Original Article

Diagnostic validity of ultrasonography in evaluation of pulmonary thromboembolism

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Abstract

Background: Diagnosis of pulmonary embolism (PE) remains difficult due to its nonspecific symptoms and signs. Therefore, many patients die undiagnosed or untreated. We decided to study the sensitivity, specificity, and accuracy of ultrasonography in the diagnosis of pulmonary thromboembolism.

Materials and Methods: In this prospective study, 77 patients with clinically suspected PE in the emergency department of Isfahan Al-Zahra Hospital were enrolled from September 2011 to September 2012. At first, they were evaluated by thoracic ultrasonography (TUS) and then divided into four groups based on their TUS findings. Multi-slice computed tomography (MSCT) was the reference method in this study performed within 24 h from admission. MSCT scans were interpreted by a radiologist who was unaware of the TUS results. Sensitivity, specificity, positive predictive value (PPV), and negative predictive values (NPVs) of thoracic ultrasonography were determined.

Results: PE diagnosis was confirmed by MSCT in 25 patients and 54 hypoechoic lesions were detected by TUS with the average size of 16.4 mm × 11.1 mm. In our study, sensitivity, specificity, PPV, NPV, and accuracy of TUS for PE diagnosis were 84%, 94.2%, 87.5%, and 92.5%, respectively.

Conclusion: TUS is an inexpensive, safe and easily available method for timely diagnosis and treatment of PE in emergency department and its NPV is high for cases with low scores for Wells criteria who had a normal or possible TUS findings. It is also specific in the diagnosis of PE in cases with high scores Wells criteria who have confirmed or probable TUS findings.

Key Words: Pulmonary embolism, thoracic, ultrasonography

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INTRODUCTION

Diagnosis of pulmonary embolism (PE) remains difficult due to its nonspecific symptoms and signs. Therefore, many patients die undiagnosed or untreated.[1-5] The prevalence of PE in the United States is about 23–69 ones per 100,000 and its mortality rate is 10 cases per 100,000 yearly.[1,2,5,6]

From diagnostic methods, ventilation and perfusion scan is not sufficient for the diagnosis of PE[1,7,8] and conventional computed tomography (CT) scan has limitations in the assessment of subsegmental arteries as well.[1,2,4,9]

Nowadays, multi-slice computed tomography (MSCT) scan helps physicians to diagnose segmental and subsegmental PE better than the past.[1,10] MSCT,

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however, not widely available in lots of hospitals[1,4] and there are reports about its carcinogenic effects, too.[2,11] Moreover, it is not suitable for patients with unstable vital signs.[2]

Results of PE by sonography were described 30 years ago in different studies.[1,4,12-15]

The role of sonography in chest evaluation has traditionally been limited to the pleural effusion and to guide thoracocentesis. However, in recent years it is considered as a valuable tool for diagnosis of lung, pleura, and heart disease especially in an emergency condition. Although, this method due to its good performance in the diagnosis of PE is highly recommended by emergency medicine specialists, but studies in this field are limited.[13-18]

Compared with CT, ultrasonography is a noninvasive tool that does not expose the patients to radiation and contrast agents.[19] Ultrasonography is a portable device which is applicable for all patients regardless to their age and conditions such as pregnancy, renal insufficiency, hemodynamic instability, or allergy to contrast.[19]

Considering the advantages and capabilities of ultrasound in the evaluation of sub pleural lung lesions in PE as well as its lower rate of mortality and morbidity,[13] this study designed to evaluate the sensitivity and specificity of ultrasonography for diagnosis of PE.

MATERIALS AND METHODS

Study design and participants

This study designed as a prospective investigation. In this study, patients aged 16–90 years with clinically suspected PE in the emergency department of Isfahan Al-Zahra Hospital, affiliated to Isfahan University of Medical Sciences (IUMS) were enrolled, from September 2011 to September 2012.

The protocol of the study was approved by regional ethics committee of IUMS.

Patients with the clinical signs, symptoms and risk factors for PE who had moderate to high probability Wells scoring system (>6 points: High risk; 2–6 points: Moderate risk; <2 points: Low risk) were included.[20] Overweight and pregnant patients were excluded from the study due to inability to obtain MSCT scan. Written informed consent was obtained from selected patients.

All selected patients had acute onset of typical symptoms of PE, including dyspnea pleuritic, chest pain, hemoptysis, tachypnea, and vertigo or syncope. They underwent thoracic ultrasonography (TUS) performed by an expert emergency medicine resident. The patient also underwent MSCT scan within the 24 h of admission. The findings of TUS were compared with MSCT scan (reference method) and sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) and its accuracy was measured.

