SCIENTIFIC RESEARCH

THE LUNG POINT: AN ULTRASOUND FINDING IN THE DIAGNOSIS AND SEMI-QUANTIFICATION OF PNEUMOTHORAX

Mai Thi Ngoc*, Dam Thuy Trang**, Nguyen Thi Thu Thao**, Nguyen Thi Khoi**, Nguyen Thanh Thuy**, Nguyen Thi Thu Hang** Nguyen Phuong Anh**, Vu Dang Luu**

SUMMARY

This study focused on evaluating the diagnostic performance of the lung point (LP)- a lung ultrasound (LUS) sign in detecting and semi-quantifying pneumothorax (PTX), using computed tomography (CT) as the reference standard. The study included 150 patients who underwent CT-guided transthoracic biopsy (TTB) for lung lesions. Two radiologists blinded to the participant's prior information performed LUS post-biopsy. The results showed that PTX was present on CT in 49/150 (32.3%) cases. The LP was positive in 36/150 (24%) patients, with a substantial agreement between the two radiologists (Cohen κ statistics = 0.8). The sensitivity and specificity of the LP were 73.5% (95%CI 66.5% to 80.5) and 100% (95%CI 97.6% to 100%), respectively. Moreover, the positive and negative predictive values were 100% (95%CI 97.6% to 100%) and 67.3% (95%CI 59.8% to 78.4%), respectively. In the semi-quantification of PTX, the location of LP was described in 36/49 (73.5%) patients. The sensitivity and specificity of this sign were 87.5% (95%CI 82.2% to 92.8%) and 96.4% (95%CI 92.4% to 98.9%), respectively. The positive and negative predictive values were 87.5% (95%CI 82.2% to 92.8%) and 96.4% (95%CI 92.4% to 98.9%), respectively. In conclusion, LP is a susceptible and specific LUS sign for diagnosing and semi-quantifying PTX.

Keywords: *lung point, lung ultrasound, pneumothorax, diagnostic performance, semi-quantification.*

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I. INTRODUCTION

CT-guided TTB has become the procedure of choice to diagnose pulmonary lesions. The most common complication post-biopsy is PTX which can occur during or immediately after the process [1]. A meta-analysis by Heerink et al. demonstrated that the rate of PTX post-biopsy was 25.3 % and of PTX requiring intervention was 5.6 % [2]. PTX is also a critical cause that could quickly lead to respiratory failure. Therefore, timely and accurate confirmation or exclusion of PTX is essential, especially in emergency and urgent care situations.

To diagnose PTX, the posterior-anterior chest X-ray (CXR) is routine as a traditional imaging modality. However, CXR has a disadvantage in showing low sensitivity in detecting PTX in trauma patients, especially in the supine position [3,4] Although CT is the gold standard diagnostic test for PTX, it causes radiation exposure and is unsafe to transport these unstable patients. On the other hand, in the past decade, there was the belief that LUS could not bring any benefits because the air is the “enemy” of ultrasound. This method just has recently focused on both clinical practice and research. However, it has not been published as an official guideline for diagnostic criteria of PTX on LUS.

A systemic review in 2020 by Chan et al [5] showed some findings associated with PTX, including the absence of lung sliding sign, lack of B lines, and LP. LP is one of the most outweighed the other LUS findings because it has evaluability in diagnosing and predicting the size of PTX. [6,7] Nevertheless, LUS is a new issue in Vietnam, not yet widely used in clinical practice and research.

For these reasons, we aim to conduct this research to evaluate the diagnostic performance of LP as an LUS sign in detecting PTX after CT- guided TTB.

II. MATERIALS AND METHODS

1. Subjects

In this study, participants had to meet all inclusion criteria, including being indicated to CT-guided TTB and undergoing LUS post-procedure within 30 minutes to diagnose PTX. The exclusion criteria were any contraindications to CT- scans as pregnancy or refusal to participate in the study.

2. Methods

This was cross-sectional research conducted at Bach Mai Radiology Center from March 2021 to July 2022.

2.1. Imaging protocol

In our hospital, the Radiology Center made a weekly schedule of CT-guided TTB for lung lesions. Immediately after the procedure, each participant underwent an additional CT with completely expanded lung fields to check for complications, especially PTX. These entire procedures were performed by those who did not participate in this study.

Conscious and stable patients, according to ACCP Guideline 2009, [8] after CT-guided TTB were transferred to the follow-up room. Within 30 minutes in that room, the radiologists involved in this study performed post-procedure LUS on the biopsy side in the supine position to detect PTX. They were blinded to the prior CT imaging information. Those two radiologists had five and four years of experience in general radiology and were well-trained in LUS. The images were obtained with a high-frequency linear probe placed in the longitudinal direction on the anterior chest wall with the probe marker pointing to the cephalad.

