ARTICLE ORIGINAL

Precision of pleural puncture sites using thoracic ultrasound

Apport de l'échographie thoracique dans le choix du site de la ponction pleurale

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Abstract

Introduction: Lung ultrasound (LUS) has been recommended by the British Thoracic Society as a standard of care before performing pleural procedures since 2010. Indeed, the choice of the puncture site based only on physical examination and chest x-ray can lead to complications. The aim of this study was to compare the accuracy of pleural puncture sites using LUS as opposed to clinical examination.

Methods: An evaluative prospective study including 43 patients hospitalized in the pneumology department at the Military Hospital of Tunis was conducted between January and November 2021.Pleural puncture sites were proposed by two groups involving 'senior' and 'junior' physicians, classified according to their experience and grades, based on the clinical examination and the chest x-ray findings. The accuracy of the proposed sites was then verified by an ultrasound-qualified "expert" using LUS.

Results. The mean age was 60 ± 17 years. LUS revealed the presence of pleural effusion in 88% of the cases (n=38). Differential diagnosis was therefore excluded in 12% of the cases (n=5), including pleural thickening (5%, n=2) and atelectasis (7%, n=3). Compared to LUS, clinical examination and chest x-ray had lower sensitivities, estimated at 74% and 83%, respectively. The clinical identification error rate was significantly higher in junior (77%) compared to senior physicians (49%) (p<0.05). LUS prevented possible accidental organ puncture in 36% of the cases (n=31). The risk factors associated with inaccurate clinical site selection included right-sided effusion and minimal pleural effusion on chest radiography, with an estimated relative risk (RR) of 1.44 [CI95%:0.56-3.72] and 1.82 [CI95%:0.52-6.40], respectively. The experience of the senior physicians influenced the choice of the clinical sites with moderate agreement (Kappa index: 0.4-0.6).**Conclusion.** Compared to the ACPA- group, the ACPA+ one had more lung-hyperinflation and OVI, and comparative percentages of RVI, MVI, and NSVI**.**

Conclusion: LUS significantly improves the accuracy of pleural puncture sites, thus minimizing the risk of complications regardless of the operator's level of clinical experience.

Key words: Pleural effusion, Ultrasonography, Thoracentesis.

Résumé

Introduction : Depuis 2010, la British Thoracic Society recommande le guidage échographique des procédures pleurales afin d'améliorer leur sécurité et leur rentabilité diagnostique. Le but de notre étude était d'évaluer l'apport de l'échographie thoracique dans le choix du site de la ponction pleurale.

Méthodes : Il s'agissait d'une étude monocentrique transversale évaluative faisant inclure 43 patients hospitalisés au service de pneumologie de l'hôpital militaire, entre Janvier et Novembre 2021, pour exploration d'une opacité d'allure pleurale sur la radiographie du thorax. Deux groupes de médecins 'seniors' et ' juniors', qualifiés selon leur expérience et leur grade, ont proposé des sites de ponction pleurale en se basant sur l'examen clinique et les données de la radiographie thoracique puis un 'Expert ' qualifié en échographie a vérifié la précision de ces sites.

Résultats : La moyenne d'âge était de 60± 17 ans. L'échographie thoracique a confirmé la présence d'un épanchement pleural dans 38 cas (88%). Cette technique a ainsi permis d'éliminer dans 12% des cas (n=5) un diagnostic différentiel : une pachypleurite (n=2, 5%) et une atélectasie (n=3, 7%). Comparées à l'échographie thoracique, les sensibilités du repérage clinique et de la radiographie thoracique dans le diagnostic positif de pleurésie étaient estimées, respectivement, à 74% et 83%. Le taux d'erreur du repérage clinique était significativement plus élevé chez les juniors estimé à 77% contre 49% chez les seniors (p<0,05). Trente et un sites (36%) correspondaient à des sites dangereux. Les facteurs de risque d'erreurs révélés étaient : le côté droit et l'aspect d'un épanchement de faible abondance à la radiographie thoracique avec un risque **r**elatif estimé, respectivement, à 1,44 [IC95% : 0,56-3,72] et 1,82 [IC95% : 0,52-6,40]. L'expérience des seniors avait un impact sur le choix des repères cliniques, avec une concordance modérée (Kappa : 0,4- 0,6).

Conclusion : L'échographie thoracique améliore significativement la rentabilité diagnostique des ponctions pleurales et diminue le risque de complications indépendamment du niveau d'expérience clinique de l'opérateur.

Mots clés : Pleurésie, Ultrasonographie, Ponction pleurale.

