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Original Article Özgün Araştırma

EFFECTIVENESS OF ULTRASONOGRAPHY IN IMAGING ASSESSMENT OF PNEUMOTHORAX, RIB FRACTURES, AND HEMOTHORAX IN PATIENTS PRESENTING TO EMERGENCY DEPARTMENT WITH BLUNT CHEST TRAUMA

Acil Servise Künt Toraks Travması ile Başvuran Hastalarda Pnömotoraks, Kosta Kırıkları ve Hemotoraks'ın Değerlendirilmesinde Ultrasonografinin Etkinliği

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ABSTRACT

Objective: We aimed to determine the effectiveness and appropriate use of ultrasonography (USG) in the diagnosis of pneumothorax, hemothorax, and rib fractures in patients presenting to emergency department with Blunt Chest Trauma (BCT).

Material and Methods: This study was prospectively conducted on patients older than 18 years of age who presented to the Emergency Department of Ankara Training and Research Hospital. Patients with BCT who needed advanced imaging studies were first examined with bedside USG and the results were recorded. Afterwards, patients underwent postero-anterior chest X-Ray (PACXR) and thorax computerized tomography (CT). The data were then statistically analyzed.

Results: A total of 124 patients were enrolled, of which 100 (80.6%) were male. Compared with thorax CT (accepted as the gold standard test), USG had a sensitivity of 84.2%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 93.5%for pneumothorax; a sensitivity of 92.6%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 98%for hemothorax; and a sensitivity of 89.8%, a specificity of 96.9%, a positive predictive value of 96.4%, and a negative predictive value of 91.3%for rib fracture. In all groups, USG outperformed PACXR in terms of sensitivity.

Conclusion: Thorax CT is regarded as the gold standard for diagnosing pneumothorax and hemothorax. Our study suggests that, among adults with BCT in settings where thorax CT is not available or difficult-to-access, or when it is not feasible to transfer the patient from emergency department to radiology unit, bedside USG appears as an extremely valuable and highly sensitive alternative to thorax CT.

Keywords: *Ultrasonography, pneumothorax, hemothorax*

ÖZ

Amaç: Acil Servise Künt Toraks Travmaları (KTT) ile başvuran hastalarda pnömotoraks, hemotoraks ve kosta kırıklarının teşhisinde Ultrasonografi (USG)'nin etkinliğini ve Acil Servislerde bu amaçla kullanımının uygun olup olmadığını tespit etmeyi amaçladık.

Gereç ve Yöntemler: Bu çalışma Ankara Eğitim Araştırma Hastanesi Acil Servisine 15 Temmuz 2011 – 15 Ocak 2012 tarihleri arasında KTT ile başvuran 18 yaş üzeri hastalarda prospektif olarak yapıldı. KTT olup ileri görüntüleme ihtiyacı olan hastalar önce yatak başı USG ile değerlendirilerek sonuçlar kaydedildi. Daha sonra hastalara supin ön-arka akciğer grafisi (SÖAAG) ve toraks Bilgisayarlı Tomografisi (BT) çekildi. Elde edilen bulguların istatistiksel analizi yapıldı.

Bulgular: Çalışmaya 100'ü (%80.6) erkek, 24'ü (%19.4) kadın toplam 124 hasta dahil edildi. Toraks BT ile karşılaştırıldığında pnömotoraks için; USG'nin duyarlılığı %84.2, özgüllüğü %100, pozitif tahmin değeri %100, negatif tahmin değeri %93.5, hemotoraks için; USG'nin duyarlılığı %92.6, özgüllüğü %100, pozitif tahmin değeri %100, negatif tahmin değeri %98, kosta kırıkları için; USG'nin duyarlılığı %89.8, özgüllüğü %96.9, pozitif tahmin değeri %96.4, negatif tahmin değeri %91.3 idi. Tüm gruplarda USG nin duyarlılığı SÖAAG'den daha fazlaydı.

Sonuç: Çalışmamızda KTT olan erişkinlerde hasta başı yapılan USG'nin pnömotoraks ve hemotoraks tespit etmede altın standard olarak kabul edilen toraks BT'nin olmadığı, ulaşımının zor olduğu veya hastanın toraks BT'ye götürülmesinin uygun olmadığı durumlarda yüksek duyarlılığa sahip, çok değerli bir alternatif olduğunu düşünüyoruz.

