

Effect of localization depth on the efficacy and safety of pulmonary nodule localization

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Abstract

Objectives

To evaluate the efficacy and safety of preoperative pulmonary nodule marking using a pulmonary nodule localization needle (PNLN) before video-assisted thoracoscopic surgery (VATS).

Methods

We retrospectively analyzed 359 localized nodules from 340 patients. Localization depth was defined as the distance from the metal anchor tip of the PNLN to the visceral pleura. Patients were categorized into two groups based on whether the anchor penetrated beyond the visceral pleura, and intergroup differences in localization efficacy and safety profiles were compared.

Results

Group A (depth < 0 mm, n = 27) presented elevated visual analogue scale (VAS) pain scores ranging from 4 to 8. Group B (depth ≥ 0 mm, n = 313) had predominantly mild VAS scores ranging from 1 to 6, with a statistically significant intergroup difference ($P < 0.001$). Two cases of pleural reaction were observed in Group A and resolved after emergency intervention. One intraoperative needle dislodgement occurred; the surgeon retrieved the needle and localized the target nodule successfully.

Conclusion

PNLN represents a safe and effective minimally invasive localization technique for pulmonary nodules. Inadequate insertion depth causes protrusion of the metallic anchor through the visceral pleura, which increases the risks of postoperative pain and pleural reaction.

Introduction

Lung cancer is one of the most prevalent malignancies worldwide, with approximately 2.2 million new cases and 1.79 million deaths annually^[1]. The 5-year overall survival rate is approximately 80% for patients with stage I non-small-cell lung cancer (NSCLC), whereas it ranges from 13% to 60% for those with stage II to III disease^[2]. Therefore, early detection, early diagnosis and early treatments are critical to improving prognosis. With the widespread application of computed tomography (CT) in population-based screening, an increasing number of pulmonary nodules have been identified at an early stage. Early intervention can be implemented for pure ground-glass nodules, part-solid nodules, and solid nodules when high malignant potential is suspected.

Video-assisted thoracoscopic surgery (VATS), with remarkable advantages including minimal trauma, rapid postoperative recovery and fewer complications, has currently become the preferred minimally invasive surgical approach for clinical diagnosis and treatment of pulmonary nodules. This surgery enables precise resection of lesions without conventional thoracotomy, and achieves one-stop diagnosis

and curative treatment, thereby significantly improving patients' medical experience and long-term prognosis. However, in clinical practice, numerous subcentimeter-sized pulmonary nodules are often characterized by tiny volume, deep location and soft texture. Such lesions are difficult to identify visually under thoracoscopic vision during surgery, and cannot be accurately detected by digital or instrumental palpation, resulting in difficult intraoperative localization, high risk of missed resection, and even forced extended resection or conversion to thoracotomy^[3]. Therefore, precise preoperative localization is an essential prerequisite for safe and minimally invasive resection.

At present, the main clinical modalities for preoperative localization of pulmonary nodules are divided into three categories: hook-wire localization^[4–5], staining agents (iodized oil, methylene blue)^[6–7] and localization needles^[8]. Hook-wire localization is prone to displacement, dislodgement and target deviation in clinical practice, which may easily lead to intraoperative localization failure and increase surgical uncertainty; and staining-agent-guided localization is limited by difficulties in precise control of injection volume and risk of dye diffusion^[9], which may result in blurred lesion boundaries and excessive marking range, thereby compromising accurate surgical resection. Additionally, it fails to provide depth measurement^[10]. In comparison, localization needles possess the advantages of simple operation, favorable localization stability, and low risk of displacement or target deviation. They can precisely anchor pulmonary nodule lesions with less susceptibility to tissue texture and respiratory motion. Such needles can effectively reduce the rate of localization failure while avoiding interference caused by staining agent diffusion, thereby exhibiting superior safety and clinical applicability.

