ORIGINAL ARTICLE

Clinical Usefulness of Preoperative Computed Tomography-Guided Needle Localization of Small Pulmonary Nodules for Video-Assisted Thoracic Surgery

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Objective: To evaluate the clinical usefulness of preoperative computed tomography (CT)-guided needle localization of small pulmonary nodules for video-assisted thoracic surgery (VATS).

Materials and Methods: Between October 2018 and June 2021, 32 consecutive small pulmonary nodules were treated with preoperative CT-guided needle localization of less than 2 cm pulmonary nodules for VATS. All basic characteristic and Procedural success, technical success, and complication rates were evaluated from the medical record.

Results: The procedures were blue-dye needle localization by isosulfan blue (94%), and hook-wire needle localization (6%). The median size of the tumor was 9 mm (range 2 to 17 mm). The initial procedural success rate of the CT-guided needle localization procedure was 100%. The technical success rate was 90.6%. Approximately 73% of the resected lung nodules were pathologically proven malignancies. Minor complications, such as minimal pneumothorax (34%) and minimal parenchymal hemorrhage (13%), occurred at the needle access site.

Conclusion: Preoperative CT-guided needle localization in VATS for small pulmonary nodules was feasible and safe.

Keywords: Thoracic surgery; Video-assisted; Multiple pulmonary nodules; Tomography; X-Ray computed

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Screening for lung nodules in asymptomatic high-risk patients by low-dose computed tomography (CT) is a proven tool for reducing the mortality rate of lung cancer by early detection of small lung nodules[1-9]. In the nodules suspected of being malignant, tissue pathological analysis is required for diagnosis. Transthoracic needle biopsy is often challenging and difficult when the nodule size is smaller than 2 cm, predominantly shows ground-glass opacity (GGO), or being located where it is difficult to reach[10]. Video-assisted thoracic surgery (VATS) has become increasingly popular for pathological diagnosis of small lung nodules because it causes less tissue injury, requires shorter hospital stays, provides better cosmetic results, and has long-term survival outcomes similar to those of conventional thoracotomy[11-13]. However, intraoperative identification of small lung nodules is challenging for thoracic surgeons during uniportal VATS because of the difficulty to apply finger palpation and lack of surface abnormalities. Thus, accurate preoperative CT-guided needle localization is helpful for performing successful VATS excision of small nodules[14-16].

There are several methods for preoperative CT-guided needle localization using various materials. In Thailand and at the authors institution, the two main methods for CT-guided needle localization are 1) blue-dye needle localization and 2) hook-wire needle localization. Both methods have high accuracy rates, low morbidity rates, short procedural times, and are cost effective[14-16]. Nevertheless, although there are reports in the literature about the technical success and safety of the procedure, there are no reports on the best practices for performing the preoperative CT-guided needle localization procedure by thoracic surgeons or the factors that may result in difficulty

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for interventional radiologists while performing the procedure. The present study aim was to evaluate the outcomes of the preoperative CT-guided needle localization procedure by thoracic surgeons and identify the most important procedural details necessary for success.

Materials and Methods

Between October 2018 and June 2021, 32 consecutives, smaller than 2 cm in size, pulmonary nodules were obtained from 27 patients who underwent preoperative CT-guided needle localization for VATS. The patients included 12 men and 15 women with age ranging between 52 and 70 years and a mean age of 66 years. Most of the patients were non-smokers at 88%. About 63% of the patients had a known history of malignancy (Table 1). The current study was approved by the Local Research Committee (institutional review board serial number: 199/63), Vajira Hospital, Navamindradhiraj University.

Pulmonary nodule characteristics

The pulmonary nodule characteristics were described according to the most recent CT study before the CT-guided needle-localization procedure. The CT images were displayed on a picture archiving and communications system workstation and reviewed by one interventional radiologist. The pulmonary nodules were described as pure solid (72%), pure GGO (7%), or partially solid (2%). All pulmonary nodules were smaller than 2 cm in size. The median size of the tumor was 9 mm (range 2 to 17 mm). The location of the tumor was classified according to the lobes and segments of the lung, which were the right upper lobe (RUL) in 34%, left upper lobe (LUL) in 25%, right lower lobe (RLL) in 19%, left lower lobe (LLL) in 13%, and right middle lobe (RML) in 9%. The distance between the pulmonary nodule and the adjacent critical structures were also measured, including the nearest pulmonary vessels, bronchus, and pleura (Table 2).