Anahtar Kelimeler: *Ultrasonografi, pnömotoraks, hemotoraks*

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INTRODUCTION

Trauma is the most common cause of death in the age group of 1-44 years and the third cause of death among all age groups (1). Approximately one fourth of trauma-associated deaths are due to thoracic trauma. It is clear that appropriate and rapid diagnostic approaches and therapeutic interventions for these patients will reduce mortality and morbidity. Although chest X-Ray is used as the first diagnostic method to detect rib fractures, hemothorax, and pneumothorax in emergency departments, it has certain limitations especially for trauma patients. Such as, it could be performed only in supine position until spinal trauma is excluded in trauma patients. On the other hand in many studies, it has been shown that chest X-Ray has low sensitivity, which limited its use in thoracic trauma patients (2-4).

Thorax Computerized Tomography (CT) is considered as gold standard for the diagnosis of pneumothorax, but also hemothorax, and rib fractures, particularly for the former. However, recent studies have shown that ultrasonography (USG) may be used as an effective and alternative diagnostic modality to detect pathological conditions such as pneumothorax and pleural effusion that may occur due to thoracic injuries among emergency service patients (5,6). Additionally, its noninvasive nature and its lacking ionizing radiation, coupled with being easy-to-access and being easily performed as bedside test, increases the value of USG in trauma patients.

We aimed to determine the effectiveness and appropriate use of USG in the diagnosis of pneumothorax, hemothorax, and rib fractures among patients presenting to emergency department with Blunt Chest Trauma (BCT).

MATERIALS AND METHODS

This prospectively designed study was conducted at the Emergency Department of Ankara Training and Research Hospital. It was approved by the local ethics committee (Date: 03.08.2011; Decision No: 427/3565).

Study Design

Patients older than 18 years of age who presented to the emergency service with BCT and those were deemed to need imaging studies by an emergency physician were enrolled in this prospective study.

Indications for Inclusion in the Chest Imaging Studies

Patients who had respiratory distress, pain in inspiration, hypoxia or cyanosis, pathologic respiratory sounds, subcutaneous emphysema, tracheal deviation, neck vein distension, ecchymosis, tissue loss, deformity or sensitivity on chest examination and altered mental status were included for imaging.

Exclusion Criteria

Patients younger than 18 years, patients who had a history of pulmonary disease such as pleural adhesions, lung fibrosis, ARDS, bullous emphysema and patients in a life-threatening condition such as need for rapid operation, hemodynamic unstability were excluded.

Ultrasonography

Examination was performed before X-ray or CT, by Emergency Medicine specialist and resident both of whom were trained in performing USG. A Mindray™ DC-3 USG device with a 7L4A model superficial transducer, which was available at the emergency service, was used for pneumothorax and rib fractures, and a 7L4A model convex transducer was used for hemothorax. The USG interpretation was recorded in the patient form along with the demographics of the study population.

In USG, pneumothorax was assessed by the widely accepted criteria of the absence of pleural shift sign, comet artefact, sea-shore sign, and the presence of the lung point and stratosphere signs.

Supine AP chest X-Ray was taken with a digital Shimatzu™ GSC20025 model X-Ray device. The gold standard thorax CT was taken with a Philips™ MX 16-Slice device. Thorax CT slides were assessed by an experienced radiologist who was unaware of the patients' emergency department presentations and chest USG results. The radiologist's interpretation was considered as the gold standard test results for the diagnosis of BCT pathologies of the chest.

Statistical Analysis

Descriptive statistics included frequency, mean, standard deviation, median, and minimum-maximum. The comparison of categoric variables was performed with Fisher's exact test and Pearson chi-square test. Performance analysis of the diagnostic tests included sensitivity, specificity, positive predictive value, negative predictive value, and AUC (Area Under Curve). A *p* value of less than 0.05 was considered statistically significant. All analyses were done with the SPSS 18.0 software package.

