Original Article

Effect of needle aspiration for treatment of moderate to severe non-tension pneumothorax after transthoracic needle biopsy

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Background: Transthoracic needle biopsy (TTNB) is a widely used technique for assessing parenchymal lung diseases. However, pneumothorax often occurs after TTNB and may sometimes require chest tube drainage. We aimed to evaluate the efficacy and safety of simple needle aspiration for treating moderate to severe non-tension pneumothorax following TTNB.

Methods: This prospective, single-center pilot study conducted between May and November 2021. Participants with non-tension pneumothorax measuring >25% in size on radiography after TTNB were included. Simple needle aspirations were performed through the second intercostal space on the midclavicular line using a 16-gauge angio-catheter. Changes in the size of the pneumothorax were assessed using chest radiographs at 1 and 12 h postprocedure.

Results: Seven patients with moderate to severe pneumothorax after TTNB were included. Needle aspirations were successful in all patients without complications. Pneumothoraces improved in five patients after needle aspiration, eliminating the need for chest tube drainage. However, in two patients, pneumothorax of a similar size persisted after needle aspiration and was subsequently resolved with chest tube drainage. The mean duration of hospital stay for the patients with successful needle aspiration was shorter (3.8 d) compared to those requiring chest tube drainage after failed needle aspiration (8 d). Two patients who underwent chest tube drainage reported pain [Numeric Rating Scale (NRS) 4] and received analgesic drugs, while no pain (NRS 0) was reported after needle aspiration.

Conclusions: Needle aspiration is a safe and effective procedure for the treatment of moderate to severe non-tension pneumothorax following TTNB. It may reduce the need for chest tube insertion, shorten hospitalization duration, and decrease procedure-related pain and analgesic use.

Keywords: Needle aspiration; transthoracic needle biopsy (TTNB); non-tension pneumothorax

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Introduction

Background

The increasing use of chest computed tomography (CT) for lung cancer screening has led to a higher frequency of detecting pulmonary nodules. Tissue confirmation of pulmonary nodules is crucial in clinical practice, as identifying them solely through radiological or clinical findings can be challenging. Transthoracic needle biopsy (TTNB) is a widely employed procedure for the tissue confirmation of peripheral lung lesions due to its relative safety and efficiency (1). Pneumothorax is the most common complication associated with TTNB, with an incidence rate ranging 14.4–46.0% (2-5). Mild pneumothorax often resolves spontaneously with oxygen inhalation alone, whereas moderate to severe pneumothorax typically requires chest tube drainage. However, chest tube drainage can be painful, lead to procedure-related complications, and potentially extend hospital stay (6).

Rationale and knowledge gap

According to the European Respiratory Society (ERS) guidelines, needle aspiration is recommended as the initial treatment for patients without underlying basal lung disease who experience moderate to severe non-tension primary pneumothorax (7). A recent meta-analysis (6) suggests that needle aspiration may reduce the rate of procedure-related complications and shorten hospital stays. However, significant differences in treatment success rates between needle aspiration and chest tube drainage for spontaneous pneumothorax have not been thoroughly reported (6). Given that most of the TTNB-related pneumothoraces improve immediately after chest tube drainage, needle aspirations may be an effective alternative.

Objective

To the best of our knowledge, data on the use of needle aspiration as a primary treatment option for pneumothorax following TTNB remains limited. Therefore, we aimed to investigate the effectiveness of needle aspiration for treating moderate to severe non-tension pneumothorax after TTNB through a prospective pilot study. This article is presented in accordance with the TREND reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-924/rc).

Highlight box

Key findings

- Needle aspiration is a useful and safe procedure for the treatment of moderate to severe non-tension pneumothorax following transthoracic needle biopsy (TTNB).

What is known and what is new?

- Needle aspiration is recommended as the initial treatment for patients with moderate to severe primary spontaneous pneumothorax.
- This pilot study is the first prospectively designed study that provides clinically meaningful data on the use of needle aspiration in pneumothorax occurring after TTNB.

What is the implication, and what should change now?

- The findings of this study provide a clinical rationale for the widespread adoption of needle aspiration for treating pneumothorax after transthoracic needle biopsy in clinical practice.
- Our study also highlights the benefits of using lung ultrasounds to confirm the occurrence of pneumothorax following TTNB.