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INTRODUCTION

The evaluation of the lung on ultrasound has constantly been considered inconsistent(1). According to the laws of physics, sonographic assessment of the chest is limited by artifacts and significant changes in impedance(2). Many inflammatory, traumatic, or tumor diseases significantly improve the acoustic transmission and allow an adequate ultrasound evaluation (1).

In 1992, Lichtenstein, a medical intensivist, defined critical ultrasound, including lung ultrasound (LUS), as a whole body approach to the critically ill(3). The advent of LUS has revolutionized the care for patients in intensive care units and emergency departments. It has contributed to the emergence of algorithms and has positively impacted patients' care (3).Medical ultrasound has considerable advantages, including bedside availability, ease of use, and reproducibility(4). Furthermore, it is non-invasive, and it helps to avoid the side effects related to radiation. It was not until 2010, that the British Thoracic Society recommended the use of LUS as a standard of care before performing pleural procedures (5). Thus, the contribution and widespread use of LUS as a point-of-care test have transformed the management of pleural diseases (6).

This prospective study was conducted to assess the role of LUS in the choice of pleural puncture sites.

POPULATION AND METHODS

Study design

It was a monocentric, prospective, and evaluative study conducted between January and November 2021. It was carried out in the pneumology department at the Military Hospital in Tunis. This study was performed during the coronavirus disease 2019 (COVID-19) pandemic. All the included patients tested negative using real-time polymerase chain reaction. The physicians applied the necessary precautions to avoid contamination in accordance with the recommendations (7).

The participating physicians were classified as either "senior" or "junior", depending on their clinical experience. The 'senior' physicians were pulmonologists with 8 to 10 years of experience, accustomed to perform pleural puncture without LUS. The 'junior' physicians were residents in their third or fourth year, considered inexperienced.

Ethical issues

Signed informed consent was obtained from all the patients included in the study.

Approval was obtained from the local ethics committee at the military hospital of Tunis. No ethical problems were raised as all pleurocenteses were guided by the accurate ultrasound site performed by the Expert.

Study Population

Figure 1 presents the study flowchart. A total of 150-200 pleural punctures are usually performed per year but during the COVID-19 pandemic, it decreased to 70 per year. Indeed, only patients older than 18 years with clinical and radiographic signs of pleural effusion were included. The patients included were those having a chest x-ray within the last 24 hours prior to admission. The physical signs of pleural effusion included dull percussion, decreased or absent breath sounds, and reduced vocal resonance.