CT-guided needle-localization procedure

The procedures were performed by a board-certified interventional radiologist of the present study institution who had three years or more of experience in the CT-guided percutaneous lung nodule biopsy and needle localization procedures. The pre-operative needle localization was recommended to the pulmonary lesions smaller than 15 mm and located more than 5 mm in depth from the pleural surface. The proper patient position and needle

Table 1. Patient's demographics data

	n=32
Age (years); mean±SD	58.5±17.6
Sex (male:female); n (%)	12:15 (44:56)
Smoking status; n (%)	
Non-Smoker	28 (88)
Smoker	4 (12)
Underlying disease; n (%)	
Diabetes	2 (6)
Hypertension	14 (44)
Dyslipidemia	5 (16)
Cardiovascular disease	1 (3)
Others	4 (13)
Known malignancy; n (%)	20 (63)

SD=standard deviation

Table 2. Pre-operative pulmonary nodule characteristics

	n=32
Characteristics; n (%)	
Pure solid	23 (72)
Partially solid	2 (6)
Pure GGO	7 (22)
Location of the pulmonary nodule; n (%)	
Right upper lobe	11 (34)
• Apical segment	5 (16)
• Posterior segment	3 (9)
• Anterior segment	3 (9)
Right middle lobe	3 (9)
• Medial segment	1 (3)
• Lateral segment	2 (6)
Right lower lobe	6 (19)
• Superior segment	2 (6)
• Anterior basal segment	2 (6)
• Lateral basal segment	2 (6)
Left upper lobe	8 (25)
• Apicoposterior segment	5 (16)
• Superior lingular segment	3 (9)
Left lower lobe	4 (13)
• Superior segment	2 (6)
• Anteromedial basal segment	2 (6)
Pulmonary nodule size (mm); median (P25 to P75)	9 (5.2 to 11)
Distance from adjacent structures (mm); median (P25 to P75)	
Pulmonary vessels	2.5 (1 to 6)
Bronchus	14.5 (9 to 28)
Pleura	9.5 (3 to 19)
Pathological results; n (%)	
Malignancy (primary or metastasis)	23 (72)
Other benign conditions	9 (28)

GGO=ground-glass opacity

access route were determined by the performing interventional radiologist depending on the location of the pulmonary nodule and the surrounding critical structures. The procedures were performed with the patient under local anesthesia administered through a standard 20-G disposable spinal anesthesia needle. All procedures were performed under sequential non-contrast CT guidance. In the present study institution, two types of localization methods were used blue-dye using isosulfan blue needle localization routinely used for sentinel lymph node biopsy procedures (Figure 1), and hook-wire needle localization (Figure 2), using a standard non-repositionable breast localization needle (Argon Medical Devices, Plano, TX, USA).

The aim of the procedure was to achieve preoperative localization of the pulmonary nodule considered to be the target lesion for the VATS excision. The patient was then transferred from the CT room to the operating room within two hours after the needle localization procedure was completed.

VATS procedure

All surgical procedures were performed by a single board-certified cardiovascular thoracic surgeon. The procedures depended on the surgeon's preference for VATS or non-intubated VATS. The number of ports depended on the surgeon's techniques, which were routinely performed via uniportal VATS through a 3 to 4-cm incision at the fifth intercostal space at the anterior axillary line.

After completing the surgery, single small chest tubes (28-French or 24-French) were routinely inserted through the incision site and placed under endoscopic vision. Extubation of the patients was attempted immediately after the operation. Routine postoperative care included adequate pain control, early mobilization, and pulmonary toilet exercise. The chest drain was removed if the content drainage was clear, had less than 200 mL/day, and showed no air leakage.