Methods

Study population

This prospective, single-center, single-arm pilot study was conducted at the Asan Medical Center, Seoul, Republic of Korea between May and November 2021. Patients were included if they met the following criteria: (I) required chest tube drainage after TTNB; (II) were >18 years of age with pneumothorax following TTNB performed for a diagnostic purpose; (III) had a pneumothorax that measured >25% in size as estimated by the Collins method (*Figure 1*) (8); and (IV) had a pneumothorax measuring ≤25% in size but exhibited symptoms of dyspnea following TTNB.

Patients were excluded if they had (I) severe lung disease, such as interstitial lung disease or tuberculosis-associated lung injury (i.e., >25% lung involvement on chest CT); (II) tension pneumothorax; (III) bilateral or recurrent pneumothorax; (IV) were pregnant; (V) had severe cardiovascular diseases; or (VI) did not consent to participate.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All procedures were conducted after obtaining written informed consent from the participants. The study protocol was approved by the Institutional Review Board of Asan Medical Center (approval No. 2021-0531) and registered at the Clinical Research Information Service (CRIS) of the Republic of

Korea on May 13, 2021 (registration number KCT0006136-13/05/2021).

Study design

The study flow chart is shown in *Figure 2*. We screened all patients with pneumothorax following TTNB. Eligible patients were invited to participate and written informed consent was obtained. Before staring the intervention, we assessed the presence of lung sliding signs on both sides using ultrasound and performed a simple needle aspiration. Chest radiography was performed 1 and 12 h after the procedure to evaluate the success or failure of needle aspiration. Needle aspiration was considered successful if the pneumothorax size was ≤25% 1 h after the procedure on chest radiography, and if no evidence of deterioration was observed on subsequent chest radiography performed after 12 h. If the pneumothorax size was >25% 1 or 12 h after the procedure, chest tube drainage was performed, and needle aspiration was deemed unsuccessful.

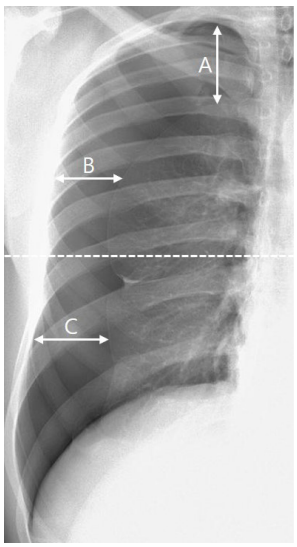

Figure 1 Measurement of pneumothorax size by interpleural distance on chest radiograph. It was measured at three locations: the apex (A) and the midpoints of the upper (B) and lower (C) halves of collapsed lung. The dash line means the borderline between the two halves. The formula to calculate the percentage of pneumothorax size using Collins method is 4.2 + {4.7 × (A + B + C)}.

We assessed the presence of breathlessness after pneumothorax occurrence and the procedure using the following question: "Do you feel significantly more breathless than usual?" as used in the previous study (9). The Numeric Rating Scales (NRS) was employed to measure the intensity of pain experienced by the patient, with scores ranging from 0 to 10, where 0 denotes "no pain" and 10 meaning "the worst pain imaginable" (10). Data on NRS scores assessed before and after the procedure were collected by the patient's nurse, along with information on analgesics administered postprocedure, were collected from medical records.

The primary outcome was to evaluate the success rate of needle aspiration after TTNB. The secondary outcomes included hospital stay duration, NRS scores assessed before and after the procedure, analgesic drug usage, and procedure-related complications such as bleeding, infection, and subcutaneous emphysema.