In this study, the CT scanner machine was a 128-slice multidetector (SOMATOM Definition Edge, Siemens, Erlangen, Germany or SCENAIRA, Hitachi Medical Corporation, Tokyo, Japan). The ultrasound machine was GE LOGIQ E9 XDclear 2.0 (GE Healthcare, Milwaukee, WI, USA) with a linear array transducer (ML 6-15Hz). They were connected to the hospital picture archiving and communication system (PACS) through Digital Imaging and Communications in Medicine networking.

Finally, the data on those CT machines were compiled using PACS by a senior residency radiology doctor following the British Thoracic Society pleural disease guideline 2010 (BTS Guideline 2010) [9] This step was conducted after performing LUS.

2.2. Study variables

The general statistics were: age, gender, body mass index (BMI), biopsy side, and position. The MAL was used to semi-quantify PTX by LUS and classify the size of PTX by CT. In particular, the following statistics were collected:

- **PTX by LUS variable:** the presence of LP on 2D imaging and M-mode.

- **Semi- quantification of PTX by LUS**: large and small PTX: using the location of the LP with the cut-off is the mid-axillary line (MAL)**.** The more anterior to the MAL the LP, the smaller the PTX.

- **Size of PTX by CT as the reference standard:** large and small PTX: A visible rim between the lung margin and the chest wall with the cut-off is 20mm at the level of the hilum in the lung window for both prone or supine biopsy position. This would be measured using reconstruction in the PACS system.

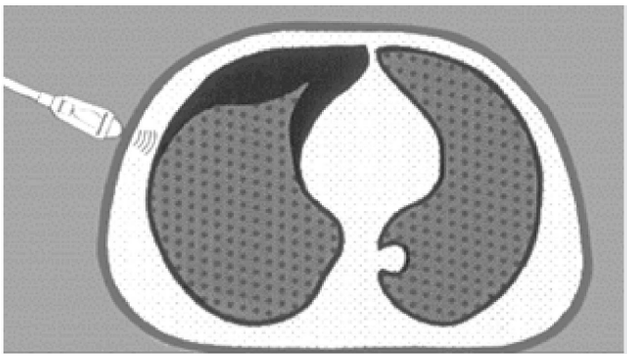

Figure 1. *Theoretical explanation of the LP in PTX. The LP locates at the boundary between the PTX and the partly deflated lung.*

Source: Lichtenstein DA, Mezière G, Lascols N, et al. Ultrasound diagnosis of occult PTX. Crit Care Med. 2005 [10].

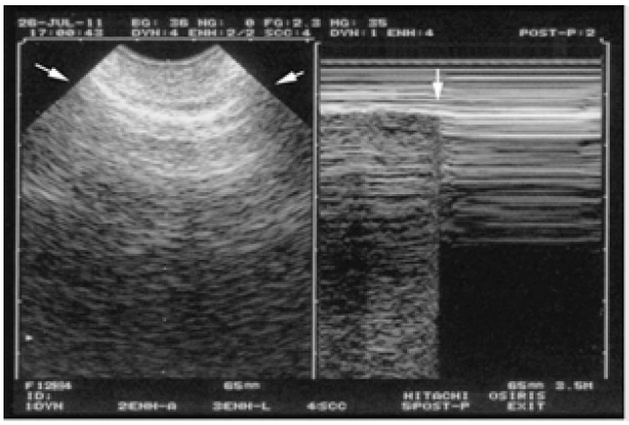

Figure 2. *LP on M-mode of LUS in PTX. On the right picture, the arrow indicates the borderline of the normal lung with a seashore sign and PTX with a barcode sign on M-mode; this is the LP.*

Source: BLUE-Protocol and FALLS-Protocol, Two Applications of Lung Ultrasound in the Critically Ill [11].

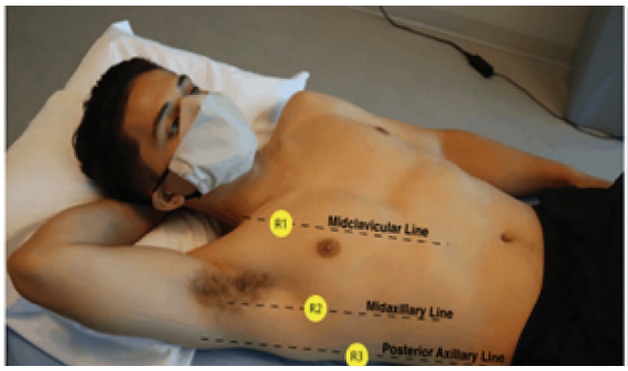

Figure 3. *The mid-axillary line.*

Source: Lung Ultrasound Made Easy: Step-By-Step Guide. POCUS 101. Accessed October 4, 2022 [12].