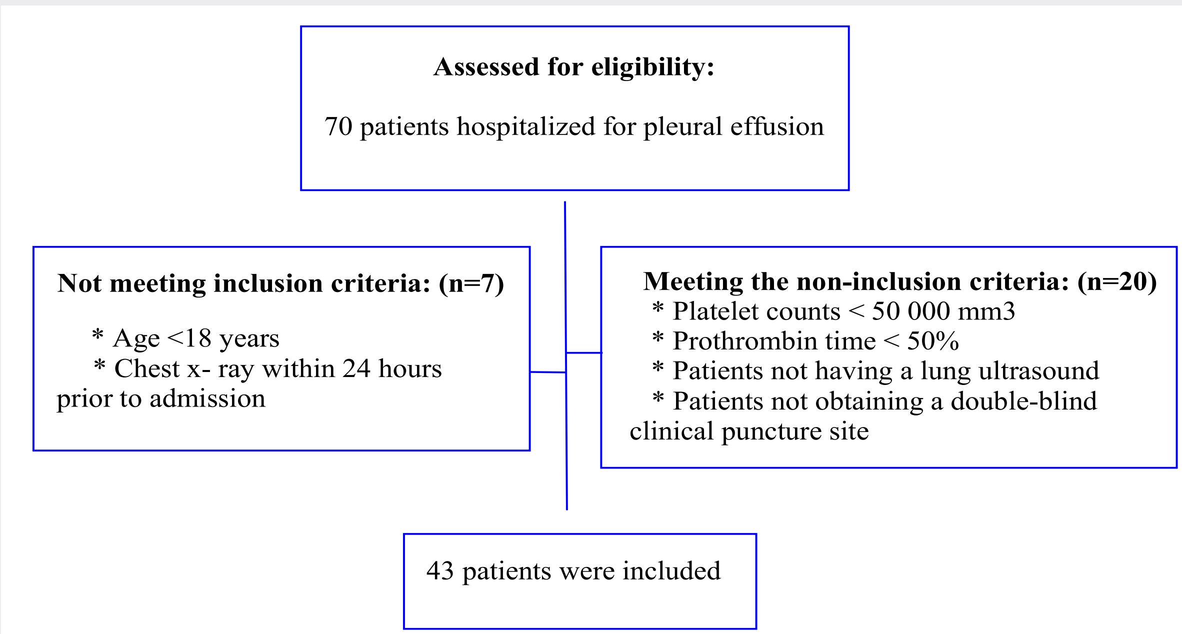

Figure 1. Study flowchart

The non-inclusion criteria were bleeding disorders, with platelet counts below 50 000 mm3 (9)and prothrombin time < 50% . Patients not having LUS and those not obtaining a double-blind clinical puncture sites were also excluded.

Procedures

Age, sex, and comorbidities were recorded. Based on the clinical and radiographic findings, pleural effusion was classified as left-sided, right-sided, or bilateral. The extent of effusion on chest x-ray was classified as small (blunting the costo-diaphragmatic angle), moderate (diaphragm not visible up to 50% of the hemithorax), or large (50% of the hemithorax) (10). Signs of loculated effusion were also recorded.

First, pleural puncture sites were proposed by the senior and junior physicians based on the clinical and radiographic findings. For bilateral effusion, both sides were explored for puncture sites. Then, LUS was performed in the same position by a qualified sonographer "expert" to verify the accuracy of the two clinical locations proposed by the senior and junior physicians. At the indicated sites of pleural punctures, the depth of pleural fluid perpendicular to the skin was registered. The minimal depth of pleural fluid necessary for a safe pleural puncture is still not known. A landmark with more than 10 mm of pleural fluid was arbitrarily rated as accurate. A site with no fluid (0 mm) was considered dangerous(11). A site with 1 to 9 mm of fluid might yield fluid on puncture. Such a site was considered unsafe and therefore inaccurate for this study(11). After conducting all the investigations related to the study, pleural puncture was performed based on the experts' ultrasound findings.

Sample Size Calculation: It was estimated that 4.7% of the patients were referred to the military hospital for exploration of pleural effusion during the study period. A sample size of 68 patients was required to achieve statistical significance (power: 0.8; alpha: 0.05), calculated using a predictive formula (8).

Statistical analysis

Categorical variables were presented using frequency distributions and percentages. Quantitative variables were presented using mean and standard deviation (SD) if they were normally distributed, or median and interquartile range (IQR) if they followed a non-normal distribution. The Shapiro-Wilk test was used to determine the normal distribution. Comparison between categorical variables was performed using the chi- squared test and the Fisher test. Cohen's kappa statistic was used to study the level of agreement between the two groups of operators. Sensibility, specificity, and positive as well as negative predictive values were calculated to assess each operator. The retained significance level is 5%. Data processing and statistical analysis were performed using IBM SPSS Statistics (version 26).

RESULTS

Table 1 presents the experience of the included physicians.

A total of forty-three patients with radiographic signs of pleural effusion were enrolled in the study. The meanage was 60 ± 17 years. Patients were predominantly male, with a sex ratio of 1.6. The main symptoms were shortness of breath (n = 38, 88%) and chest pain (n = 31,72%). Based on the radiographic findings, pleurisy was classified as right-sided effusion in 49% of the cases (n = 21), left-sided effusion in 46% of the cases (n = 20), and bilateral effusion in 5% of the cases (n = 2) (Table2). On radiography, loculated pleurisy was registeredin 4 cases (10%).

Table1. Physicians' experience

	Seniors (n=4)	Juniors (n=10)
Age (years)	40 ±9	27±4
Grade	3 Associate Professors 1 Assistant Professor	Residents (Third and fourth year)
Approximate previous numbers of performedpleural punctures	200	50

Note: Age was mean ±standard deviation.

For bilateral effusion, one side was selected as a puncture site. LUS confirmed the presence of pleural effusion in 38 cases (88%). Thus, usingLUS, pleural effusion was declined in 5 cases (12%): atelectasis in 3c ases (7%), and pleural thickening in 2 cases (5%). In addition, LUS revealed 14 cases (32%) with effusion of low-abundance and 4 cases (10%) with loculated effusion.

Overall, each patient benefited of two propositions of puncture sites, one performed by a senior physician and another by a junior one. A total of 86propositions were made for the 43 radiological aspects (only one side was considered for patients with bilateral effusions).