RESULTS

During the study period, a total of 124 patients were enrolled. The mean age of the study population was 41.48±17.18 years. Hundred patients (80.6%) were male and 24 (19.4%) were female. Men had a significantly greater presentation rate than women (p<0.01).

All patients underwent chest X-Ray, thorax CT, and chest USG. The mean time from physical examination to USG was 4.52±3.62 minutes. The corresponding figures for AP chest X-Ray and CT were 14.38±4.2 minutes and 57.89±28.12 minutes, respectively. Excluding USG performed to detect rib fractures, the mean duration of chest USG examination was 3.41±0.93 minutes. Table 1 presents mean times to radiological imaging studies.

Considering thorax CT as the gold standard, 38 (30.65%) patients were found to have pneumothorax, 27 (30.65%) hemothorax, and 59 (47.58%) rib fractures. Of the 38 pneumothorax cases, 32 (84.2%) were diagnosed by chest USG and 22 (57.8%) by supine AP chest X-Ray.

For pneumothorax, chest USG had a sensitivity of 84.2%, a specificity of 100%, a negative predictive value of 93.5%, and a positive predictive value of 100%. The corresponding figures for supine AP chest X-Ray were 57.9%, 100%, 84.31%, and 100%, respectively (Table 2).

Considering thorax CT as the gold standard, USG had a better performance than direct radiography for detecting pneumothorax (p=0.011) (Table 3).

The rates of the signs of pneumothorax on chest USG, namely the absence of pleural shift sign, sea-shore sign, and comet aretefact, and the presence of lung point sign and stratosphere sign, are given in Table 4.

Of the 27 hemothorax cases by diagnosed thorax CT, 25 were detected by USG and 7 by supine AP chest C-Ray. Chest USG had a sensitivity of 92.6%, a specificity of 100%, a negative predictive value of 98%, and a positive predictive value of 100%for detecting hemothorax, while supine AP chest X-Ray had a sensitivity of 25.9%, a specificity of 100%, a negative predictive value of 82.9%, and a positive predictive value of 100%for the same condition (Table 5).

Considering thorax CT the gold standard, USG had a better diagnostic performance than AP chest X-Ray for detection of hemothorax (p<0.001).

Thorax CT detected rib fractures in 59 (47.58%) patients. A total of 62 (50%) rib fractures were detected, of which two fractures could not be detected by thorax CT but were detected by USG and one fracture could not be detected by thorax CT and detected by USG (2.4%).

Table 1. Time to radiological imaging studies (in minutes)

	N	Min	Max	Med	Mean	SD
Time to USG examination	124	2	9	4	4.52	3.62
USG examination time	124	2	7	3	3.41	0.93
Time to AP chest X-Ray	124	7	25	14	14.38	4.28
Time to CT examination	124	18	180	50	57.89	28.12

Table 2. Performance of chest USG and PA chest X-Ray relative to thorax CT

		Pneumothorax in thorax CT				**Total**	
		No		Yes			
		n	%	n	%	n	%
Pneumothorax in USG	No	86	100	6	15.78	92	74.2
	Yes	0	0	32	84.22	32	25.8
	Total	86	100	38	100	124	100
Pneumothorax in AP chest X-Ray	No	86	100	16	42.2	102	82.25
	Yes	0	0	22	57.8	22	17.75
	Total	86	100	38	100	124	100

Table 3. Comparison of the performances of USG and radiography for detection of pneumothorax

	AUC	95% CI	p
Pneumothorax in radiography	0.789	0.707-0.858	0.011
Pneumothorax in USG	0.921	0.859-0.962	

Among 59 rib fractures diagnosed with the gold standard modalities in 124 patients, 53 (89.83%) were diagnosed with chest USG and 32 (54.2%) with supine AP chest X-Ray. Chest USG had a sensitivity of 89.8%, a specificity of 96.9%, a negative predictive value of 91.3%, and a positive predictive value of 96.4%for detection of rib fractures. The corresponding figures for AP chest X-Ray were 54.2%, 98.5%, 70.3%, and 98.5%. When thorax CT was regarded as the gold standard, USG (AUC=0.934) had a superior performance than plain radiography (AUC=0.763) in detecting rib fractures (p<0.001).