Pulmonary nodule localization needle (PNLN) is specially designed for marking pulmonary nodules and has been widely applied in clinical practice^[5, 8, 11]. The PNLN achieves stable marking via fixation of its four front-end anchors to the lung parenchyma, with a low risk of dislodgement. The rear end of the anchors is connected to a soft and smooth tailing thread, which causes minimal damage to surrounding tissues and facilitates rapid identification under thoracoscopy. Nevertheless, risks associated with inappropriate insertion depth remain for PNLN localization. This study aimed to investigate the effects of different localization depths on the efficacy and safety of PNLN marking.

Materials and Methods

This retrospective study was approved by the Ethics Committee of Fuyang First People's Hospital. The requirement for informed consent was waived, as this analysis utilized anonymized patient data extracted from medical records.

Study Population

From March 2022 to June 2025, a total of 340 patients underwent CT-guided localization with PNLN followed by VATS resection at our hospital. A total of 359 pulmonary nodules from these patients were included in the final study.

Among the 340 patients:

- (1) 322 patients underwent single-nodule localization;
- (2) 17 patients underwent dual-nodule localization, of whom 14 had ipsilateral dual nodules and 3 had bilateral single nodules;
- (3) 1 patient underwent ipsilateral triple-nodule localization.

Criteria for Pulmonary Nodule Localization

The need for preoperative localization was determined jointly by two thoracic surgeons, based on the size, location, and density of the nodules. Nodules that underwent preoperative localization with the PNLN were included in this study if they met the following criteria:

- (1) Pure ground-glass nodules (pGGNs) with a diameter < 30 mm and a distance > 10 mm from the visceral pleura;
- (2) Part-solid nodules with a solid component $\leq$ 10 mm and a distance $\geq$ 10 mm from the visceral pleura;
- (3) Solid nodules with a diameter $\leq$ 10 mm and a distance $\geq$ 10 mm from the visceral pleura.

For nodules predicted to be benign, patients were informed and consented to undergo wedge resection first; if intraoperative frozen section pathology indicated malignancy, radical lung cancer resection was performed subsequently. Additionally, for nodules requiring palliative treatment, the need for preoperative localization was not restricted to those meeting the above characteristics.

Structure of the Pulmonary Nodule Localization Needle

The Pulinmeng disposable pulmonary nodule localization needle (Product Registration Certificate No.: Su Xie Zhu Zhun 2022202153) was used in this study. Its structure is similar to the localization needle manufactured by Ningbo Senke Biotechnology, as previously described by Li et al^[12].

The needle consists of four components: a blue-tailed suture anchor, a hollow tube pusher, a needle sheath, and a safety clip. Details of each component are as follows (Fig. 1):

- (1) The anchor is equipped with four blunt claws and connected to a 10-cm blue suture tail. The blue suture tail and the anchor claws are housed inside the hollow tube.
- (2) Both the anchor claws and the hollow tube are enclosed within the needle sheath. The needle sheath features a graduated cannula (10 cm in length, 0.9 mm in diameter) with a sharp tip to facilitate puncture.
- (3) The safety clip separates and secures the pusher from the needle sheath, preventing accidental release of the anchor claws caused by unintended movement of the pusher.

Pulmonary Nodule Localization Process

The procedure was mainly performed by one experienced thoracic surgeon, assisted by another thoracic surgeon for localization, and one radiologist responsible for CT scanning. All CT scans were conducted on a Siemens 64-slice CT scanner with a scanning voltage of 100 kV, current of 120 mA, slice thickness of 1.25 mm, window width of 1500 HU, and window level of -500 HU.

Step 1: An appropriate positioning posture (supine, lateral decubitus, prone) with both hands raised was selected according to the location of the patient's nodule. A metal positioning grid was placed to cover the body surface projection area of the pulmonary nodule, with the direction of the metal strips parallel to the long axis of the body, followed by the first CT scan.

Step 2: The axial plane of the pulmonary nodule was determined based on the CT images, and the sagittal plane of the nodule was confirmed according to the metal strips of the metal positioning grid. The radiologist adjusted the pulmonary nodule plane to a specific position and indicated it with a red projection line; the intersection of the red projection line and the metal strip was the body surface projection point of the nodule, or the proposed positioning puncture point.

