Original Article

Diagnostic accuracy and safety of electromagnetic navigation transthoracic needle biopsy under moderate sedation for the diagnosis of peripheral pulmonary lesions

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Background: Novel approaches using virtual computed tomography (CT) guidance, namely electromagnetic navigation transthoracic needle biopsy (EMN-TTNB), enable physicians to perform percutaneous lung biopsies. However, there are very few studies on the clinical experiences of EMN-TTNB, and in previous studies, the procedure was usually performed under deep sedation. This study aimed to determine the diagnostic accuracy and safety of EMN-TTNB under moderate sedation.

Methods: We conducted a retrospective analysis of patients who underwent EMN-TTNB under moderate sedation between May 2021 and November 2022 at Hallym University Dongtan Sacred Heart Hospital in South Korea. Moderate sedation was achieved with midazolam injection in the bronchoscopy room using the Veran SPiNperc EM guidance system (Veran Medical, St Louis, MO, USA). Clinical data were collected by review of medical records, and diagnostic accuracy and safety were calculated.

Results: Thirty-two patients were enrolled (mean age 70.8±11.1 years); 56.3% were male. The mean size of the pulmonary lesions was 36.9±17.4 mm, and the median (interquartile range) distance from the pleura was 15.5 (0.0–30.0) mm. The diagnostic accuracy of EMN-TTNB was 75.0% (21/28), excluding four indeterminate cases. Fourteen patients (50.0%, 14/28) had true-positive and seven patients (25.0%, 7/28) had true-negative lesions. There were no severe adverse reactions such as pneumothorax, respiratory failure, or death, except one case of hemoptysis.

Conclusions: EMN-TTNB under moderate sedation showed an acceptable diagnostic accuracy and good safety profile. The new technology allows physicians to perform percutaneous lung biopsies without the intervention of a radiologist or anesthesiologist.

Keywords: Electromagnetic navigation transthoracic needle biopsy (EMN-TTNB); pulmonary lesion; diagnostic accuracy; safety; moderate sedation

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Introduction

Lung cancer is the leading cause of cancer death worldwide (1). The most effective way to reduce lung cancer mortality is early detection and treatment. Two large randomized controlled trials (RCTs), the National Lung Screening Trial (NLST) and Dutch-Belgian Randomized Lung Cancer Screening Trial (NELSON), showed that screening with low-dose computed tomography (LDCT) reduced lung cancer mortality (2,3). As LDCT screening increases worldwide, the number of lung lesions requiring diagnostic evaluation is increasing significantly (4). The biopsy of pulmonary nodules remains challenging because clinical decision-making usually requires the consideration of several clinical and radiological characteristics including size, location, invasiveness of the available procedure, and risk of complications.

In the case of peripheral lesions, CT-guided percutaneous core needle biopsy (PCNB) is widely performed by interventional radiologists, and the diagnosis rate is as high as 90%. However, studies have reported the occurrence of complications from CT-guided PCNB such as pneumothorax at 20% and bleeding at <2% (5,6). The number of adverse events with PCNB is significantly higher than that with bronchoscopic sampling; therefore, bronchoscopic biopsy may be favored not only in centrally located lesions, but also in peripheral lesions when a positive bronchus sign is present (7). Furthermore, there is no consensus on which of the two methods is superior. Whatever approach is chosen, non-diagnostic procedures often require consideration of alternative approaches, followed by additional procedures performed by other specialists.

With recent advent of electromagnetic navigation (EMN), EMN transthoracic needle biopsy (EMN-TTNB) allows physicians to perform percutaneous lung biopsies. EMN is a method similar to the global positioning system (GPS), which uses a small sensor to determine the position by creating an electromagnetic field around the thorax. Image-guided catheters and minimally invasive methods allow access to peripheral lung lesions (8,9). The prospective pilot study by Yarmus *et al.* that analyzed 24 cases of EMN-TTNB, published in 2016, suggested that the novel EMN-TTNB system has an acceptable safety and feasibility profile (10). A retrospective multicenter study by Mallow *et al.* [2019] that analyzed 129 cases of EMN-TTNB also showed that EMN-TTNB is safe and feasible and has an appropriate diagnostic yield (11). The ALL IN ONE Trial, a prospective multicenter single arm study by Thiboutot *et al.* that aims to evaluate the diagnostic yield of a staged procedure using endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA), electromagnetic navigation bronchoscopy (ENB), and EMN-TTNB for the diagnosis of pulmonary nodules, is currently underway (NCT03338049) (12).