All patients were followed up at the cardiovascular thoracic clinic two weeks after discharge to evaluate clinical symptoms by chest X-ray radiography.

Risk factors analyzed

Risk factors related to complications of the CT-guided needle localization procedure were nodule size, nodule location, distance from the nearest critical structures including pulmonary vessels and bronchus, distance from the nearest pleura that may increase the risk of pneumothorax, and anatomical structures that must be avoided during needle access, such as the scapula, vertebra, and rib.

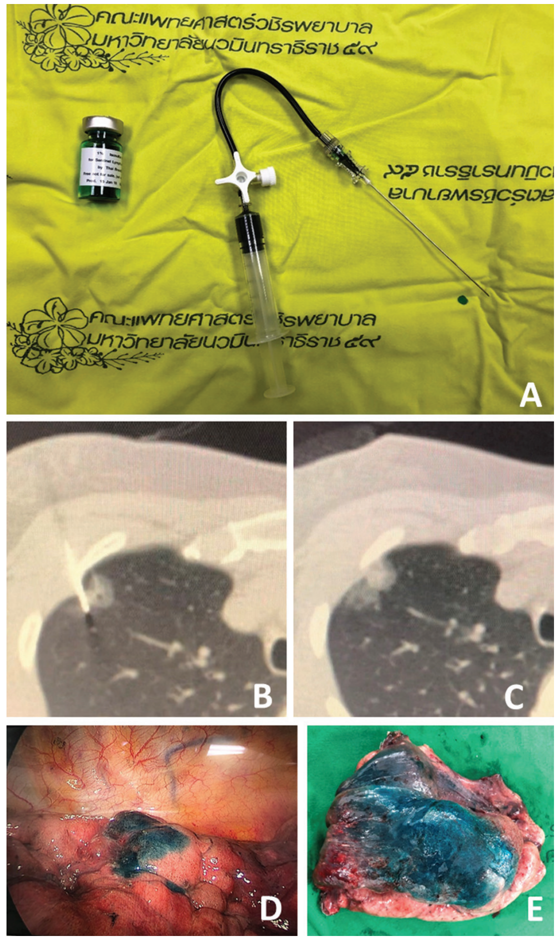

Figure 1. (A) Blue-dye needle localization using isosulfan blue injected via a 20-G spinal needle connected to a three-way stop cock via an extension tube, (B) Computed tomography (CT)-guided needle placement at the lateral border of a 1.1-cm part-solid ground-glass opacity nodule at the anterior segment of the right upper lobe, (C) Post-procedural CT image after administration of about 1.5 mL of isosulfan blue via the needle showing ground-glass opacity surrounding the target nodule, (D) Intraoperative findings of isosulfan blue staining during the video-assisted thoracic surgery procedure, and (E) Gross specimen of the wedge lung resection.

Procedural assessment

The initial procedural success was defined as successful needle localization of the targeted pulmonary nodule in the final CT images. The difficulty of the procedure was determined by the total procedural time and total number of CT sequences to correctly localize the needle in the targeted pulmonary nodule. Complications were evaluated by imaging findings and clinical symptoms during and after the CT-guided needle localization

