The role of thoracic ultrasound prior to medical thoracoscopy with an artificial pneumothorax

Zhen-Chuan Xing，Jing Zhou，Zi-Liang Hou，Yuan Yuan，Hong-Xia Zhang，Jin-Xiang Wang，Shuai Zhang

Beijing Luhe Hospital, Capital Medical University, Beijing 101100, China

Introduction. Much data suggest that thoracic ultrasound prior to MT could reliably and safely identify sites for trocar entry in patients without artificial pneumothoraces. However, its value on MT patients with artificial pneumothoraces has not been fully explored. This study aimed to evaluate the role of thoracic ultrasound prior to MT in patients with artificial pneumothoraces.

Methods. A total of 62 patients underwent pneumothorax induction and MT concurrently. The safety of pneumothorax induction and the feasibility of ultrasound-guided pleural entry site localization were recorded.

Results. Artificial pneumothoraces were successfully induced in all 62 patients without severe complications (subcutaneous emphysema occurred only in 3 patients). Thoracic ultrasound located appropriate entry points for trocar insertion in all patients. Conclusion. Artificial pneumothorax induction is a relatively safe procedure, and ultrasound-guided pleural entry site localization is feasible for patients with artificial pneumothoraces.

1. INTRODUCTION

Medical thoracoscopy (i.e., thoracoscopy with local anesthesia under conscious sedation, MT) is a safe, minimally invasive, and low-cost endoscopic technique that can significantly improve the diagnostic rate of pleural diseases [1, 2]. A critical issue prior to MT is locating the best pleural access point to avoid adhesions and tearing the lung with instruments when entering the chest cavity. It is not always possible to note adhesions and fibrous septations on pleural CT, whereas thoracic ultrasound detects

these more readily [3, 4]. Moreover, current data support the novel use of thoracic ultrasound to indicate the optimal point of entry and successful thoracoscopy [3, 5, 6]. However, these studies focused on patients with visible pleural effusion at the affected side in the lateral decubitus position. For patients with small or no pleural effusion, artificial pneumothoraces are often induced to collapse the lung and allow access [2]. A chest radiograph or CT scanning was commonly performed to confirm the separation of the lung from the chest wall, potentially adding considerable time to the MT procedure and exposing the patient to ionizing radiation.

Thoracic ultrasonography has developed into a well-established method for examining structures of the chest wall and pleura. However, though it holds the advantage of portability, simplicity, rapidity, and higher sensitivity and accuracy compared to CXR to confirm pneumothorax [7-9], there are few published data regarding the role of thoracic ultrasound prior to MT in a patient with an artificial pneumothorax. Therefore, we reviewed cases from our center where pneumothorax induction and thoracoscopy were performed to assess the role of thoracic ultrasound prior to MT.

2. METHODS

2.1. Study Population. Sixty-two patients with pleural effusion underwent pneumothorax induction and MT concurrently in Beijing Luhe Hospital, Capital Medical University, from July 2018 to December 2021. The inclusion and exclusion criteria followed the guideline of the British Thoracic Society published in 2010 [2]. The study was carried out ethically in conformity with the World Medical Association Declaration of Helsinki and approved by the Ethics Committee of Beijing Luhe Hospital, Capital Medical University (2019-LHKY-041-01). Informed consent was obtained from all the participants.

2.2. Pneumothorax Induction. Firstly, thoracic drainage catheterization was performed for pleural effusion sample collection and relief of shortness of breath. Then, the

patient sat in the sterilized therapy room, and 300ml of air was slowly injected into the thoracic cavity through the thoracic drainage catheter (Mode K1, Changzhou Medical Instrument Co., Ltd., Changzhou, Jiangsu Province, China) to induce the artificial pneumothorax. The patients were closely monitored and queried for any discomforts during the procedure, such as chest tightness, chest pain, and palpitation. The procedure will be suspended immediately if any discomfort occurs. If discomforts were relieved after a few minutes, induced pneumothorax could be continued to reach the target volume of 300ml. Otherwise, the procedure was stopped, and patients were given oxygen, monitored closely, and transferred to the ward.

2.3. Pneumothorax Formation Confirmation. After pneumothorax induction, the patient was placed in a lateral decubitus position with the affected side upward. A thoracic CT scan was conducted to observe intrathoracic adhesions and gas distribution in the thoracic cavity. A site with sufficient pleural space separating the lung from the chest wall was marked (the pleural access point in the CT scan, shown in Figure 1A).