Step 3: The skin within 15 cm around the puncture point was disinfected with povidone-iodine, and 5 ml of 0.5% lidocaine was injected for local infiltration anesthesia. Stepwise localization was performed according to the depth of the pulmonary nodule: during the first needle insertion, the tip of the localization needle did not enter the thoracic cavity but remained in the subcutaneous soft tissue (Fig. 2-a), followed by a second CT scan. The puncture angle, direction, and depth were adjusted based on the latest images. Finally, remove the safety clip and press the pusher to push the anchor claws out of the needle sheath, the anchor claws are subsequently released and fixed in the pulmonary parenchyma surrounding the lesion (Fig. 2-b), the needle sheath was withdrawn, and the puncture point was covered with a sterile dressing.

After pulmonary nodule localization, the patient was transferred to the bedside by wheelchair with assistance from family members and medical staff. The patient was instructed to lie supine for rest, receive supplemental oxygen appropriately, refrain from excessive speaking, and await surgical notification.

VATS

All patients underwent surgery on the day of localization. The surgical procedure was as follows: After general anesthesia, the patient was placed in a lateral decubitus position with the affected side upward (jackknife position) to widen the intercostal spaces. Double-lumen endotracheal tube ventilation was performed, and an indwelling urinary catheter was placed if necessary. Disinfection and draping were conducted. An approximately 1.0 cm observation port was incised at the 7th or 8th intercostal space on the midaxillary line. After identifying the blue tail wire of the pulmonary nodule localization needle, an approximately 3.0 cm operation port was incised at the 4th or 5th intercostal space on the anterior

axillary line. During VATS, endoscopic scissors were used to cut off and remove the tail wire of the localization needle. The position of the pulmonary nodule was confirmed by combining the relationship between the localization needle and the pulmonary nodule on CT. According to the distance between the pulmonary nodule and the pleura, a stapling device was used to perform wedge resection or segmentectomy with a margin of more than 2 cm from the edge of the pulmonary nodule. The specimen was opened immediately to confirm that the pulmonary nodule and the localization needle were in the resected specimen. Intraoperative frozen section examination was performed. Surgery could be terminated in patients with benign lesions or non-invasive lung cancer. Patients with invasive lung cancer without contraindications underwent thoracoscopic lobectomy and lymphadenectomy.

Data Collection and Statistical Analysis

Data Collection

Patient demographics (age, gender), pulmonary nodule characteristics (location, density, pathological results), localization position (supine, lateral, or prone), localization depth (distance from the tail end of the localization hook to the visceral pleura) and complications were collected from the electronic medical record system.

The technical success criteria were defined as follows: (1) the claw portion of the PNLN was placed within the pulmonary parenchyma (confirmed by intraoperative CT); and (2) the tail suture of the PNLN was visible on the surface of the visceral pleura during VATS (confirmed by surgical records). Technical failure was defined as either dislodgement of the PNLN claw from the lung tissue or retention of the entire PNLN in the subcutaneous soft tissue.

Localization Depth

The localization depth was defined as the distance from the tail end of the metal anchor of the PNLN to the visceral pleura. If the tail end of the metal anchor is fully embedded into the lung parenchyma, the localization depth is defined as a positive value (Fig. 2-c); if the distal end of the metallic anchor protrudes beyond the visceral pleura, the localization depth is defined as a negative value (Fig. 2-d).

VAS Pain Score

The VAS was used for pain assessment, with scores defined as follows: 0 = no pain, 1–3 = mild pain, 4–6 = moderate pain, and 7–10 = severe pain. A VAS score of ≥ 4 was considered indicative of moderate to severe pain.

After completing positioning in the radiology department, the patient returned to the ward and was made to lie supine on the hospital bed for VAS 0–10.