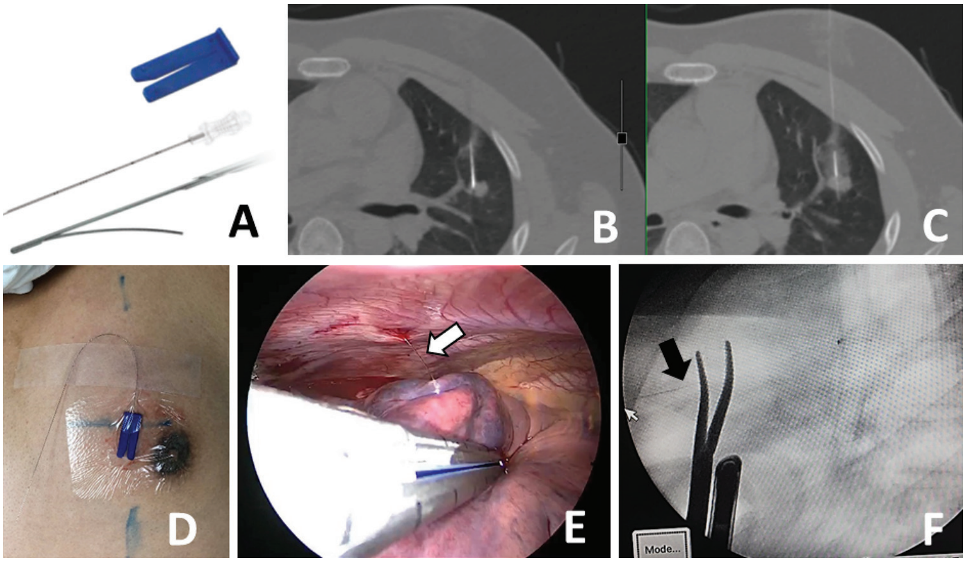

Figure 2. (A) Hook-wire needle localization using a standard non-repositionable breast localization needle in the present study institution, (B) Computed tomography (CT)-guided needle placement at the anterior border of a 1.1-cm solid nodule at the superior lingular segment of the left upper lobe, (C) Post-procedural CT image after hook-wire placement via the needle showing minimal parenchymal hemorrhage after needle removal, (D) A skin-retention clip is used to secure the position of a hook-wire during transfer to the operating room, (E) Intraoperative findings of hook-wire (white arrow) during the video-assisted thoracic surgery (VATS) procedure, (F) Fluoroscopy is used simultaneously with VATS to identify the tip of the hook-wire (black arrow) during wedge lung resection.

procedure. Technical success was achieved if there was effective localization during the VATS procedure with successful excision of the targeted pulmonary nodule and favorable pathological results.

Statistical analysis

Categorical variables were presented as frequencies and proportions; continuous variables were presented as the median (P25 to P75) for dichotomous data and skewed distributed data. Data were analyzed by performing simple logistic regression to determine if the initial procedural and technical success rates were related to the tumor size, access route, tumor location, and nearby critical structures.

All statistical analyses were performed in IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, USA). Differences with p-value less than 0.05 were considered statistically significant.

Results

The 32 pulmonary nodules achieved successful needle localization in the final CT images, so the initial procedural success rate of the CT-guided needle localization was 100%. Twenty-nine lesions showed effective localization during the VATS procedure. Two lesions were unidentifiable because the blue dye splashed over a large area of the parietal pleura. Another lesion was unidentifiable because no blue-dye staining of the visceral pleura was observed. Therefore, the technical success rate was 90.6%. Successful removal of these three non-visualized pulmonary nodules was still achieved by performing anatomical-based curative resection with confirmed definitive pathological diagnosis. Twenty-three of the resected pulmonary nodules or about 73%, were pathologically proven malignancies (Table 2).

The median total CT sequences to achieve the target nodule was eight (range 6 to 10), whereas the median procedural time was 17 minutes (range 0 to 25) (Table 3).

There were no major complications and no procedure-related death occurred. Only minor complications were observed, including minimal pneumothorax (34%) and minimal parenchymal hemorrhage (13%) at the needle access site with no serious clinical consequences, so they required no further interventional management.

All patients developed green urine on the day of isosulfan blue administration (Figure 3) with fading color of the urine over the next few days.

Univariate analysis for evaluation of the risk factors for procedure-related complications (Table 4)

Table 3. CT-guided needle-localization procedural details

	n=32
Position; n (%)	
Supine	15 (47)
Prone	12 (38)
Right or left lateral decubitus	2 (6)
Right or left anterior oblique	3 (9)
Localization technique; n (%)	
Blue-dye localization	30 (94)
Hook-wire localization	2 (6)
Total CT sequences to achieved the target nodules; median (P25 to P75)	8 (6 to 10)
Total procedural time (minutes); median (P25 to P75)	17 (8 to 25)
Complication; n (%)	
Minimal pneumothorax	11 (34)
Minimal parenchymal hemorrhage	6 (19)