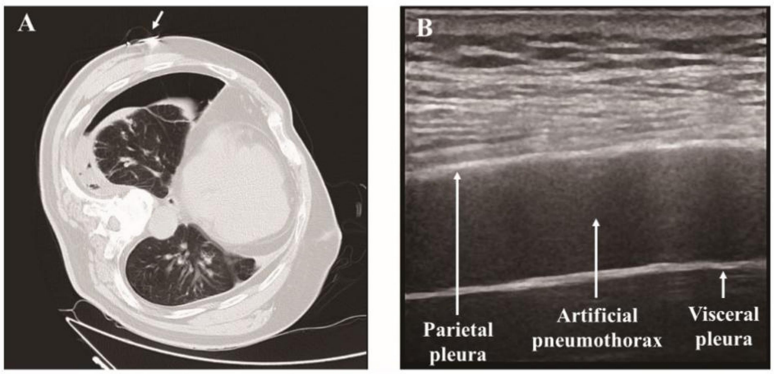

Figure 1: Thoracic CT and ultrasound images of an artificial pneumothorax. (A) Artificial pneumothorax image in a lateral decubitus position CT scan. White arrow indicated the pleural access point marked by a clip. (B) Artificial pneumothorax image in thoracic ultrasound.

2.4. Thoracic ultrasound and medical thoracoscopy. A thoracic ultrasound was further performed to confirm the access point and assess adhesion prior to MT. The linear array probe (7.5-10MHz, Hitachi Medical Corporation, Tokyo, Japan; or 3-9MHz, Philips Healthcare, Bothell, Washington, USA) was placed in the costal margins between the fourth intercostal space and the eighth intercostal space on the lateral anterior chest wall, range between the anterior axillary line and the posterior axillary line to visualize pleural adhesions and pleural calcifications. Moreover, the B-mode or M-mode was used to observe the signs of pneumothorax, such as the absence of lung sliding [10], stratosphere sign [11], lung point sign [12], and absence of B-lines [13]. The optimal site for pleural access was also marked (pleural access point in ultrasound, shown in Figure 1B). The marked pleural access point was infiltrated with lidocaine. Next, a small port was dissected bluntly from the skin to the pleura, and a trocar was placed through the port. Then, MT (LTF 240, the outer diameter of 7mm, working channel diameter of 2.8mm, Olympus, Japan) was performed under local anesthetic with continuous ECG monitoring and 2L/min oxygen supply. The following information was recorded: pleural access problems, need for a change of entry site (from the pleural access point in CT scan to the pleural access point in ultrasound), and presence of adhesions.

2.5. Statistical analysis. All statistical analyses were processed by the SPSS for windows, version 18.0 software. The continuous variables were described as mean and standard deviation (SD), and the discrete variables were described as frequency and proportion.

3. RESULTS

Sixty-two patients were included in this study; 41 were male with an average age of 58.53±20.90 years, and 21 were female with an average age of 59.14±14.93 years. Among the 62 patients with pleural effusion, 26 (41.94%) had left-sided pleural effusion, 30 (48.39%) had right-sided pleural effusion, and 6 (9.68%) had bilateral

pleural effusion. The other detailed characteristics of participants are depicted in Table 1.

Table 1: Baseline characteristics of the 62 patients.

Variables	Data
Gender, n (%)	
Male	41 (66.13%)
Female	21 (35.48%)
Age, years	
Male	58.53 ± 20.90
Female	59.14 ± 14.93
Pleural effusion distribution	
Left-sided	26 (41.94%)
Right-sided	30 (48.39%)
Bilateral	6 (9.68%)
Pleural effusion volume	
Small	10 (16.13%)
Moderate	27 (43.55%)
Large	25 (40.32%)
Amount of artificial pneumothorax	
300ml	54 (87.10%)
<300ml	8 (12.90%)
Complications during pneumothorax induction	
Chest tightness	9 (14.52%)
Chest pain	0
Palpitation	0
Subcutaneous emphysema	3 (4.84%)

Data are presented as mean ± SD or number (%)

Pneumothorax was artificially induced in all patients prior to the MT operation. Most patients (n=54, 87.10%) can tolerate the pneumothorax volume of 300ml. Of the 54 patients, one patient with a large amount of pleural effusion felt chest tightness and subcutaneous emphysema occurred in two patients (with obvious adhesion). The induced pneumothorax volumes of the remaining 8 (12.90%) patients did not reach 300ml because of unbearable chest tightness, and the gas volume was 225±65 ml. One of the eight patients developed subcutaneous emphysema, and the patient had obvious pleural adhesion. All three patients with subcutaneous emphysema had stable vital signs and did not need special treatment.