LUS confirmed an accurate puncture site in 32 out of the 86 propositions (37%). It prevented possible accidental organ puncture in 31 propositions (36%): Lung (n = 11, 13%), liver (n = 10,12%), diaphragm (n = 7,8%), and spleen (n = 3, 3%).

Compared to LUS, clinical examination and chest x-ray had sensitivities, estimated at 74% and 83%, respectively. The risk factors associated with inaccurate clinical site selection included right effusion(1.44 [CI95%:0.56-3.72]) and minimal pleural effusion on chest radiography (1.82 [CI95%:0.52-6.40]) (table 3).The clinical identification error rate was significantly higher in junior compared to senior physicians (77% versus 49%, respectively, $p < 0.05$). The experience of senior physicians influenced the choice of the clinical sites with moderate agreement (Kappa index: 0.4-0.6).

Table 2. Immunological, biological, hematological, and radiological data and profile of patients with rheumatoid arthritis (RA): Algiers (Algeria): 2018- 2019.

Data	Outcome	Unit/Category	Total sample (n=59)	ACPA- (n=33)	ACPA+ (n=26)	p-value
Immunological dataand profile	ACPA	(U/ml)	59±175	1±1	133±248	0.0034*
	ANA cut-off (titer)	≥1/160(%)	161±238	128±161	202±308	0.2453
	Rheumatoid factor (RF)	(IU/ml)	85±124	62±91	114±154	0.1122
	RF subgroups	Negative	13 (22.0)	2 (6.1)	11 (42.3)	0.009*
		Positive	46 (78.0)	31 (93.9)	15 (57.7)	0.009*
	RF levels	Light	22 (37.3)	18 (54.5)	4 (15.4)	0.0020*
		Moderate	11 (18.6)	9 (27.3)	2 (7.7)	0.0551
		High	7 (11.9)	2 (6.1)	5 (19.2)	0.1225
		Very high	6 (10.2)	2 (6.1)	4 (15.4)	0.2412
Biologicaldata and profile	ESR (1st hour)	(mm)	52±33	51±30	54±37	0.6831
	C-reactive protein	(mg/L)	28±43	21±33	36±51	0.1640
	High ESR	(yes)	15 (25.4)	8 (24.2)	7 (26.9)	0.8130
	High C-reactive protein	(yes)	28 (47.5)	13 (39.4)	15 (57.7)	0.1623
	Biological inflammatory syndrome	(yes)	48 (81.4)	25 (75.8)	23 (88.5)	0.2204
Hematological data and profile	Hemoglobin	(g/L)	12±2	12±2	12±2	0.9362
	White blood cells	(/mm^3)	7810±2682	7953±2551	7627±2881	0.6469
	Polynuclear neutrophils	(/mm^3)	4657±1916	4796±1939	4481±1910	0.5352
	Polynuclear eosinophils	(/mm^3)	258±543	189±139	346±804	0.2746
	Lymphocytes	(/mm^3)	2272±948	2304±846	2231±1080	0.7733
	Monocytes	(/mm^3)	623±244	665±257	570±219	0.1373
	Anemia	(yes)	22 (37.3)	13 (39.4)	9 (34.6)	0.7050
	Leukocytosis	(yes)	8 (13.6)	5 (15.2)	3 (11.5)	0.6803
Radiological data	Bronchiectasis	(yes)	16 (27.1)	7 (21.2)	9 (34.6)	0.2503
	Bronchial wall thickening	(yes)	2 (3.4)	0 (0.0)	2 (7.7)	0.1048
	Thickened septal/non-septal lines	(yes)	45 (76.3)	23 (69.7)	12 (46.2)	0.0681
	Interstitial lung disease	(yes)	43 (72.9)	27 (81.8)	16 (61.5)	0.0817
	Nonspecific interstitial pneumonia	(yes)	32 (54.2)	19 (57.6)	13 (50.0)	0.5607
	Bronchiolitis	(yes)	18 (30.5)	8 (24.2)	10 (38.5)	0.2362
	Ground glass attenuation	(yes)	34 (57.6)	20 (60.6)	14 (53.8)	0.5998
	Usual interstitial pneumonia	(yes)	9 (15.3)	6 (18.2)	3 (11.5)	0.4772
	Micro nodule	(yes)	35 (59.3)	19 (57.6)	16 (61.5)	0.7621
	Air space consolidation	(yes)	32 (54.2)	19 (57.6)	13 (50.0)	0.5607

ACPA: Anti-Citrullinated Peptides Antibodies. **ANA**: Anti-Nuclear Antibody. **ESR**: Erythrocyte Sedimentation Rate. Quantitative and categorical data were mean±SD and number (%), respectively. ***p-value < 0.05:**
2 sided Chi-square test (comparison of categorical data between the 2 groups)Student's T test (comparison of quantitative data between the 2 groups).

