study, the ultrasound results were available considerably earlier than the chest radiograph. Our study demonstrated that the ultrasound examination can serve as sensitive, specific and accurate diagnostic tool in detecting traumatic hemothorax in major trauma patients as comparable to CT scan besides the advantages of decreased cost, avoidance of ionizing radiation and availability at the bedside. The speed and accuracy of ultrasound examination with the possibilities to detect smaller quantities of hemothorax than the chest radiograph may be of benefit in the diagnosis and treatment of trauma patients. Ultrasonography could also be done simultaneously along with resuscitation in trauma room to explore life-threatening injuries without any delay or even interruption in resuscitation.

Conclusion

Thoracic ultrasonography as a bedside diagnostic modality for the diagnosis of hemothorax is a better diagnostic test than clinical examination and Chest X-Ray when evaluating patients with chest trauma patients in the emergency department. US is readily available in the emergency department even at peripheral centres and Chest ultrasound should be included as part of the basic survey in patients with major chest trauma which can rapidly and accurately diagnose haemothorax and other associated findings. E-FAST which includes chest ultrasound is reliable and time saving. Chest ultrasound for the diagnosis of hemothorax can be performed simultaneously along with resuscitation in trauma room to explore life-threatening injuries without any delay. Therefore, more efforts are required to improve familiarity with thoracic ultrasound in critical care units and emergency departments.

Limitations

There are few limitations in our study. Only a small number of patients have been included in our study. It selected patients who were more severely injured than patients who may only receive a chest radiograph or an ultrasound without undergoing CT Scan which may have led to some selection bias. Also, most of the patients included in our study were very sick and hemodynamically unstable, hence examination on most of the patients had to be done hastily and in limited time. In patients with subcutaneous emphysema due to trauma caused obscuration of the ultrasound waves leading to poor acoustic window. Lastly, ultrasound is user dependent and opinions may different from one operator to another.

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