However, there are very few studies on EMN-TTNB, and the procedure has usually been performed under deep sedation in previous studies (10-12). Therefore, the purpose of this study was to demonstrate the diagnostic accuracy and safety performing EMN-TTNB under moderate sedation for diagnosing peripheral pulmonary lesions suspected to be cancerous lesions and to determine clinical factors associated with favorable diagnostic accuracy. We present this article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/

Highlight box

Key findings

- Electromagnetic navigation transthoracic needle biopsy (EMN-TTNB) for peripheral pulmonary lesions under moderate sedation showed an acceptable diagnostic accuracy (75.0%) for malignancy and good safety profile with one case of hemoptysis and no pneumothorax.

What is known and what is new?

- Novel approaches, such as EMN-TTNB, enable physicians to perform percutaneous lung biopsies. There are a few studies on the clinical experiences of EMN-TTNB where the procedure was performed under deep sedation.
- The aim of this study is to determine the diagnostic accuracy and safety of EMN-TTNB under moderate sedation.

What is the implication, and what should change now?

- This new technology allows physicians to perform percutaneous lung biopsies without the intervention of radiologists and anesthesiologists. EMN-TTNB can be used as an alternative to computed tomography-guided percutaneous lung biopsy in certain circumstances.

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Methods

Study design and patients

This study was a single-center, retrospective cohort study. We enrolled adults aged ≥18 years of age who were referred to the pulmonology department for a pulmonary lesion suspected to be cancerous and underwent EMN-TTNB for lung lesion biopsy under moderate sedation between May 2021 and November 2022 at Hallym University Dongtan Sacred Heart Hospital in South Korea. The pulmonary lesions were ≥10 mm, and they were accessible by an anterior or lateral chest percutaneous approach. Patients who were unable to express their opinions and did not cooperate due to cognitive impairment were excluded. Prior to the procedure, recent platelet count and coagulogram were checked to rule out coagulation abnormalities. Anticoagulants and antiplatelet agents were discontinued before EMN-TTNB referring to the published guideline (13). Clopidogrel and aspirin were discontinued for 5 days and new oral anticoagulants (NOACs) for 1–4 days considering the type and renal function. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Hallym University Dongtan Sacred Heart Hospital (No. 2022-08-003). The Institutional Review Board waived the requirement of participants' written informed consent since this was a retrospective study.

EMN-TTNB procedure

Moderate sedation was performed during the procedure by administration of 1–5 mg of midazolam and 25–50 μg of fentanyl intravenously at the beginning of the procedure. The attending physician also administered an additional dose of midazolam during the procedure to ensure adequate sedation. Patients were observed under standard bronchoscopy monitoring protocols. The standard monitoring consisted of non-invasive blood pressure, heart rate, electrocardiogram, pulse oximetry, and respiratory rate. In order to avoid desaturation episodes, oxygen support provided by nasal prongs was usually required during and after the procedure. Furthermore, a fasting duration of at least 4 hours was recommended before the procedure.

EMN-TTNB was performed using the Veran SPiNperc EMN system (Veran Medical, St Louis, MO, USA). On the day of the procedure, all patients underwent inspiration/expiration chest CT; the scans were used to create a virtual airway map with 0.5-mm intervals and 0.67–0.75-mm thickness after attaching a navigational tracking pad (vPAD2, Veran Medical) on the patient's anterior chest. The tracking pad functioned as a stationary reference point, obtained from the CT dataset, on the patient. A process called registration refers to matching a patient's airway with a virtual bronchial tree. The bronchoscope is moved through the bronchial tree sampling each lobe, and the system matches the locus of movement to the CT bronchial tree, thus locking in the bronchial tree map to the patient's airways. Once registration is complete, the probe is placed on the primary and secondary carinas to ensure exact alignment with the carinas with each scan. With moderate sedation, it is difficult to insert a bronchoscope for the registration process in the prone position; therefore, EMN-TTNB has to be performed in the lateral decubitus position for lesions that are difficult to access in the supine position. If a lateral approach was required, CT had to be performed in the same lateral decubitus position as that adopted during the procedure. Before the procedure, the physician identified and marked the target lesion and determined the chest wall entry site to avoid organ or vascular injury. The software then provided the needle's entry site and pathway during real-time EMN for percutaneous access.