Table 3: Risk Indicators for inaccurate puncture sites (n=54)s

	N	RR	CI 95%
Abundance			
Blunted costo-diaphragmatic angle	1	0.97	0.91 -1.02
Small	16	1.82	0.52 – 6.40
Medium	16	0.73	0.38 – 1.39
Large	2	0.45	0.04 – 4.44
Radiological features			
Unloculated	32	1.04	0.78 -1.38
Loculated	3	0.68	0.08 -5.76
Effusion side			
Right	19	1.44	0.56 – 3.72
Left	16	0.73	0.38 – 1.39

CI95%: 95%confidence interval, RR: relative risk.

DISCUSSION

LUS has become an essential tool for pulmonologists. It is readily available for bedside application, and it is non-invasive and can be repeated as necessary. In the present study, LUS was found to be more accurate in diagnosing pleural effusions compared to the clinical examination and radiographic findings. Differential diagnosis, including pleural thickening (n = 3) and atelectasis (n = 4) were excluded in 16% of the cases.

The present study showed that compared to LUS, clinical examination and chest x-ray had lower sensitivities, estimated at 74% and 83%, respectively. A study conducted by Lichtenstein et al. (12) demonstrated that auscultation and bedside chest radiography have diagnostic accuracies for pleural effusionof

61% and 47%, respectively compared to LUS.

LUS has a considerably better diagnostic performance than chest x-ray in the diagnosis of pleural effusion. In their study, Xirouchaki et al. (13) reported that the sensitivity, specificity, and diagnostic accuracy of LUS for pleural effusion are 100%, 100%, and 100%, respectively. Also Lichtenstein et al. (12) reported 92%, 93%, and 93% accuracy, respectively of the aforementioned parameters.

In addition, it has recently been demonstrated that quantitative ultrasound assessment of pleural effusion is comparable to computerized tomography(14). A systematic review with meta-analysis published in 2021 showed that compared to computerized tomography scan, LUS has a sensitivity of 91% and a specificity of 92% in the diagnosis of pleural effusion (15).

Furthermore, LUS is a reproducible and rapid examination with reliable results. Indeed, the average ultrasound examination time is 2.3 ± 2.9 minutes compared to 12.4 ± 6.7 minutes for chest x-rays (16). In this study, small and right-sided effusions on chest radiography were associated with an inaccurate puncture site. The lack of homogeneity within the group and the reduced sample size could explain the relative high risk of a sharp costo-diaphragmatic angle on chest x-ray (RR: 0.97).

Ault et al. (17) identified other risk factors, including theremoval of > 1500 mL of fluid, unilateral procedures, and more than one needle passing through the skin.The experience of the senior physicians in this study influenced the choice of the clinical sites with moderate agreement (Kappa index: 0.4-0.6). The rate of agreement between residents and faculty members is variable(18). Even for physicians with a minor experience in LUS, an overall interpretation agreement rate of 95.9% is retained in emergency ultrasound education (18). Indeed, training on ultrasound techniques improves the management of pleural pathology and decreases complications. A prospective study conducted by Duncan et al. (19) compared the diagnostic accuracy of pleural effusions between radiologists and pulmonologists after a training session,and found that this approach reduces the risk of iatrogenic pneumothorax, with an estimated diagnostic accuracy of 99.6% (19).

A study conducted by Belhar et al. (18)suggested that for the majority of ultrasound examination types, a minimum of 50 examinations, as proposed by the American College of Emergency Physicians guidelines(20), results in a reasonable performance level.

This study has two limitations. First, the population group was small. In fact, this study was conducted during the COVID-19 pandemic, which affected the usual medical activities.The second limitation was the inclusion of a single LUS expert. This is due to the fact that LUS is still emerging in Tunisia and North Africa. Indeed, only few pulmonologists master this technique.

In conclusion, LUS has significantly improved the accuracy of pleural puncture sites by minimizing the risk of complications regardless of the operator's clinical experience. The usability, rapidity, and reproducibility of LUS make this technique a preferred modality for imaging the pleura in an efficient, economical, and safe way. LUS can reduce the use of standard chest radiography and computerized tomography. It is therefore highly recommended to use bedside LUSfor all pleural procedures by trained physicians, whenever it is possible. This study paves the way to promote the use of LUS in clinical practice in Tunisia.

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