Evaluation of Pneumothorax and Pulmonary Hematoma

The final CT images obtained during pulmonary nodule localization were re-interpreted jointly by one senior thoracic surgeon and one senior radiologist. In cases where the re-interpretation results differed from the original findings, the discrepancies were discussed with the two thoracic surgeons who performed the localization procedure until a consensus was reached.

Statistical Methods

Continuous variables were presented as mean ± standard deviation (SD) for normally distributed data, or median and interquartile range (IQR) for non-normally distributed data.

The independent samples t-test (for normally distributed data) and nonparametric Mann-Whitney U test (for non-normally distributed data) were applied to compare the localization depth between the experimental groups (pneumothorax group or hematoma group) and their respective control groups.

All statistical analyses were performed using SPSS 26.0 software (IBM Corp., Armonk, NY, USA). A two-tailed P-value < 0.05 was considered statistically significant.

Results

Participant Demographics

A total of 340 patients underwent computed tomography (CT)-guided pulmonary nodule localization with a localization needle followed by VATS. Among these patients, 37.6% were male (128/340), with a mean age of 60 ± 11.93 years. (Table 1)

Table 1 Demographics of patients with pulmonary nodules for localization	
Number of patients	340
Age (year)	60 ± 11.93
Gendar	
Male	128(37.6%)
Female	212(62.4%)

Position during localization

the supine position was adopted in 30.9% of cases (111 out of 359), the lateral decubitus position in 42.3% (152 out of 359), and the prone position in 26.7% (96 out of 359). (Table 2)

Table 2
Localization characteristics in patients with pulmonary nodules for localization

Variables	
Number of nodules	359
Pulmonary nodule density	
Pure ground-glass	272
Part-solid	22
Solid	65
Position during localization	
Supine position	111
Lateral decubitus position	152
Prone position	96
Location of nodules	
Left upper lobe	110
Left lower lobe	49
Right upper lobe	135
Right middle lobe	16
Right lower lobe	49
Location by Pulmonary Segment	
Apical segment (S1)	91
Posterior segment (S2)	45
Apicoposterior segment(S1 + 2)	4
Anterior segment(S3)	98
Lingular segment(S4 + 5)	7
Lateral segment(S4)	13
Medial segment of the right middle lobe(S5)	3
Superior segment of the lower lobe(S6)	55
Medial basal segment(S7)	5
Anterior basal segment(S8)	12

Variables	
Outer basal segment(S9)	17
Posterior basal segment(S10)	9
Pathological of nodules	
Minimally invasive adenocarcinoma	162
Invasive adenocarcinoma	108
Inflammation	42
Carcinoma in situ	26
Mucinous adenocarcinoma	6
Squamous cell carcinoma	5
Hamartoma	3
Small cell lung cancer	2
Cryptococcus infection	1
Pulmonary tuberculosis	1
Epithelioid hemangioendothelioma	1
Bronchial adenoma	1
Colloid carcinoma	1
Distance from visceral pleura to needle tip(mm) mean±min, max (N = 358)	11.05(−6, 45.5)
Proportions of pain at rest	
VAS 0–3	257
VAS 4–6	78
VAS 7–10	5
asymptomatic pneumothorax	69(19.2%)
asymptomatic hematoma	73(20.3%)

Nodules

A total of 359 nodules were included. Regarding density: pure ground-glass nodules (pGGNs) accounted for 75.8% (272 out of 359); mixed-density nodules accounted for 6.1% (22 out of 359); and solid nodules (SNs) accounted for 18.1% (65 out of 359). (Table 2)

Lung Lobes

Distribution of nodules across lung lobes was as follows: the left upper lobe (LUL) accounted for 30.6% (110 out of 359); the left lower lobe (LLL) for 13.6% (49 out of 359); the right upper lobe (RUL) for 37.6% (135 out of 359); the right middle lobe (RML) for 4.5% (16 out of 359); and the right lower lobe (RLL) for 13.6% (49 out of 359). (Table 2)