The biopsy site was prepared and draped under sterile conditions; then, 1% lidocaine was injected subcutaneously. An EMN tip tracking biopsy needle introducer was used to identify the entry site following navigational guidance. An introducer needle was passed through the pleura, and a 20-gauge coaxial core biopsy instrument (SuperCore Argon Medical, Frisco, TX, USA) was used through the introducer needle to obtain tissue samples. After taking the EMN-TTNB sample, the needle introducer was removed and the wound was bandaged. All patients underwent chest radiography after the procedure and on the next day. Rapid on-site examination and fine-needle aspiration were not performed in any of the cases.

Outcome measures

We collected data on demographic characteristics, radiological findings including target lesion size and distance from the pleura, procedure reports, pathological outcomes, and adverse events through the electronic

medical records.

EMN-TTNB samples indicating non-malignant or indeterminate conditions on pathological examination were referred to as "negative" cases. In these cases, according to the judgment of the physician, short-term follow-up with chest CT or another type of biopsy was performed. The following cases were defined as "false-negative": (I) repeat biopsy, such as surgical, CT-guided PCNB, and bronchoscopic proved malignancy, (II) follow-up chest CT within 1 year showed progression, (III) lung cancer was confirmed from a non-index lesion, and (IV) patient was treated as having lung cancer without pathological confirmation. In contrast, the following cases were defined as "true-negative": (I) other diagnostic tests confirmed non-malignancy, (II) the lesion improved without cancer treatment, and (III) follow-up chest CT up to 1 year did not show progression.

Adverse events were identified and classified according to the Common Terminology Criteria for Adverse Events (CTCAE), version 5.0 (14). If pneumothorax was found on chest radiography, a chest tube was inserted in accordance with the chest tube insertion criteria of the British Thoracic Society guidelines (15). For pneumothorax that did not require a chest tube, chest radiography was followed with oxygen application.

Statistical analysis

Categorical variables were described as simple proportions (%), and continuous variables as means with standard deviation (SD) or median [interquartile range (IQR)]. The diagnostic accuracy of EMN-TTNB was calculated by dividing the sum of positives and negatives by the total number of cases excluding uncertain cases. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were also calculated. Patients with initially negative results and insufficient follow-up were assumed to be true-negative or false-negative cases, respectively, and included in the analysis. This method provided low and high estimates of the diagnostic accuracy, sensitivity, specificity, and PPV and NPV of EMN-TTNB for malignant diagnosis.

Univariate analysis was performed using a logistic regression model to determine which factors increase diagnostic accuracy. A P value of <0.05 was considered statistically significant. All statistical analysis was conducted using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA).

Results

Patients and procedural characteristics

A total of 32 patients who underwent EMN-TTNB were enrolled. For analysis of the diagnostic accuracy, a total of 28 patients were finally evaluated after excluding patients with initially unclear biopsy results from EMN-TTNB without 1 year of chest CT follow-up. The baseline characteristics of the 32 patients, lung lesions sampled, and procedures are summarized in *Table 1*. The mean age of the patients was 70.8±11.1 years, 56.3% were male and 50.0% were never smokers. The mean size of the pulmonary lesions was 36.9±17.4 mm. Six patients (18.8%) had lesions 10–20 mm, 6 patients (18.8%) had lesions between >20–30 mm, and the remaining 20 patients (62.5%) had lesions >30 mm.

The median distance from the pleura was 15.5 (IQR, 0.0–30.0) mm. The right upper and left lower lobes were the most prevalent locations at 31.2% each, followed by the right lower lobe at 15.6%. In all cases, the introducer needle was passed only once, and core biopsy was performed 5.0 (IQR, 4.0–5.0) times. The total duration of EMN-TTNB, defined as the time from the start of sterile field preparation prior to initial needle placement to needle removal, was 16.5 (IQR, 15.0–25.3) minutes. Midazolam and fentanyl were administered for moderate sedation at median doses of 3.0 (IQR, 2.0–3.0) mg and 50.0 (IQR, 25.0–50.0) μg.