2.3. Statistical analysis

- Consequently, the IBM Statistical Package for the Social Sciences, version 25 (IBM SPSS Statistics Corp; Armonk, NY, USA) was used for data analysis. The study sample was described with descriptive statistics. Continuous variables are expressed as medians and standard deviations, while categorical variables are expressed as frequency and percentage.

- The inter-reader, Cohen κ statistics, was used to calculate the agreement between the two radiologists.

- The sensitivity, specificity, positive and negative predictive value, and disease prevalence are expressed as percentages. The confidence intervals were Clopper-Pearson (Exact methods) or normal approximation for the qualitative variable. The significance level was $p < 0.05$.

III RESULTS

A total of 150 patients (mean age, 60.5 years; range, 26-83 years; male/female, 4.2/1) were included in this study. Table 1 summarises the general features of the participants.

The inter-reader *κ values were 0.8, indicating a s*ubstantial to almost perfect agreement between the two radiologists.

Table 1. *Summary of patient's characteristics.*

Characteristic		Frequency (n)	Percent (%)
Gender (n, %)	Male	121	80.7
	Female	29	19.3
Biopsy side (n, %)	Left lung	78	52
	Right lung	72	48
Biopsy position (n, %)	Supine	64	42.7
	Prone	86	57.3
Age (years): mean, range		60.5, 26-83	

Of 150 patients, LP was detected in 36/150 cases (24%). Besides, on the lung window of CT scans, 49/150 patients were confirmed to have PTX (32.7%). The others (n=101, 67.3%) were absent from PTX. The results are summarised in Table 2.

Table 2. *Reliability of the presence of LP on LUS in the detection of PTX*

		PTX on CT as the reference standard (n)		Total (n)
		yes	no	
Presence of LP on LUS (n)	yes	36	0	36
	no	13	101	114
Total (n)		49	101	150

The sensitivity and specificity of the LP in the detection of PTX, compared with CT as the gold standard, were 73.5% (95%CI 66.5% to 80.5) and 100% (95%CI 97.6% to 100%), respectively. Moreover, the positive and negative predictive values were 100% (95%CI 97.6% to 100%) and 67.3% (95%CI 59.8% to 78.4%), respectively.

Table 3. *Performance of LUS (LP projections) to predict the size of PTX*

small PTX (< 20mm)		Classification of the size of PTX on CT as the reference standard (n)		Total (n)
		large PTX (≥ 20mm)		
Classification of the size of PTX on LUS (n)	no detected	13	0	13
	small PTX	27	1	28
	large PTX	1	7	8
Total (n)		41	8	49

Of 49 PTX cases confirmed by CT, LP was detected in 36/49 (73.6%) cases. Regarding the location of LP with the MAL, 28/49 patients had LP located anteriorly (57.1%) and 8/49 posteriorly (16.3%). The others (n=13, 26,4%) failed to detect LP. Consequently, according to BTS Guideline 2010, 57.1% of cases (n=28/49) were small PTX, and 16.3% (n=8/49) were large PTX on LUS. Table 3 indicates the results.

The sensitivity and specificity of the LP sign in the semi-quantification of PTX were 87.5% (95%CI 82.2% to 92.8%) and 96.4%, respectively. The positive and negative predictive values were 87.5% (95%CI 82.2% to 92.8%) and 96.4% (95%CI 92.4% to 98.9%), respectively.