Procedures and variables assessments

Ultrasonography was performed using real-time, wide-angle phased-array system (Akola SSD-2000; Aloka Co Ltd., Tokyo, Japan) by a trained emergency medicine resident using 3.5 and 7 MHz probes in the sitting, lateral or supine positions. The presence of typical triangular or round hypoechoic pleural-based lesion which are often wedge-shaped and move with respiration[1,15] [Figure 1] and pleural effusion (as an indirect sign) were considered as signs of PE.

According to ultrasonography results, the diagnosis of pulmonary thromboembolism (PTE) considered as confirmed if the included patients had at least two typical pleural triangular or round shaped lesions.

Cases with pleural effusion that had only one typical lesion considered as probable.

Those with the presence of a pleural lesion smaller than 5 mm in diameter or cases who had just pleural effusion on the whole considered as possible and lastly patients who had not meet above criteria categorized as a normal group.

The number, shape, size, and location of the lesions were recorded.

The authors compared the above ultrasonography findings with the results of 64 MSCT scan as a reference method using a multi-detector CT scanner (LightSpeed

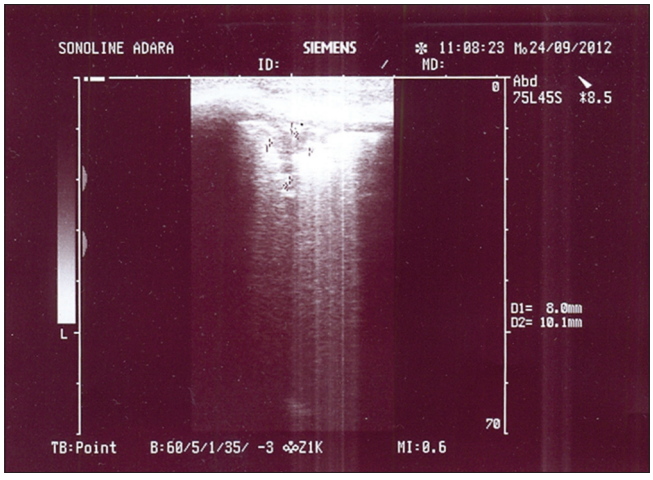

Figure 1: Wedge-shaped lesion

VCT 64, GE Healthcare, Salt Lake City, Utah, USA). Scan parameters were: Collimation 64 mm × 0.625 mm; slice thickness 5 mm; pitch 1.375; table speed/gantry rotation 55 mm; kV 140; and mA 240.

All MSCT scans interpreted by a radiologist blinded to the ultrasonography findings.

Statistical analysis

Data were processed by SPSS statistical software program version 20 (SPSS Inc., Chicago, IL, USA.) and Student's *t*-test and Chi-square test and Chi-square test for comparing quantitative and qualitative variables, respectively. $P < 0.05$ considered statistically significant. Analyses for sensitivity, specificity, NPV, PPVs, and accuracy were made using cross-tables in SPSS.

RESULTS

In this study, 77 patients (31 [40.3%] males and 46 [59.7%] female) with a mean age of 52.8 ± 20.24 years were studied.

According to the TUS results, diagnosis of PE was confirmed, probable, possible, and normal in 16 (20.8%), 8 (10.4%), 28 (36.4%), and 25 (32.5%) of studied population, respectively. The final diagnosis of PE (cases with confirmed and probable PE) was confirmed by TUS in 24 (31.2%) of patients.

The final diagnosis of PE was confirmed by MSCT in 25 (32.5%) patients. Details of the two diagnostic methods for diagnosis of PE are presented in [Table 1]. The sensitivity, specificity, PPV, NPV, and accuracy of TUS for diagnosis of PE in comparison with MSCT, the reference method were 84%, 94.2%, 87.5%, 92.5%, and 91%, respectively.

Characteristic of all studied population and those with and without PE are presented in [Table 2].

According to calculated Wells score no one in the PE-positive group had scores <2 (low risk). Those in the PE-positive group had significantly higher Wells score ($P = 0.001$) [Figure 2].

In patients with positive TUS findings based on confirmed and possible criterion as mentioned above that had high-risk Wells criteria, TUS was highly specific (98%) for diagnosis of PTE. On the other hand, NPV for TUS in the evaluation of PE in patients with negative TUS findings (possible and normal criterion as mentioned above) and those who had low-risk Wells criteria was 100%.