Manual needle aspiration

After positioning the patients in the semi-Fowler position,

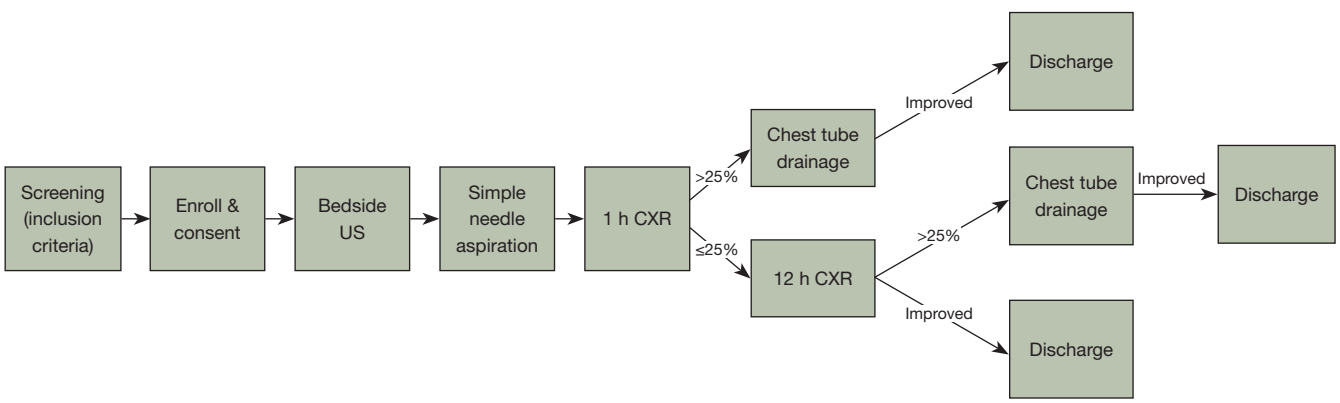

Figure 2 Study flow chart. US, ultrasound; h, hour; CXR, chest radiograph.

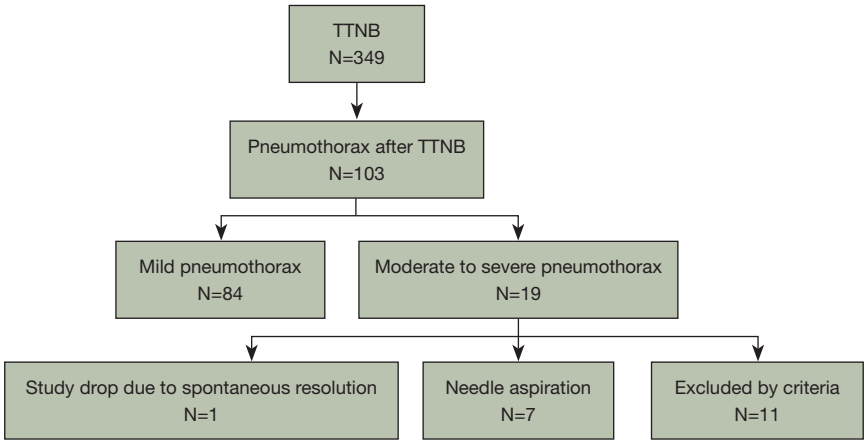

Figure 3 Flow chart of the screening protocol. TTNB, transthoracic needle biopsy.

the absence of lung sliding sign on the affected side was confirmed using ultrasound. Subsequently, a 16-gauge intravenous angio-catheter was inserted through the affected side at the second intercostal space on the midclavicular line following skin sterilization. Once the tip of the angio-catheter was properly positioned at the apex of the interpleural space, the needle was removed, and a three-way valve with a 50 mL syringe was connected to the angio-catheter. After ensuring that the angio-catheter and syringe ware functioning properly, manual aspiration was performed until no more air could be aspirated. If lung sliding sign ware confirmed by ultrasound, the procedure was considered completed. All procedures were performed in an interventional room by interventional pulmonologists.

Statistical analysis

Baseline and demographic values of the patients were compared. The mean durations of hospital stay were compared between patients who underwent successful needle aspiration and those who required chest tube drainage due to the failure of initial needle aspiration. Statistical significance was set at P value <0.05. Statistical analyses were performed using IBM SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Participants screening

The flowchart of the screening process is presented in *Figure 3*. A total of 349 patients underwent TTNB at Asan Medical Center from May to August 2021. Pneumothorax following TTNB occurred in 103 patients (103/349, 29.5%). Among these, 19 patients (19/349, 5.4% overall; 19/103, 18.4% of the pneumothorax group) experienced moderate to severe pneumothorax, while the remaining 84 patients had mild pneumothorax. Of the 19 patients with moderate to severe pneumothorax, 8 met the inclusion criteria. One patient's pneumothorax resolved spontaneously before the procedure (confirmed using bedside ultrasonography) and was excluded from the study. Consequently, seven patients were included and needle aspiration was performed on them.

Baseline characteristics of patients

Baseline characteristics of the patients are detailed in *Table 1*. Patient age ranged 58–87 years (median age 67 years). Of the cohort, one patient (14.3%) was female, and the remaining six patients (85.7%) were male. Most patients with moderate to severe pneumothorax following TTNB had the condition in the left hemithorax (6/7, 85.7%). All patients had a history of smoking exceeding 10 pack-years, with a mean of 35 pack-years. Pulmonary function tests showed a mean forced vital capacity of 85.9% and a mean forced expiratory volume of 87.7%. Although three patients had a history of extrathoracic malignancy and one patient had a history of stroke, all these patients maintained acceptable levels of physical activity.