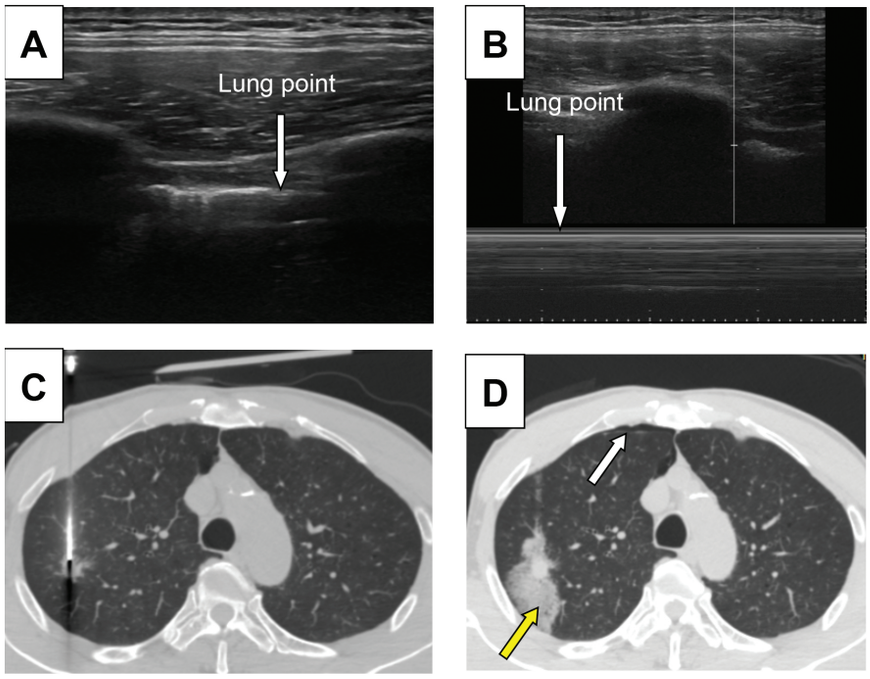

Figure 1. *LP on 2D imaging (A) and M-mode (B) is the boundary of normal lung and PTX. The location of LP, in this case, was anterior to the MAL, which predicted a small PTX.*

On the lung window of chest CT of the same case, (C): the needle was inside the right lung nodule in the supine position. (D): a rim of gas after removing the biopsy needle (white arrow). Besides, the hemothorax surrounding the lesion was present (yellow arrow).

*(**Nguyen Van V**, a 67-year-old patient, ICD J18/537)*

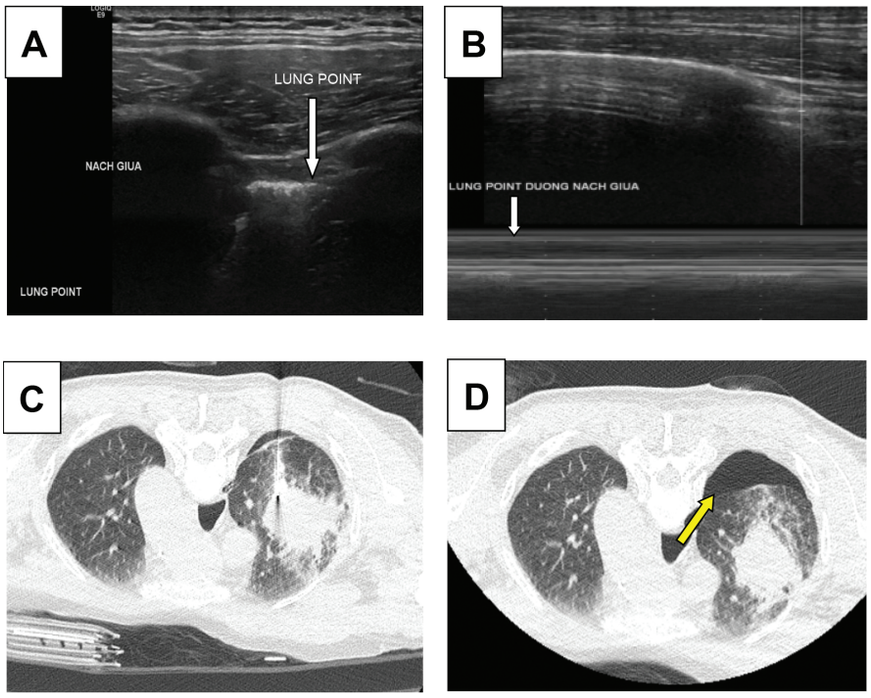

Figure 2. *(A), (B) LP was identified at the junction where visceral and parietal pleura contacts each other. The LP, in this case, was located on the MAL, indicating a large PTX on LUS. (C), (D) CT of this patient confirmed large PTX post-biopsy.*

*(**Nguyen Thi L,** a 48-year-old patient, ICD D38/2)*

IV. DISCUSSION

1. The diagnostic power of LP on LUS in detecting PTX after CT-guided TTB

Our study demonstrated that LP is a feasible and accurate LUS sign in detecting PTX with high sensitivity and specificity after CT-guided TTB. Pathophysiologically, PTX is caused by entrapped air in the pleural space, which causes the dissociation of the visceral and parietal pleura. The LP indicates PTX that may be observed at the boundary between average lung sliding and PTX. A systematic review by Chan et al.[5] listed that LP, in combination with other signs, is associated with PTX. Besides, LP projection on the chest wall plays a vital role in predicting the size of PTX.