Diagnostic outcomes of EMN-TTNB for lung cancer

The final diagnostic results of EMN-TTNB are shown in *Figure 1*. Of the 32 patients who underwent EMN-TTNB procedures, 14 (43.8%) were diagnosed as malignant and 18 (56.3%), as non-malignant. Twelve out of 14 patients were diagnosed with adenocarcinoma, one with squamous cell carcinoma and one with small cell lung cancer. Of the 18 initially negative cases, 7 (38.9%) were confirmed as true-negatives and 7 (38.9%) as false-negatives. Because malignancy was clinically suspected, a different method of biopsy was performed for the seven patients with false-negative findings: (I) chronic inflammation was confirmed on EMN-TTNB, but squamous cell carcinoma was confirmed on subsequent surgery; (II) chronic inflammation was confirmed on EMN-TTNB, but adenocarcinoma was confirmed on subsequent surgery; (III) normal lung tissue was confirmed on EMN-TTNB, but squamous cell carcinoma was confirmed on subsequent surgery; (IV)

Table 1 Characteristics of the study patients and procedure

Characteristics	Total (n=32)
Age, years, mean ± SD	70.8±11.1
Male, n (%)	18 (56.3)
Smoking, n (%)	
Never smoker	16 (50.0)
Former smoker	6 (18.8)
Current smoker	10 (31.2)
Pack years, median (range)	4.0 (0.0–24.0)
Comorbidities, n (%)	
Diabetes	6 (18.8)
Hypertension	11 (34.4)
Chronic obstructive pulmonary disease	4 (12.5)
Asthma	3 (9.4)
Interstitial lung disease	1 (3.1)
Chronic neurological disease	2 (6.2)
Heart disease	3 (9.4)
Chronic liver disease	1 (3.1)
Chronic kidney disease	0 (0.0)
Size, mm, mean ± SD	36.9±17.4
Lesion, n (%)	
10–20 mm	6 (18.8)
>20–30 mm	6 (18.8)
>30 mm	20 (62.5)
Location, n (%)	
Right upper lobe	10 (31.2)
Right middle lobe	3 (9.4)
Right lower lobe	5 (15.6)
Left upper lobe	4 (12.5)
Left lower lobe	10 (31.2)
Position, n (%)	
Supine	14 (43.8)
Lateral	18 (56.2)
Type of lesion, n (%)	
Solid	29 (90.6)
Part-solid	3 (9.4)
Ground-glass opacity	0 (0.0)
Distance from skin to pleura, mm, median (range)	29.0 (26.0–42.5)
Distance from pleura to lesions, mm, median (range)	15.5 (0.0–30.0)
Target motion (inspiration/expiration difference), median (range)	2.9 (2.0–5.8)
Total dose of sedatives, median (range)	
Midazolam, mg	3.0 (2.0–3.0)
Fentanyl, μg	50.0 (25.0–50.0)
Total procedure (EMN-TTNB) time, min, median (range)	16.5 (15.0–25.3)
Number of biopsies, median (range)	5.0 (4.0–5.0)
Skin shift, yes, n (%)	3 (9.4)

Skin shift: a phenomenon in which the location of the consumable tip shown on the screen and the actual tip location are different. SD, standard deviation; EMN-TTNB, electromagnetic navigation transthoracic needle biopsy.

chronic inflammation was confirmed on EMN-TTNB, but adenocarcinoma was confirmed on subsequent surgery; (V) chronic inflammation was confirmed on EMN-TTNB, but adenocarcinoma was confirmed on subsequent surgery; (VI) normal lung tissue was confirmed on EMN-TTNB, but on ENB, metastatic adenocarcinoma from colorectal cancer was confirmed, and the same result was confirmed on subsequent surgery; (VII) normal lung tissue was confirmed on EMN-TTNB, but on ENB, squamous cell carcinoma was confirmed, and the same result was confirmed on subsequent surgery.

The final diagnostic accuracy of EMN-TTNB was 75.0% and diagnostic yield for lung cancer is 14/21 (66.7%) excluding false negatives, and 14/28 (50.0%) including false negatives. Sensitivity was 66.7%, specificity was 100%, positive predictive value was 100%, and negative predictive value was 50.0% (*Table 2*). Four indeterminate cases were initially considered negative on EMN-TTNB and did not complete 1 year of follow-up CT imaging. Assuming that all indeterminate cases were false-negative or true-negative cases, the diagnostic accuracy was between 65.6% and 78.1%, sensitivity was between 56.0% and 66.7%, specificity was 100%, positive predictive value was 100%, and negative predictive value was between 38.9% and 61.1%.