Main outcomes of needle aspiration

The outcomes of needle aspiration for moderate to

Table 1 Baseline characteristics of patients with moderate to severe pneumothorax following TTNB

Cases	Age (years)/ sex	Comorbidities	Current smoker	Smoking history (pack-years)	BMI (kg/m^2)	FVC (%)	FEV_1 (%)	FEV_1/FVC (%)	Affected side
Case 1	75/M	Prostate cancer, history of pulmonary TB	No	40	23.9	78	78	66	Left
Case 2	58/F	Breast cancer	Yes	10	18.3	114	112	80	Left
Case 3	58/M	Buccal cancer, HTN	No	40	25.1	83	84	76	Left
Case 4	87/M	HTN	No	50	20.2	90	116	71	Right
Case 5	65/M	–	No	30	24.9	62	63	73	Left
Case 6	67/M	HTN	No	20	28.8	115	121	73	Left
Case 7	77/M	Stroke history	Yes	55	21.3	59	40	46	Left

TTNB, transthoracic needle biopsy; BMI, body mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; M, male; F, female; TB, tuberculosis; HTN, hypertension.

Table 2 Main outcomes of needle aspiration for moderate to severe pneumothorax following TTNB

Cases	Size of PNX before NA (%)	Size of PNX 1 h after NA (%)	Size of PNX 12 h after NA (%)	Persistent air aspiration	Presence of lung sliding sign just after NA	Chest tube drainage	Success or failure	Complications	Size of PNX 1 h after chest tube drainage (%)	Hospital stay (day)
Case 1	32.7	27.4	33.9	Yes	Yes	Yes	Failure	No	7.1	11
Case 2	40.4	17.0	14.4	No	Yes	No	Success	No	–	5
Case 3	31.8	12.3	11.0	No	Yes	No	Success	No	–	2
Case 4	25.7	13.4	13.4	No	Yes	No	Success	No	–	6
Case 5	58.3	55.7	–	No	Yes	Yes	Failure	No	0	5
Case 6	34.7	0	0	No	Yes	No	Success	No	–	2
Case 7	28.8	16.2	16.7	Yes	Yes	No	Success	No	–	4

TTNB, transthoracic needle biopsy; PNX, pneumothorax; NA, needle aspiration; h, hour.

severe pneumothorax following TTNB are presented in *Table 2*. Needle aspirations were performed for all seven patients with pneumothoraces >25% in size. No complications related to needle aspiration were observed. Chest radiography taken 1 and 12 h after needle aspiration showed that pneumothorax size was ≤25% in five of the seven patients, thus eliminating the need for chest tube drainage. Radiographic images taken before and 1 and 12 h after needle aspiration on Case 3 are shown in *Figure 4*. In contrast, two patients did not experience a reduction in pneumothorax to <25% after needle aspiration and required chest tube drainage. The mean duration of hospital stay for patients with successful needle aspiration was 3.8 d, compared to 8 d for those requiring chest tube drainage after failure of needle aspiration.

Outcomes related to clinical signs of patients

Outcomes related to clinical signs of patients undergoing needle aspiration for moderate to severe pneumothorax after TTNB are presented in *Table 3*. Vital signs were stable in all patients before needle aspiration, and oxygen saturation remained above 90% in all patients. Prior to the procedure, three out of seven patients reported breathlessness; symptoms improved following the procedure. Two patients who required chest tube drainage experienced pain both 1 (mean NRS score: 4) and 12 h (mean NRS score: 3.5) after the procedure. No pain was reported by patients after needle aspiration (mean NRS score: 0). Analgesics were administered to the two patients who underwent chest tube drainage.