Based on signs of pneumothorax, safe and feasible entry sites were identified in all 62 patients using thoracic ultrasound. No lung injury occurred in all patients. Of note, the ultrasound pleural access points of 60 patients were basically the same as those of CT scans, without the need for a change to a new site. In two patients, the CT pleural access points were located at the adhesive bands, which were not found by CT but detected by ultrasound, accepting a change of the entry sites.

The final diagnoses for the 62 patients are shown in Table 2. 11 out of 16 malignant patients were diagnosed with lung cancer, followed by four patients with breast cancer and 1case of lymphoma. In total, 29 out of the other 46 patients had tuberculous pleurisy, and the remaining diseases were parapneumonic effusion in 3 and temporary nonspecific pleurisy in 14.

Table 2: The diagnoses of the 62 patients.

Diagnosis	n
Malignant diseases	16
Lung cancer with pleural metastasis	11
Breast cancer with pleural metastasis	4
Lymphoma	1
Other diseases	46
Tuberculous pleurisy	29
Parapneumonic effusion	3
Nonspecific pleurisy	14

4. DISCUSSION

Medical thoracoscopy (MT) is an excellent tool for diagnosing unexplained pleural effusion [1]. Before MT, it is necessary to locate the optimal pleural access point to avoid lung stabbing injury or to avoid lacerating the adhesions. Many data suggest that thoracic ultrasound prior to MT could reliably and safely identify sites for trocar entry in patients without an artificial pneumothorax [3, 5]. Our study further highlights its role in MT with an artificial pneumothorax.

MT is a minimally invasive endoscopic technique working on patients with spontaneous breathing. Hence, there would be a possibility of lung injury at the time of trocar insertion if there is no collapse. Usually, inducing artificial pneumothoraces to collapse the lung and allow access is our practice, especially for patients with loculated effusion or without enough pleural effusion in the lateral decubitus position. However, not all MT units do this because of the time factor [14]. In our institution, a chest drainage catheter is commonly indwelled during a routine thoracentesis for subsequent drainage of the pleural effusion to relieve symptoms, avoiding repeated thoracentesis. Therefore, inducing artificial pneumothorax using this drainage catheter

does not delay the MT procedure.

Moreover, artificial pneumothorax is relatively safe. The vast majority of patients can tolerate artificial pneumothorax without serious complications. Only three patients developed subcutaneous emphysema in our study, but no special treatment was required. However, it is essential to note that the patients should be closely monitored and queried for any discomforts during the procedure.

After pneumothorax induction, a chest X-ray, fluoroscopy, or CT examination is required to confirm its formation-which may cause a delay to the MT procedure and expose the patient to ionizing radiation. With the application of ultrasound in the thorax, thoracic ultrasound offers an alternative approach to confirm the successful development of a pneumothorax based on the signs of pneumothorax in ultrasound. In this study, we used a portable thoracic ultrasound instrument to ensure the separation of the lung from the chest wall and to locate the appropriate entry point further. The thoracic ultrasound exam adds only a few minutes to the procedure and reliably identifies a pleural access point where there is sufficient space for the trocar insertion. Much evidence supports its application in this field regarding the role of ultrasound in the localization of thoracic entry points. In the 1990s, Macha et al. used ultrasound to indicate the optimal thoracic entry points with a 100% access rate and 20-30 min could be saved for each procedure in an uncontrolled study of 687 patients [14]. A prospective cohort study of 20 patients illustrated that ultrasound could identify entry sites prior to MT, even in cases with pleural adhesions [5]. Another prospective cohort study by Medford et al. suggested that pre-MT ultrasound could reduce the pleural space access failure rate from 16.7% to zero [3]. However, this series of studies focused on the role of ultrasound prior to MT without artificial pneumothoraces. Our study extended and suggested the application of ultrasound to MT with an artificial pneumothorax. Besides locating the best pleural access point, thoracic ultrasound can detect thick fibrous septation. A previous study by Medford et al. showed that thick fibrous septations were found in only 12.5% of cases on the pleural CT, while thoracic

ultrasound was more likely to detect these [3]. Similarly, two pleural access points were initially located at the adhesive bands, which were not found by CT but detected by ultrasound, causing a change of the entry sites in our study. The performance of thoracic ultrasound in detecting fibrous adhesive bands and its characteristics of portability and non-ionizing radiation compared with CT indicates the prominent role of thoracic ultrasound in locating the best entry site prior to medical thoracoscopy.