This study's result was similar to a survey by Lichtenstein et al [13], which showed that the presence of an LP allows a positive diagnosis of PTX at the bedside using LUS. In particular, the LP was observed in 44 of 66 cases of PTX. The location of this sign roughly correlated with the radiological size of the PTX. The LP, therefore, had an overall sensitivity of 66% and a specificity of 100%. Another study by Santos Silva et al [14] also confirms that LP is still a specific sign of PTX.

In recent years, however, several findings have mimicked the LP as case reports. These are not generated by PTX but by other conditions such as large bullous lung disease [15] or a lung contusion [16]. Therefore, in diagnosing PTX, a comprehensive evaluation of all LUS signs is always necessary and must be interpreted in a clinical context, as is typical for the point-of-care approach.

Following confirmation of the existence of PTX, the next critical step is to quantify the amount of PTX. The latter is significant since it may indicate whether a conservative or surgical technique is required. By LUS, we used the LP location to the MAL according to the BTS Guideline 2010. Our study's data showed that the LP location had significantly high sensitivity and specificity in the semi-quantification of PTX.

This result was similar to research in the literature. A study by Volpicelli et al. discovered that the position of the LP might correctly categorise PTX size [6]. A total of 124 patients with PTX were enrolled (76 spontaneous, 20 traumatic, and 28 post-procedural). Ninety-four CXR and 58 CT were available for the analysis. An LP posterior to the MAL corresponded to three different CXR criteria for large PTX with sensitivity from 81.4 to 88.2 % and specificity from 64.7 to 72.6 %.

In another study, Hooman Hosseini-Nik et al. showed that the LP had the sensitivity and specificity of 69.23% (95%CI 38.6% to 90.1%) and 96.0% (95%CI 79.6% to 99.9%), respectively, in detecting PTX of any size. The sensitivity and specificity of 100% (95%CI 39.8% to 100%) and 100% (95%CI 89.7% to 100%), respectively, in the detecting large PTX [7]. In our study, thanks to the gold standard of CT in the lung window, we could measure precisely the size and classify PTX.

2. The study's pros and cons

This study had several strong points. Firstly, it was conducted using CT as the reference standard. According to the BTS Guideline 2010 [9] CT can be considered the gold standard in detecting small PTX and estimating size. However, practical constraints preclude its general use as the initial diagnostic modality, as CT causes radiation exposure and is unsafe for transporting unstable patients. LUS, on the other hand, is more widely available, inexpensive, and does not expose patients to radiation. LUS can be repeatedly performed at the bedside. Using CT as the gold standard tool to evaluate the diagnostic performance of imaging findings on LUS, including LP, could bring more benefits than CXR, as in some previous studies in the literature.

Secondly, we had two well-trained radiologists perform LUS post-procedure. They had anatomical knowledge and a formal educational program in doing LUS. Another radiology resident collected data on CT independently from those radiologists. This could increase the reliability of the results with the substantial agreement between the two radiologists.

On the other hand, this study had some limitations. Firstly, the sample size was relatively small. Although the LP sign in our study showed high diagnostic performance in detecting PTX, future studies with a more significant number of patients should be conducted.

Secondly, thirteen false-negative normal lungs on LUS had PTXs on CT. These might be due to small focal PTXs localised to the site of needle entry outside the monitored zone (for example: in the back in the prone biopsy position). The focal PTX at the needle entry site can be seen on CT images during or at the end of the procedure; in our study, patients remained stable. Performing the LUS over the needle entry location may require patients to reposition and remove the dressing, which did not benefit post-procedure patients in our experience.

In our study, we only scanned the anterior chest wall; this is due to, in most cases, gas in the pleural cavity following the gravity rule. Sartori et al [17] used an LUS protocol that examined the entire chest in both supine and prone positions. That LUS protocol consumed a significant amount of time and required post-biopsy patients to change their positions. This is inconvenient and sometimes impossible, especially in unstable patients in emergency conditions, which may explain why it is not widely used.

V. CONCLUSION AND RECOMMENDATION

In summary, by using CT as the reference standard, our study had an advantage in evaluating the power of the LP sign on LUS in detecting PTX. This LUS finding showed high sensitivity and specificity in diagnosing the presence and the semi-quantification of the PTX. Besides, LUS offers the benefit of availability, cost saving, bedside, and repeatedly performed without radiation exposure. Therefore, we believe this study's results could be extrapolated to other conditions of PTX with or without trauma in emergency and critical care settings, especially in pregnant women, pediatric or neonatal.

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Recieved: 06/11/2022. Assessed: 06/11/2022. Reviewed: 10/11/2022. Accepted: 09/12/2022