Table 4. Comparison of the absence of the pleural shift sign and comet artefact and the presence of the lung point and stratosphere signs in chest USG with thorax CT

		Pneumothorax in thorax CT				**Total**	
		No		Yes			
		n	%	n	%	n	%
Pleural shift	No	86	100	6	15.78	92	74.2
	Yes	0	0	32	84.22	32	25.8
	Total	86	100	38	100	124	100
Comet artefact	No	86	100	6	15.78	92	74.2
	Yes	0	0	32	84.22	32	25.8
	Total	86	100	38	100	124	100
Stratosphere sign	No	86	100	6	15.78	92	74.2
	Yes	0	0	32	84.22	32	25.8
	Total	86	100	38	100	124	100
Absence of seashore sign	No	86	100	6	15.78	92	74.2
	Yes	0	0	32	84.22	32	25.8
	Total	86	100	38	100	124	100
Lung point	No	86	100	10	26.3	96	77.41
	Yes	0	100	28	73.7	28	22.6
	Total	86	100	38	100	124	100

Table 5. Assessment of chest USG and AP chest X-Ray relative to thorax CT in detection of hemothorax

		Hemothorax in thorax CT				**Total**	
		No		Yes			
		n	%	n	%	n	%
Hemothorax in chest USG	No	97	100	2	7.4	99	79.84
	Yes	0	0	25	92.6	25	20.16
Total		97	100	27	100	124	100
Hemothorax in Supine AP chest X-Ray	No	97	100	20	74.1	117	94.4
	Yes	0	0	7	25.9	7	5.6
Total		97	100	27	100	124	100

DISCUSSION

Thoracic trauma is the most common among men and under the age of 50 years (7). Studies executed in Turkey have reported an age range of 38-43 years for thoracic trauma victims (8-10). In a study of 109 chest trauma victims, 63%of whom were male, Soldati et al. reported a mean age of 41.4±20 years (11). Similarly, in our study the mean age was 41.48±17.18 years. The reason for thoracic trauma to be commonly seen in men and in the first four decades of life is that men in this age group more commonly work in jobs risking accidents, and that men more actively take part in social and commercial life.

All patients in our study group underwent chest USG, AP chest X-Ray, and thorax CT. Zhang et al reported a time to chest USG of 2.3±2.9 minutes, 12.4±6.7 minutes for AP chest X-Ray, and 16.3±7.8 minutes for chest CT (12). Time to USG and AP chest X-Ray examinations in our study are in agreement with the literature. However, the average time to thorax CT was 57.89±28.12 minutes (18-180 minutes), which was longer than what has been previously reported. This may be due to several reasons like our emergency service's crowdedness and availability of only a single CT unit. Therefore, we suggest that the CT unit was occupied, and the radiologist was busy when a CT was requested.

Blaivas et al., in a study of 176 patients with BCT, compared USG and AP chest X-Ray by taking thorax CT as gold standard. They found USG to be 98.1%sensitive, 99.2%specific, and it had a positive predictive value of 98.1%and a negative predictive value of 99.2%. AP chest X-Ray had a sensitivity of 75.5%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 90.4% (13). Zhang et al. studied 135 multitrauma patients and detected pneumothorax in 86.2%of 29 (21.5%) patients by using USG. They reported false negative cases in 4 patients and false positive cases in 3 patients. They reported a sensitivity of 86.2%, a specificity of 97.2%, a positive predictive value of 89.3%, and a negative predictive value of 96.3%for USG in diagnosing pneumothorax. They also reported that AP chest X-Ray had a sensitivity of 27.6%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 83.5% (12). In a 109 patient study of thoracic and multiorgan trauma, Soldati et al identified 23 (92%) of 25 patients with pneumothorax. They detected two false negatives and one false positive. AP chest X-Ray could detect pneumothorax in 13 (52%) patients. They reported a sensitivity of 92%, a specificity of 99.4%, a positive predictive value of 95.8%, and a negative predictive value of 98.9%for USG to detect pneumothorax and a sensitivity of 52%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 94.1%for AP chest X-Ray for the same condition (11). A meta analysis performed by Stauba et al. revealed that USG had a sensitivity of 0.81 (95%CI, 0.71-0.88) and a specificity of 0.98 (95%CI, 0.97-0.99) for detection of pneumothorax (14). Similar results have been reported in several other studies in the literature (11,15). The sensitivity, specificity, and negative and positive predictive values of chest USG and AP chest X-Ray for detecting pneumothorax were in agreement with those reported in the previous studies. This study suggests us that USG has a high sensitivity and specificity for detection of pneumothorax and can be used as an alternative to thorax CT for the diagnosis of pneumothorax among patients with BCT.