CT=computed tomography

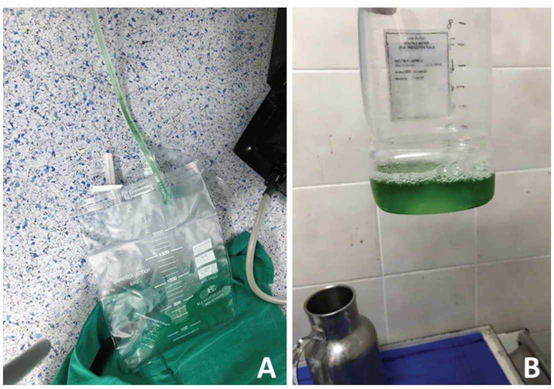

Figure 3. (A, B) All patients developed green urine on the day of isosulfan blue administration, with fading color of the urine over the next few days.

Table 4. CT-guided needle-localization procedural details

Factor	OR	95% CI	p-value
Pulmonary nodule			
Pure solid	1.00	(reference)	
Partially solid	0.00	(0.00)	0.999
Pure GGO	3.05	(0.54 to 17.37)	0.210
Location of nodule			
Right upper lobe			
• Apical	0.50	(0.05 to 5.36)	0.567
• Posterior	4.00	(0.31 to 52.07)	0.290
• Anterior	1.00	(0.08 to 13.02)	1.000
Right lower lobe			
• Superior	1.89	(0.11 to 33.89)	0.666
• Anterior	1.89	(0.11 to 33.89)	0.666
• Lateral	0.00	(0.00)	0.999
Left upper lobe			
• Apicoposterior	0.00	(0.00)	0.999
• Superior lingular	0.70	(0.06 to 8.82)	0.783
Left lower lobe			
• Superior	2.50	(0.14 to 45.01)	0.534
• Anteromedial	0.00	(0.00)	0.999
Right middle lobe			
• Medial	0.00	(0.00)	1.000
• Lateral	1.90	(0.11 to 33.70)	0.191
Nodule size	0.91	(0.74 to 1.13)	0.406
Adjacent critical structures			
Vessel	1.23	(0.96 to 1.57)	0.099
Bronchus	1.12	(1.03 to 1.23)	0.009*
Pleura	0.94	(0.86 to 1.03)	0.193

CT=computed tomography; GGO=ground-glass opacity; OR=odds ratio; CI=confidence interval

revealed the location of the nodule adjacent to the bronchus was the only prognostic factor with a statistically significant effect on the pneumothorax (p=0.009). The remaining potential prognostic factors had no statistically significant effect (p>0.05).

Discussion

Currently, the use of low-dose chest CT for screening lung cancer has been gradually increased in all areas of Thailand due to health promotion. As a consequence, many small lung nodules are incidentally detected during screening. Tissue pathological diagnosis is then required for those lung nodules that seem malignant. There are several techniques to gain a tissue diagnosis starting from bronchoscope, CT guide needle biopsy, and surgery. For small lesions that are smaller than two centimeters, tissue diagnosis is very difficult. Almost every method is not accurate enough to get a tissue due to small lesion. In the past few years, VATS has become increasingly popular for pathological diagnosis of those small lung nodules. However, intraoperative identification of small lung nodules is challenging for thoracic surgeons during VATS. Thus, the accuracy of preoperative CT-guided needle localization is helpful and could be a key to get a tissue diagnosis.

The present study showed a 100% initial procedural success rate, which means that all of the small lung nodules, smaller than 2 cm, in any location of the lung segments were successfully localized with CT guidance, and there were no major complications. Minor complications, including non-clinically significant minimal pneumothorax and parenchymal hemorrhage, were also comparable to those in the previous studies[17-20] (Table 5).