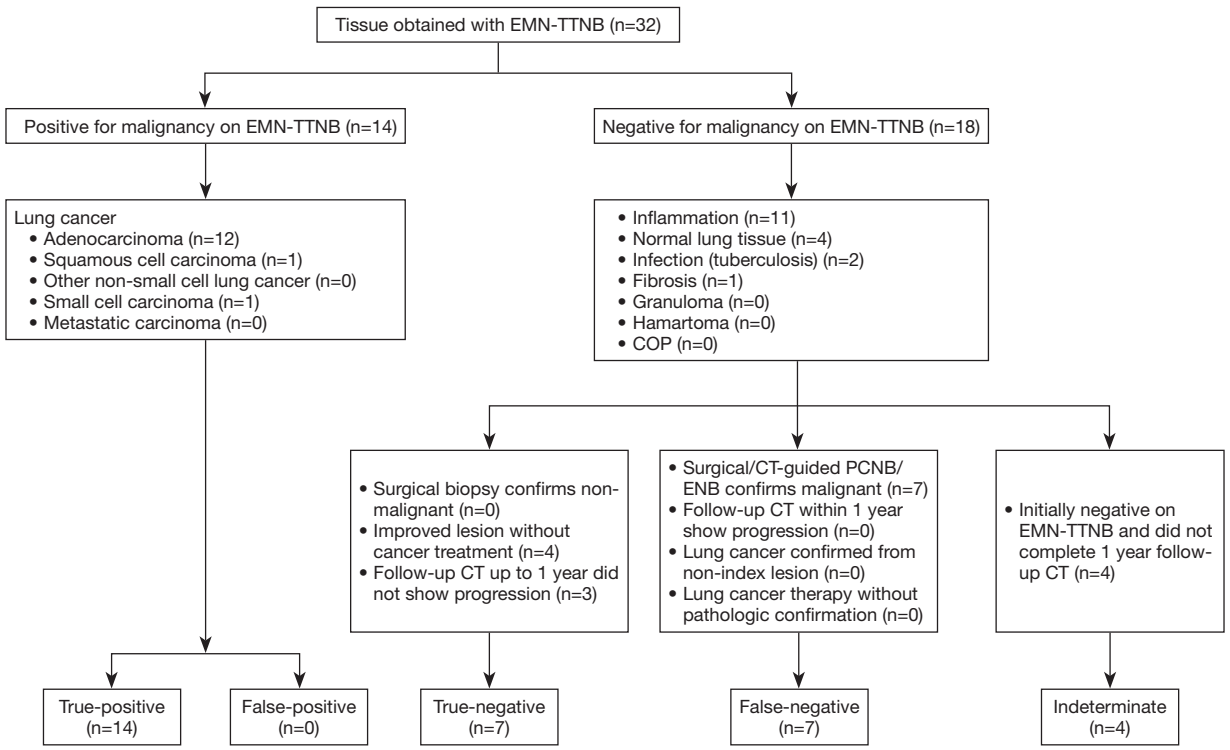

Figure 1 Flow chart of diagnostic outcomes of the study subjects. EMN-TTNB, electromagnetic navigation transthoracic needle biopsy; COP, cryptogenic organizing pneumonia; CT, computed tomography; CT-guided PCNB, CT-guided percutaneous needle biopsy; ENB, electromagnetic navigation bronchoscopy.

Safety profile

There were no adverse events during the procedure including acute toxicity related to sedation, hypoxemia, hypotension, cardiac arrhythmia, and cardiorespiratory arrest. There were no cases of pneumothorax, respiratory failure, or death. However, there was one case of hemoptysis (CTCAE grade 3), which was stabilized after transfusion of one pack of red blood cells.

Factors associated with high diagnostic accuracy

Table 3 shows the univariate analysis of factors related to the high diagnostic accuracy of EMN-TTNB. Diagnostic accuracy using EMN-TTNB did not show any association with lesion size, distance from the pleura, procedure position, and number of core biopsies obtained. None of the factors was associated with diagnosis rate.

Discussion

In the present study, the overall diagnostic accuracy of EMN-TTNB under moderate sedation for lung cancer was 75.0%, excluding the indeterminate cases. In addition, the adverse event rate was low as 3.1% (1/32), with one case of hemoptysis. There were no cases of pneumothorax, respiratory failure, or death, indicating the good safety profile of EMN-TTNB.