Many studies performed to date have reported that the absence of pleural shift and comet artefacts are diagnostic of pneumothorax (14,16,17). In a meta analysis performed by Stauba et al comprising 19 studies, the absence of pleural shift and comet signs were accepted as diagnostic for pneumothorax in 13 studies that had a combined sensitivity of 0.81 (0.71-0.88) and a combined specificity of 0.98 (0.97-0.99). A study that investigated the lung point sign found a sensitivity of 0.73 (0.56-0.86) and a specificity of 1 (0.92-1) (14).

We investigated the diagnostic accuracy of the sea-shore sign, stratosphere sign, and lung point sign in addition to pleural shift and comet signs. The absence of the sea-shore sign and the presence of the stratosphere sign both had equal sensitivity, specificity, positive and negative predictive values as those for the pleural shift sign, which was consistent with literature reports. Based on these findings, we suggest that sea-shore sign and stratosphere signs could be used as good alternatives to the absence of pleural shift and comet signs in the diagnosis of pneumothorax.

Lung point sign had a sensitivity of 0.73 and a specificity of 1 in a report by Mümtaz et al. and a sensitivity of 66%and a specificity of 100%in another report by Lichtenstein et al (17,18). In agreement with the literature reports, our study showed a lower sensitivity for pneumothorax compared to other signs defined for the latter. We consider that a low sensitivity results from the absence of the lung point sign in near-total pneumothoraces, but as it has a specificity of nearly 100%, it almost definitely confirms the diagnosis of pneumothorax when seen, and thus it may be of use in equivocal cases.

Brooks et al. reported that USG had a sensitivity of 92%, specificity of 100%, negative predictive value of 98%, and positivite predictive value of 100%when compared with the gold standard CT (19). In a meta analysis Stauba et al. reported that USG had a sensitivity of 0.60 (95%CI, 0.31-0.86) and a specificity of 0.98 (95%CI, 0.94-0.99) (14). In another study USG had a sensitivity of 96.2%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 99.5% (20). These findings were consistent with our study results. Sisley et al. found that chest X-Ray had a sensitivity of 92.5%, a specificity of 99.7%for detecting trauma-induced hemothorax (21). In our study, AP chest X-Ray had a considerably lower sensitivity than those reported previously in the literature. We believe that this results from the fact that chest X-Rays were all taken with the patients in the supine position (at least 175 ml fluid is required to visualize hemothorax). The amount of hemothorax of the majority of patients was below 175 ml. In that study, USG examination time was shorter than that needed for supine chest X-Ray, and USG could detect trace amount of pleural fluid.

Rib fractures are one of the most common pathological conditions associated with BCT. Kara et al. reported that USG detected rib fractures in about 40%of patients with minor blunt chest trauma and without any rib fracture identifiable by plain radiograms (22). Similarly, in a prospective study on 14 patients suspected of having rib fractures, Hurley et al. reported that USG was marginally more sensitive than plain X-Ray for detecting rib fractures (23). Performance of USG for detection of rib fractures in our study was similar to those in other studies. Despite being more sensitive than AP chest X-Ray in detecting rib fractures, we consider chest USG being not very useful in the emergency department as it takes a long time for examination and the fractures in the retroscapular region cannot be visualized. But it may still be used in equivocal cases in the similar setting.

There is a limitation of our study. No standardization has been done between emergency medical professionals and assistants performing ultrasound.

In conclusion, we determined that bedside USG has acceptable sensitivity and high specificity rates than AP chest X-Ray taken in supine position for detection of rib fractures, pneumothorax, and hemothorax among adult blunt chest trauma cases. We recommend the use of transthoracic USG in managing chest trauma patients as part of the primary survey performed on all chest and multiple trauma patients in the emergency department.

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