A total of 54 hypoechoic lesions were detected in TUS with the mean of 2.16 (range of 1–8 lesions) per patient with the average size of 16.4 mm × 11.1 mm (range: 3.2–22.2 mm × 4.8–32.3 mm).

The number of right and left side hemithorax lesions were 34 (63%) and 20 (37%), respectively. Most lesions were wedge-shaped ($n = 30$, 55%) and located in the posterior basal lung regions ($n = 37$, 68.5%). 70% of patients who had positive ultrasonographic findings for PTE had some kind of pleural effusion.

Table 1: Diagnostic classification of PE according to TUS and MSCT

	Diagnosis of PE by MSCT (%)		Total
	PE positive	PE negative	
Diagnostic classification of TUS for PE			
Confirmed	15 (93.75)	1 (6.25)	16
Probable	6 (75)	2 (25)	8
Possible	3 (10.72)	25 (89.28)	28
Normal	1 (4)	24 (96)	25
Total	25	52	

PE: Pulmonary embolism, TUS: Thoracic ultrasonography, MSCT: Multi-slice computed tomography

Table 2: Characteristic of all studied population and those with and without PE

Variable	All studied patients (*n*=77)	Patients with PE (*n*=25)	Patients without PE (*n*=52)	*P*
Age (years)*	52.8±20.24	57.2±19.73	50.8±20.34	0.19
Gender[a]				
Male	31 (40.3)	13 (52)	18 (34.6)	0.11
Female	46 (59.7)	12 (48)	34 (65.4)	
Symptoms[a]				
Dyspnea	64 (83.1)	21 (84)	43 (82.7)	0.58
Pleuretic pain	25 (32.5)	9 (36)	16 (30.8)	0.41
Hemoptysis	9 (11.7)	3 (12)	6 (11.50	0.61
Palpitation	11 (14.3)	5 (20)	6 (11.5)	0.25
Cough	24 (31.2)	8 (32)	16 (30.8)	0.55
Risk factors				
Smoking	15 (19.5)	5 (20)	10 (19.2)	0.58
Thromboembolism	12 (15.6)	3 (12)	9 (17.3)	0.40
Cancer	13 (16.9)	4 (16)	9 (17.3)	0.58
Trauma	6 (7.8)	5 (20)	1 (1.9)	0.01
Surgery	16 (20.8)	6 (24)	10 (19.2)	0.42
Immobility	18 (23.4)	11 (44)	7 (13.5)	0.004
Physical exam				
Tachypnea	40 (51.9)	16 (64)	24 (46.2)	0.11
Tachycardia	36 (46.8)	14 (56)	22 (42.3)	0.18
ECG finding				
Sinustachycardia	35 (46.1)	13 (54.2)	22 (42.3)	0.18

*Mean (SD), [a]*n* (%). SD: Standard deviation, PE: Pulmonary embolism, ECG: Electrocardiogram

DISCUSSION

In this study, we investigated the utility of TUS in the diagnosis of PE and the sensitivity and specificity

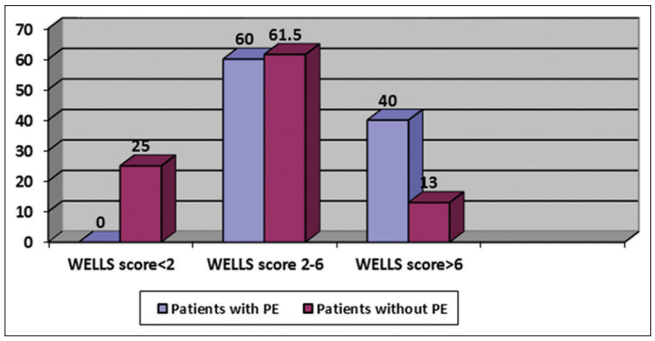

Figure 2: Frequency of patients with and without pulmonary embolism according to Wells score classification

of this method in the diagnosis of PE. The findings indicated that though the method has high sensitivity, specificity, and accuracy but its specificity is more prominent especially in accordance with low Wells score.