In a prospective pilot study, Yarmus *et al.* [2016] analyzed 24 cases of EMN-TTNB. The feasibility of EMN-TTNB was 96%, and the diagnostic yield was 83%. This was the first human pilot study demonstrating an acceptable feasibility and diagnostic yield with a novel EMN-TTNB system (10). In a retrospective multicenter study, Mallow *et al.* [2019] analyzed 129 cases of EMN-TTNB. The diagnostic yield of EMN-TTNB was 73.7%, and this study also showed that EMN-TTNB was feasible and had an appropriate diagnostic yield (11). In our study, the diagnosis accuracy of EMN-TTNB was 75.0%, similar to that reported in previous studies.

In this study, there were seven false-negative cases. In one case, the pulmonary lesion was difficult to access because it was located near the heart. In another case, it was

Table 2 Diagnostic outcomes of EMN-TTNB for lung cancer

Diagnostic outcomes	Excluding indeterminate cases (n=28)	Low estimate (n=32)	High estimate (n=32)
Diagnostic accuracy	75.0% (21/28)	65.6% (21/32)	78.1% (25/32)
Sensitivity	66.7% (14/21)	56.0% (14/25)	66.7% (14/21)
Specificity	100% (7/7)	100% (7/7)	100% (11/11)
Positive predictive value	100% (14/14)	100% (14/14)	100% (14/14)
Negative predictive value	50.0% (7/14)	38.9% (7/18)	61.1% (11/18)

Low estimate: all indeterminate cases are assumed to be false negatives; High estimate: all indeterminate cases are assumed to be false positives; Diagnostic accuracy: (true-positive + true-negative)/all biopsies performed. EMN-TTNB, electromagnetic navigation transthoracic needle biopsy.

Table 3 Factors associated with the diagnostic accuracy of EMN-TTNB

Variable	Univariate	
	OR (95% CI)	P value
Age	0.88 (0.75–1.04)	0.127
Female sex (*vs.* male)	0.92 (0.02–42.46)	0.964
Smoking history (*vs.* never smoker)	0.27 (0.01–9.07)	0.465
Lesion size in mm	1.05 (0.96–1.15)	0.268
Lower lobe distribution (*vs.* upper or middle lobe)	2.01 (0.05–84.66)	0.715
Distance from pleura in mm	1.00 (0.93–1.09)	0.945
Position (*vs.* supine)	2.28 (0.06–88.59)	0.660
The number of core biopsies obtained	0.98 (0.08–11.73)	0.988
Total procedure time in minutes	0.93 (0.80–1.08)	0.340

EMN-TTNB, electromagnetic navigation transthoracic needle biopsy; OR, odds ratio; CI, confidence interval.

relatively deep and difficult to access because it was located at the end of the outer one-third of the lung zone. In three out of seven patients, since the procedure was performed in the lateral decubitus position, it is thought that the CT-body divergence error was maximized in comparison to that in the supine position. CT-body divergence means that the CT scan before the procedure does not perfectly match the patient's airway direction at the time of the procedure due to changes in the patient's orientation (16). This eventually creates a serious difference between real lesion and virtual target. In addition, skin shift occurred in 3 (9.4%) out of 32 patients, and one of them was confirmed as a false-negative case, which is considered to be a factor that reduces the accuracy of diagnosis. Skin shift is a phenomenon in which the location of the consumable tip shown on the screen and the actual tip location are different (17). Furthermore, the fact that the five out of seven patients were examined in the initial period of the use of EMN-TTNB before the operator became accustomed to the procedure may have had some influence on the diagnostic accuracy.

In this study, all the procedures were conducted under moderate sedation. Deep sedation is safe, but it is associated with potential complications that may contribute to morbidity (18). In the prospective pilot study by Yarmus *et al.*, all patients were placed under deep sedation by a board-certified anesthesiologist with a laryngeal mask airway in place (10). In another retrospective multicenter study by Mallow *et al.*, all patients were placed under moderate or deep sedation (11). Moderate sedation does not need any assistance from an anesthesiologist, and the risk of adverse event of deep sedation can be avoided (18). Although this study was conducted only under moderate sedation, the diagnosis rate was similar and the safety profile was better than that reported in previous studies. Moreover,

in this study, EMN-TTNB took only 16.5 (15.0–25.3) min, on median (IQR), which was relatively shorter than the 18.3 and 20 min, on average, respectively, in the two previous studies (10,11). These results suggest that moderate sedation is a suitable option for performing EMN-TTNB.