Lung Segments

The distribution of nodules in each lung segment was as follows: the apical segment (S1) for 25.3% (91 out of 359); the posterior segment (S2) for 12.5% (45 out of 359); the apicoposterior segment (S1 + 2) for 1.1% (4 out of 359); the anterior segment (S3) for 27.3% (98 out of 359); the lingular segment (S4 + 5) for 1.9% (7 out of 359); the medial segment (S5) for 0.8% (3 out of 359); the lateral segment (S4) for 3.3% (13 out of 359); the superior segment of the lower lobe (S6) for 15.3% (55 out of 359); the medial basal segment for (S7) 1.4% (5 out of 359); the anterior basal segment (S8) for 3.3% (12 out of 359); the outer basal segment (S9) for 5.0% (17 out of 359); and the posterior basal segment (S10) for 2.5% (9 out of 359). (Table 2)

Pathology

The pathological classifications of the nodules and their proportions were as follows: minimally invasive adenocarcinoma (MIA) accounted for 45.1% (162 out of 359); invasive adenocarcinoma (IA) for 30.1% (108 out of 359); inflammation for 11.7% (42 out of 359); carcinoma in situ (CIS) for 7.2% (26 out of 359); mucinous adenocarcinoma for 1.7% (6 out of 359); squamous cell carcinoma (SCC) for 1.4% (5 out of 359); hamartoma for 0.8% (3 out of 359); small cell lung cancer (SCLC) for 0.6% (2 out of 359); colloid carcinoma for 0.3% (1 out of 359); Pulmonary tuberculoma for 0.3% (1 out of 359); epithelioid hemangioendothelioma (EHE) for 0.3% (1 out of 359); bronchial adenoma for 0.3% (1 out of 359); and cryptococcosis for 0.3% (1 out of 359). (Table 2)

Distance from visceral pleura to needle tip

After exclusion of one case with needle dislodgement, a total of 358 cases were included in the analysis. The mean insertion depth of all localization needles was 11.05 mm, with the minimum depth of -6 mm and the maximum depth of 45.5 mm. (Table 2)

Post-localization pneumothorax and post-localization Pulmonary Hematoma

In this study, postoperative pneumothorax occurred in 69(19.2%)patients and hemorrhage occurred in 73(20.3%)patients, all of which were asymptomatic and managed properly during the same operation. (Table 2)

VAS Pain Score

VAS scores were collected from 340 patients who rested in the supine position on the hospital bed after completion of localization. Among them, 257 patients had scores of 0–3, 78 had scores of 4–6, and 5 had scores of 7–10. (Table 2)

A total of 340 patients were divided into two groups. Group-A consisted of patients with one or more puncture positioning needles having a depth of less than 0 mm, with 27 patients in this group. Among them, 6 patients had a VAS score of 4, 8 patients had a VAS score of 5, 8 patients had a VAS score of 6, 4 patients had a VAS score of 7, and 1 patient had a VAS score of 8. Group-B comprised patients with puncture positioning needles having a depth of no less than 0 mm. In Group B, 49 patients had a VAS score of 1, 111 patients had a VAS score of 2, 96 patients had a VAS score of 3, 41 patients had a VAS score of 4, 10 patients had a VAS score of 5, and 5 patients had a VAS score of 6. Chi-square test was performed for comparison between the two groups, and the result showed a statistically significant difference with $P < 0.001$. (Table 3)

Table 3
Grouping according to the depth of pulmonary localization needles

Patients, n = 340	Group-A(n = 27)	Group-B(n = 313)	P
	There is one or more localization needles with a distance<0mm	localization needles with a distance≥0mm	
VAS			
VAS-1	0	49	<0.001
VAS-2	0	111	
VAS-3	0	96	
VAS-4	6	41	
VAS-5	8	10	
VAS-6	8	5	
VAS-7	4	0	
VAS-8	1	0	
pleural reaction	2	0	
Nodules, n = 358	Group-C(n = 29)	Group-D(n = 329)	
Distance between the tail of the localization needle and the visceral pleura	<0mm	≥ 0mm	
average distance	-2.29 ± 1.33	12.23 ± 9.59	<0.001
asymptomatic pneumothorax	8(27.59%)	61(18.48%)	0.233
asymptomatic hematoma	3(10.34%)	70(21.21%)	0.163

Pleural reaction

A total of two cases of pleural reaction occurred after pulmonary nodule localization in this study, both of which were allocated to Group-A.