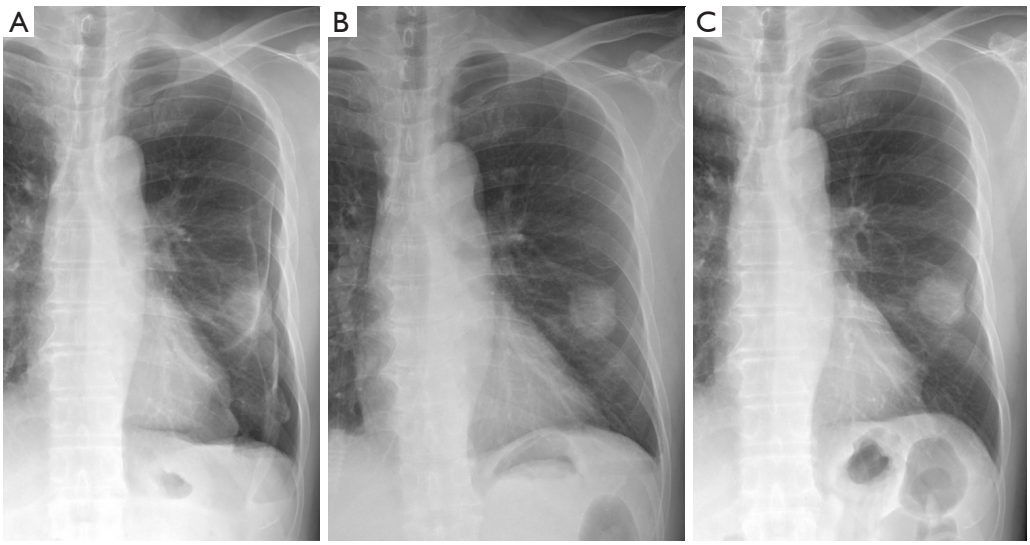

Figure 4 Chest radiographs taken on the Case 3. (A) Before needle aspiration. (B) One hour after needle aspiration. (C) Twelve hours after needle aspiration.

Table 3 Outcomes related to clinical signs of patients for needle aspiration for moderate to severe pneumothorax following TTNB

Cases	Before NA				Presence of breathlessness		Numerical rating scale				Analgesic drug usage (total dose)	
	SBP (mmHg)	HR (bpm)	RR (bpm)	Oxygen saturation (room air)	Before NA	After NA or CTD	Before NA	1 h after NA	1 h after CTD	12 h after CTD	After NA	After CTD
Case 1	134	60	16	98%	No	No	0	0	2	2	No	Ketoprofen patch (30 mg)
Case 2	110	72	16	97%	Yes	No	0	0	–	–	No	–
Case 3	116	72	16	96%	No	No	0	0	–	–	No	–
Case 4	131	64	16	97%	No	No	0	0	–	–	No	–
Case 5	148	61	18	95%	Yes	No	0	0	6	5	No	Tramadol (150 mg)
Case 6	138	56	18	94%	No	No	0	0	–	–	No	–
Case 7	118	83	18	92%	Yes	No	0	0	–	–	No	–

TTNB, transthoracic needle biopsy; NA, needle aspiration; SBP, systolic blood pressure; HR, heart rate; RR, respiratory rate; CTD, chest tube drainage.

Discussion

Key findings

In this prospective pilot study, we safely conducted needle aspirations in patients with moderate to severe pneumothorax following TTNB. No procedure-related complications were observed. Among these patients, the pneumothorax improved in five patients (71.4%) after a simple needle aspiration, and they did not require chest tube drainage. Additionally, needle aspiration reduced hospital stay duration, procedure-related pain, and the need for analgesic medication.

Comparison with similar research

Several studies have demonstrated that although needle aspiration and chest tube drainage have a similar treatment success rate, needle aspiration is the recommended first

line of treatment for spontaneous pneumothorax due to its lower complications rate and reduced hospital stay (6,11,12). A randomized controlled trial found that the immediate success rate of needle aspiration was higher than that of chest tube drainage, even in patients with secondary spontaneous pneumothorax and underlying lung disease (9). Noppen *et al.* proposed that diffuse areas of defection and porosity in the visceral pleura, rather than a single breach such as bleb rupture, were major cause of air leaks in spontaneous pneumothorax (13). However, since pneumothorax following TTNB is typically caused by a single puncture site, it is theoretically expected to be heal relatively quickly. In our study, pneumothoraces in two patients were reduced within an hour of chest tube drainage, as confirmed by chest radiography. These findings suggest that needle aspiration is useful and effective for the treatment of pneumothoraces following TTNB.

Explanation of findings

A meta-analysis on the use of needle aspiration for primary spontaneous pneumothorax reported a success rate of 55.7% (14). Our study showed a higher success rate of 71.4% with needle aspiration. A randomized controlled trial for spontaneous pneumothorax reported a 50% success rate of first needle aspiration with the success rate of the second aspiration reached 46% if the initial attempt failed (9). In our study, we performed chest tube drainage immediately after the first needle aspiration failed, rather than attempting a second aspiration. Given that pneumothorax after TTNB may have easier-to-heal air leakage compared to spontaneous pneumothorax, the success rate might improve with a second needle aspiration. These findings need validation a large-scale prospective study.