In the prospective pilot study by Yarmus *et al.*, 5 patients experienced pneumothorax (5/24, 21%) of which only 2 (2/24, 8%) required chest tube insertion. No bleeding, hemoptysis, or respiratory events occurred (10). In the retrospective multicenter study by Mallow *et al.*, 23 patients experienced pneumothorax (23/129, 17.8%) of which 16 (16/129, 12.4%) underwent small-bore chest tube placement. Minor bleeding (2/129, 1.6%), chronic obstructive pulmonary disease (COPD) exacerbation (1/129, 0.78%), transient hypercapnia (2/129, 1.6%) and transient hypoxemia (1/129, 0.78%) were encountered (11). In our study, there were no severe adverse reactions such as pneumothorax, respiratory failure, or death, except one case of hemoptysis. This result indicated the good safety profile with EMN-TTNB under moderate sedation.

The anesthesia method may affect the incidence of pneumothorax during EMN-TTNB. Because this study was conducted under moderate sedation, no patient received positive pressure ventilation; therefore, pneumothorax is less likely to occur (19). However, moderately sedated patients move more in the lateral decubitus position, have more difficulty maintaining the position, and breathe more irregularly than deeply sedated patients. Eventually, these factors increase the risk of pneumothorax. In addition, the distance from pleura to lesion may affect the incidence of pneumothorax. The average distance from pleura to lesion in previous studies were 12.6 and 13.2 mm, respectively (10,11), which were similar with 15.5 mm (median) in our study. In previous studies, the incidence rates of pneumothorax were 17.8% and 21%, respectively (10,11), which are comparable to the incidence of pneumothorax for CT-guided PCNB (5,6); however, it is surprising that there was no case of pneumothorax in this study despite moderate sedation. This discrepancy can be attributed to the lower prevalence of COPD (11.5% *vs.* 38.0%, 38.7%) and larger size of pulmonary lesions (36.9 *vs.* 27.3, 20.3 mm) in our study than in the previous studies (10,11). In other words, larger size of lesions and small numbers may also reflect only one complication (hemoptysis).

Taken together, the advantages of EMN-TTNB are as follows: First, EMN-TTNB prevents the operator from being exposed to radiation, meaning the physicians and staff do not need to wear lead to perform the procedure. Second, EMN-TTNB tracks the patient's breathing, and this gives the operator increased confidence in determining the needle position. Third, EMN-TTNB can be performed in any sterile field such as a bronchoscopy room and not just a CT suite, and this give physicians some flexibility in terms of planning their procedure schedule. EMN-TTNB is expected to be a useful alternative in hospitals where there is an absence or shortage of chest interventional radiologists.

This study has several limitations. First, this was a single-arm, retrospective study involving a single center. Therefore, the results cannot be generalized. A prospective multicenter study using EMN technology is currently underway (NCT03338049). Therefore, additional data on the diagnosis rate and safety profile will be available in the future. Second, EMN-TTNB under moderate sedation cannot be performed in the prone position because of the registration process using bronchoscopy. When performing CT-guided PCNB or EMN-TTNB under deep sedation, usually the anterior or middle mediastinal lesions are approached from the supine position, and the middle, posterior mediastinal lesions are approached from the prone position (20). Therefore, EMN-TTNB under moderate sedation, the middle, posterior mediastinal lesions have no choice but to approach it in the lateral decubitus position. However, it is difficult to maintain posture in the lateral decubitus position and the chest wall motion is greater than in the prone position (21). Considering that the safety and success of EMN-TTNB depend on patient cooperation, more attention should be paid to sedation and posture, especially in the lateral decubitus position. Third, none of the physicians had prior experience with the EMN system. Therefore, the diagnosis accuracy and safety of the procedure are expected to increase as more experience is accumulated. Fourth, EMN systems cannot be introduced in all hospitals because initial system deployment is costly and financially burdensome.

Conclusions

In conclusion, EMN-TTNB under moderate sedation showed an acceptable diagnostic accuracy and good safety profile. This new technology allows physicians to perform percutaneous lung biopsies without the intervention of radiologists and anesthesiologists. Furthermore, EMN-TTNB can be performed as an alternative to CT-guided PCNB in certain circumstances. Further prospective, large multicenter studies of EMN-TTNB under moderate sedation are needed.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-111/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. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Institutional Review Board of Hallym University Dongtan Sacred Heart Hospital (No. 2022-08-003). The Institutional Review Board waived the requirement of participants' written informed consent since this was a retrospective study.

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