In summary, although this is a single-center study with a limited sample, our data suggest that artificial pneumothorax is safe and ultrasound-guided pleural entry site localization is feasible. Our study addressed for the first time the benefits of pre-MT ultrasound when introducing a pneumothorax, further extending the application of ultrasound prior to MT.

DATA AVAILABILITY

Data and materials are available on reasonable request by contacting the first author.

ETHICAL APPROVAL

The study was carried out ethically in conformity with the World Medical Association Declaration of Helsinki and was approved by the Ethics Committee of Beijing Luhe Hospital (2019-LHKY-041-01). All subjects provided written informed consent.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

FUNDING STATEMENT

This work was supported by Grants from Special Construction for Incubation of

Capital Clinical Features Applied Research Projects of Beijing Luhe Hospital, Beijing, China [KJ2019CX012-25].

AUTHORS' CONTRIBUTIONS

Hong-Xia Zhang and Shuai Zhang designed and coordinated the study. Shuai Zhang wrote the first draft of the manuscript. Shuai Zhang, Jing Zhou, and Zhen-Chuan Xing collected and analyzed the data. Zi-Liang Hou and Yuan Yuan recruited the patients. All authors reviewed, revised, and approved the final version of the manuscript.

ACKNOWLEDGMENT

We thank all the patients who agreed to participate in the study.

REFERENCES

1 Hooper C, Lee YC, Maskell N, Group BTSPG. Investigation of a unilateral pleural effusion in adults: British Thoracic Society Pleural Disease Guideline 2010. Thorax. 2010;65 Suppl 2:ii4-17.

2 Rahman NM, Ali NJ, Brown G, Chapman SJ, Davies RJ, Downer NJ, et al. Local anaesthetic thoracoscopy: British Thoracic Society Pleural Disease Guideline 2010. Thorax. 2010;65 Suppl 2:ii54-60.

3 Medford AR, Agrawal S, Bennett JA, Free CM, Entwisle JJ. Thoracic ultrasound prior to medical thoracoscopy improves pleural access and predicts fibrous septation. Respirology. 2010;15(5):804-8.

4 Kearney SE, Davies CW, Davies RJ, Gleeson FV. Computed tomography and ultrasound in parapneumonic effusions and empyema. Clin Radiol. 2000;55(7):542-7.

5 Hersh CP, Feller-Kopman D, Wahidi M, Garland R, Herth F, Ernst A. Ultrasound guidance for medical thoracoscopy: a novel approach. Respiration. 2003;70(3):299-301.

6 Medford AR. The utility of thoracic ultrasound before local anesthetic video-assisted thoracoscopy in patients with suspected pleural malignancy. J Clin Ultrasound. 2010;38(4):222-5.

7 Ding W, Shen Y, Yang J, He X, Zhang M. Diagnosis of pneumothorax by radiography and ultrasonography: a meta-analysis. Chest. 2011;140(4):859-66.

8 Ron E, Alattar Z, Hoebee S, Kang P, vanSonnenberg E. Current Trends in the Use of Ultrasound Over Chest X-Ray to Identify Pneumothoraces in ICU, Trauma, and ARDS Patients. J Intensive Care Med. 2022;37(1):5-11.

9 Chan KK, Joo DA, McRae AD, Takwoingi Y, Premji ZA, Lang E, et al. Chest ultrasonography versus supine chest radiography for diagnosis of pneumothorax in trauma patients in the emergency department. Cochrane Database Syst Rev. 2020;7:CD013031.

10 Lichtenstein DA, Menu Y. A bedside ultrasound sign ruling out pneumothorax in the critically ill. Lung sliding. Chest. 1995;108(5):1345-8.

11 Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J Emerg Trauma Shock. 2012;5(1):76-81.

12 Lichtenstein D, Meziere G, Biderman P, Gepner A. The "lung point": an ultrasound sign specific to pneumothorax. Intensive Care Med. 2000;26(10):1434-40.

13 Lichtenstein D, Meziere G, Biderman P, Gepner A. The comet-tail artifact: an ultrasound sign ruling out pneumothorax. Intensive Care Med. 1999;25(4):383-8.

14 Macha HN, Reichle G, von Zwehl D, Kemmer HP, Bas R, Morgan JA. The role of ultrasound assisted thoracoscopy in the diagnosis of pleural disease. Clinical experience in 687 cases. Eur J Cardiothorac Surg. 1993;7(1):19-22.

Corresponding Author:

Shuai Zhang

Beijing Luhe Hospital, Capital Medical University, Beijing 101100, China

E-mail: zhangshuai1974@ccmu.edu.cn