Recently, ultrasound has been widely used in intensive care units and operating rooms for diagnosing lung pneumothorax, as it can be performed bedside and allows real-time diagnosis (15). According to a meta-analysis, lung ultrasound was competitive diagnostic accuracy (sensitivity =0.91 and specificity =0.99), with higher sensitivity than supine radiographs (16). In this study, we performed lung ultrasound immediately before and after needle aspiration to confirm the presence of the lung sliding sign. In one patient with moderate to severe pneumothorax, lung sliding was detected via bedside lung ultrasound. For this patient, we re-checked the chest radiograph without performing needle aspiration, and it found that the pneumothorax improved spontaneously. This suggests that lung ultrasound can be an efficient and easy-to-use modality for diagnosing pneumothorax following TTNB. Further well-designed studies are needed to validate this.

The British Thoracic Society pleural disease guidelines recommend discontinuing needle aspiration if >2.5 L of air is aspirated (17), as this indicates a high likelihood of persistent air leak. In our study, persistent air aspiration occurred in two patients, and one of whom required chest tube drainage the day after the needle aspiration due to worsening pneumothorax. Interestingly, lung sliding signs were observed on lung ultrasound immediately after the needle aspiration in both the patients. It is possible that once a collapsed lung re-expands fully after the procedure, the pneumothorax gradually worsens as the air leakage continues. Given that a perforated visceral pleura in pneumothorax following TTNB heals more quickly than in spontaneous pneumothorax, air leakage is expected to decrease relatively quickly. In fact, in one of the two patients with persistent air aspiration, the pneumothorax improved after needle aspiration, indicating that the procedure was successful. We believe that if a second needle aspiration is performed a few hours later or the next day, the success rate of the procedure may increase even in patients who exhibit persistent air aspiration.

Implications of actions needed

A recent meta-analysis of 32 studies on CT-guided TTNB reported a total incidence of pneumothorax following TTNB of 25.3%. In that study 5.6% of patients developed moderate to severe pneumothorax and required intervention (18). Factors such as older age (3), smaller lesion size (18,19), and presence of emphysema or chronic obstructive pulmonary disease (19-21) have been identified as risk factor for pneumothorax after TTNB. Our study's findings align with these previous studies. Pneumothorax developed in 29.5% (103/349) of the patients, and moderate to severe pneumothorax occurred in 5.4% (19/349) of total cohort. Notably, all patients with moderate to severe pneumothorax after TTNB had a history of smoking of >10 pack years, and most exhibited an obstructive pattern in pulmonary function tests. Previous studies have highlighted the increased occurrence of pneumothorax required intervention after TTNB in patients with obstructive lung disease. Yang *et al.* (22) demonstrated a higher frequency of chest tube placement after TTNB in patients with obstructive lung disease, possibly due to dilated and impaired alveolar structure preventing immediate sealing of

air leaks. Dines *et al.* (23) suggested that that pneumothorax absorption progresses more slowly in patients with obstructive lung disease. Therefore, greater caution should be exercised when assessing the risk of moderate to severe pneumothorax after TTNB in these patients.

Strengths and limitations

This study had several limitations. it was a single-arm, single-center study with a small sample size. Therefore, we cannot definitively establish the superiority of needle aspiration over chest tube drainage for treating pneumothorax following TTNB. Additionally, factors such as hospital facilities and operator skills, which could influence the procedure's outcomes, were not considered. However, our findings suggest that in patients with moderate to severe pneumothorax requiring chest tube drainage, successful needle aspiration can reduce the need for chest tube insertion. Moreover, we did not analyze the TTNB characteristics that might affect the amount and persistence of air leakage in the visceral pleura, such as the number of pleural passes, diameter of needle, and distance of pleura-to-lesion. We plan to conduct a large-scale prospective study to investigate these factors and their impact on success rate of needle aspiration in patients with pneumothorax after TTNB.

Despite its limitation, this pilot study is the first prospectively designed research to provide clinically meaningful and useful data on the use of needle aspiration for pneumothorax after TTNB.

Conclusions

Needle aspiration may be a safe, less invasive, and efficient treatment option for managing moderate to severe non-tension pneumothorax after TTNB. This approach has the potential to decrease hospital stay duration, procedure-related pain, and analgesic drug use in patients. However, further well-designed and large-scale prospective clinical trials are needed to confirm these findings.

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None.

Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-924/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-924/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This research was approved by the appropriate institutional review board (approval No. 2021-0531 from Asan Medical Center, Seoul, South Korea). All procedures were conducted after obtaining written informed consent from the participants.

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