As mentioned diagnosis of PE considered, as a challenging issue, especially in emergency medicine. Although, many diagnostic methods have been introduced in this regard but all of them have their limitations. Even MSCT scan which recently recognized as a sensitive method for diagnosis of PE specially segmental and subsegmental emboli, is a time consuming method, not widely available and could not use for all group of patients specially those admitted in emergency department.[1-4]

Among the diagnostic methods, TUS had some advantages which made it more appropriate for emergency and bedside diagnosis of PE such as safety, availability, low cost, and the diagnosis of other lesions including consolidation, atelectasis, and local pleural effusion.[1-18] So, considering the fact that timely diagnosis and treatment of PE is important and potentially life-saving, we design this investigation. Many studies in different regions have evaluated the validity of TUS in the diagnosis of PE. However, there were few studies comparing the results of TUS with MSCT.[5,21]

The sensitivity, specificity, PPV, NPV, and accuracy of TUS for diagnosis of PE in comparison with MSCT, the reference method, in the present study were 84%, 94.2%, 87.5%, 92.5%, and 91%, respectively.

Pfeil *et al*. in Germany, for the first time have compared the results of TUS with MSCT in the detection of PE among 33 patients with symptoms of suspected PE. The design of our study was similar to theirs. They reported 70% sensitivity and 69.6% specificity for TUS in this regard. The NPV and PPV were 84.25% and 50%, respectively.[5]

In a recent study in Turkey, Comert *et al*. have compared the findings of TUS with computed tomography pulmonary angiography, the first line imaging method for diagnosis of patients with suspected clinically PE. They showed that the sensitivity, specificity, NPV, PPV, and accuracy of TUS in clinically suspicious PE cases were 90%, 60%, 80%, 77.1%, and 78%, respectively.[21]

In the study of thorax ultrasound (TUS) in the diagnosis of PE thoracic ultrasound for diagnosing PE, the reported sensitivity, specificity, PPV, NPV, and accuracy were74%, 95%, 95%, 75%, 84%, respectively.[15]

Though comparing our results with mentioned studies is not accurate enough due to factors such as patients settings and subjectivity and operator dependency of ultrasonography, but it seems that in our study all measured parameters were higher especially specificity of the method.

The majority of lesions were wedge-shaped in our study. This finding was similar to that reported in previous studies.[1,4,5,15] The anatomy of the lung could explain the finding. Wedge-shaped opacities are representative of pulmonary ischemia which characterized, as areas of lung filled with red blood cells, with or without tissue necrosis.[1,21]

Regarding the localization of PE, the most detected lesions in this study were located in the posterior basal lung regions. This finding was similar to previous studies.[1,5,15,21] It is well documented that TUS mostly detected lesions located in lower lobes due to the appropriate visibility of TUS in these regions.[21]

In current study, TUS revealed 54 hypoechoic lesions among a total number of 24 PE cases with the mean of 2.16 (range of 1–8 lesions) per patient. The mean of the lesions size was 16.4 mm × 11.1 mm (range: 3.2–22.2 mm × 4.8–32.3 mm).

The size of lesions in the study of Comert *et al*. was 22.9 × 31.2 (range: 5–49 mm × 11–60 mm).[21] The mean of lesions size was reported to be 15.5 mm × 12.4 mm by Mathis *et al*.[15]

The limitation of the current study was a small sample size of patients. Another limitation which could be considered as the consequence of small sample size as well as incomplete data was an evaluation of risk stratification for the occurrence of PE. Another suggested limitation was the nonsimultaneously use of TUS and MSCT. Thromboembolism is a dynamic process associated not only with recurrent embolization

but also with spontaneous lysis. Evidences indicated that intrinsic lysis could destroy previous thrombus. So, in these cases TUS could detect PE whereas CT could not verify it, resulting in a false-positive TUS report.

However, there are some limitations related to TUS including the inability of the technique in detecting central pulmonary artery thrombosis and invisibility of some parts of lungs by TUS due to bony structure coverage of lungs.

CONCLUSION

The results of current study indicated that TUS with its reported high rate of sensitivity, specificity and accuracy in addition to having some characteristics including simplicity, noninvasiveness, availability and low complications, could be used as an appropriate and safe alternative to MSCT for diagnosis of PE at bedside and emergency settings and facilitating the treatment of critically ill patients. The results also indicated that though false negative ratio in the patients with high scores of Wells criteria who had confirmed or probable TUS findings is high but it is more specific. TUS can rule out PE in patients with negative TUS findings who have low-risk Wells criteria.

For evaluating the use of this technique as a screening tool for diagnosis of PE in emergency settings, further multicentral well-designed studies with larger sample size are needed.

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Conflicts of interest
There are no conflicts of interest.

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