Table 5. Comparison of technical success rates and complication rates between the present study and other contemporary studies

	Present study	Lenglinger et al.[16]	Chen et al.[18]	Chen et al.[19]	Seo et al.[20]
Duration of recruitment	2018 to 2021	1992 to 1993	2008 to 2009	2001 to 2007	2003 to 2010
Total number of subjects	32	15	43	41	174
Technical success rate	90.6%	100%	95.3%	95.3%	95%
Complication					
Major complication	None	None	None	None	None
Minor complication					
• Pneumothorax	34%	33%	24.4%	18.6%	40%
• Hemorrhage	13%	N/A	2.4%	16.2%	36%

N/A=not applicable

Most of the needle localization in the present study used the blue-dye method, and the hook-wire method was only used in two early cases. In the present study institution, the blue-dye method was preferred as it made the VATS procedure easier because the hook-wire method required fluoroscopic guidance. Furthermore, it yielded easy dislodgement.

The hook-wire method may be preferred from the point of view of interventional radiologists because of their greater familiarity with the procedure, which is rather similar to a CT-guided lung biopsy. Additionally, the precise locations of the needle and wire tips are clearly shown on CT images, whereas the blue-dye method is rather blind and uncontrolled during injection via the needle. The post-injection CT image will show only the GGO surrounding the target nodule that may lead to equivocal intraoperative interpretations that may not be adequate.

Most of the needle localizations in the present study were effective during the VATS procedure. However, three lesions could not be identified by the blue-dye method during the VATS procedure, so, the technical success rate of the present study was 90.6%. After retrospective review of these cases, the main cause of the nodule in which the visceral pleura was not stained with blue dye was probably due to the central location of the nodule, which was further than usual from the pleura, whereas in the other two cases, the probable cause of blue-dye splashing over a large area of the parietal pleura was that the needle was placed in a subpleural location of the nodule with peri-procedural minimal pneumothorax during placement.

After about three years of the author learning curve, which involved good communication between the interventional radiologist and the thoracic surgeon, the problems that led to unidentifiable nodules were less frequent. The key solution is to precisely place the blue-dye marker at the visceral pleura, so injection along the needle tract is necessary. In the nodule with a subpleural location, the authors advanced the needle tip about 10 mm beyond the pleura before injecting the blue dye to avoid splashing of the parietal pleura (Figures 1B, 1C), whereas in the nodule with a central location, the authors used two- or three-needle projection and the superficial blue-dye injection method (Figure 4).

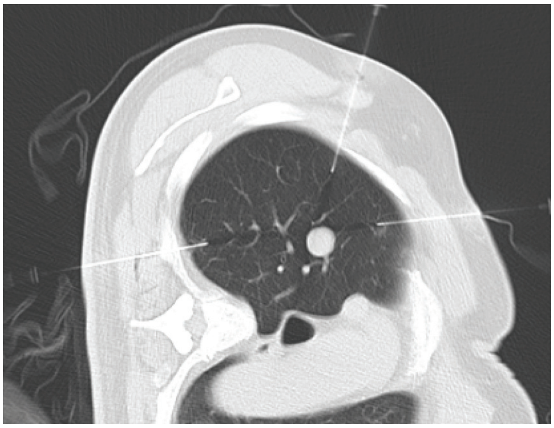

Figure 4. For computed tomography-guided needle localization of a nodule with a central location, two- or three-needle projection with the superficial blue-dye injection method is recommended.

About 73% of the smaller than 2 cm in size, resected lung nodules in the present study were pathologically proven to be malignant. Thus, the authors highly recommend low-dose CT screening for lung nodules in asymptomatic high-risk patients to reduce the mortality rate from lung cancer by early detection with early treatment.

The limitations of the present study included the retrospective design, non-randomized control, and small number of patients, which may have led to selection bias and to non-statistically significant differences among some of the results. In the near future, the authors believe that a comparable study between blue-dye needle localization and hook-wire needle localization should be studied.

In conclusion, preoperative CT-guided needle localization for VATS of small pulmonary nodules that are smaller than 2 cm in size was found to be feasible and safe.

What is already known on this topic?

CT guide was advocated to be useful tool for pre-operative localization for small lung nodule especially in ground glass nodule for VATS.

What this study adds?

This study is claimed to be a first report presenting a case series of outcome in CT-guided needle localization for VATS in Thailand.

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Conflicts of interest

The authors declare no conflict of interest.

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