In the first case, the depth of the localization needle was – 6 mm. The patient presented with obvious chest pain immediately after localization, accompanied by pneumothorax with a depth of 9 mm. Significant chest tightness and shortness of breath were reported right after the procedure. The patient was immediately transferred from the CT examination room to the operating room via a transfer bed for emergency surgery. The operation was uneventful, and no additional adverse events were observed postoperatively.

In the second case, the depth of the localization needle was -1.34 mm, with a postoperative pain score of 5 points. Although a small amount of pneumothorax was detected, the patient had no obvious discomfort immediately after localization. The patient refused wheelchair transportation and insisted on walking back to the ward voluntarily. During the walking process from the CT room to the ward accompanied by medical staff and family members, the patient suddenly fainted and fell to the ground. Carotid artery palpation revealed palpable pulsation on site. The patient was rapidly moved to the ward nurse station, and the fingertip blood glucose was measured as 5.6 mmol/L. The patient was placed in a supine position on the hospital bed and given mask oxygen inhalation promptly. The patient gradually regained consciousness and recovered uneventfully without subsequent obvious discomfort or further adverse reactions.

According to the localization depth, exclusion of one case with needle dislodgement, a total of 358 pulmonary nodules were reclassified into two groups. A total of 29 nodules were assigned to Group-C, in which the depth of the localization needle was less than 0 mm. The remaining 329 nodules were allocated to Group-D, with the localization needle depth ≥ 0 mm. The mean localization depth was -2.29 ± 1.33 mm in Group-C and 12.23 ± 9.59 mm in Group-D. Independent sample t-test revealed a significant intergroup difference ($P < 0.001$). In Group-C, pneumothorax occurred in 8 cases and hematoma in 3 cases. In Group-D, pneumothorax was observed in 61 cases and hematoma in 70 cases. Chi-square test showed no significant differences in the incidence of pneumothorax and hematoma between the two groups. (Table 3)

Failure of Pulmonary Nodule Localization

Among all cases, 1 case of localization PNLN dislodgement occurred (Fig. 3), with an incidence rate of 0.28% .

Evaluation of Localization Results

In this study, all 358 pulmonary nodules were successfully identified under VATS with preoperative localization, localization effectiveness rate 99.7% ($358/359$). One case with localization PNLN dislodgement underwent pulmonary wedge resection by referencing the relationship between the intrathoracic puncture site and the lung surface after lung inflation.

Discussion

This cross-sectional study demonstrates the efficacy and safety of PNLN localization for pulmonary nodules. A total of 359 pulmonary nodules in 340 patients were included in this study. Among them, 358 PNLN were firmly anchored in lung tissue, and both the PNLN and nodules were successfully identified under thoracoscopy. Although one dislodgement PNLN failed to directly assist surgeons in locating the nodule, the pulmonary nodule was successfully identified and resected by referencing the relationship between the intrathoracic puncture site and the lung surface following lung inflation. This case involved localization of two nodules on unilateral Lung: pneumothorax (with an air band width of 14.5 mm)

occurred after the first localization, which consequently led to dislodgement of the second localization needle.

Depth is a crucial factor affecting the success rate of CT-guided pulmonary nodule localization^[13]. Our study also confirmed this finding. Excessively shallow positioning often causes needle deviation, which inevitably reduces localization efficacy. Among 359 pulmonary nodules enrolled, 358 achieved successful localization, with needle tips anchored in lung parenchyma, and both needles and nodules were successfully identified during VATS. The mean depth of the 358 valid localizations was 11.05 mm, ranging from - 6 mm to 45.5 mm. A considerable margin exists for effective needle positioning of pulmonary nodules. Compared with hook-wire with a miss rate of approximately 2%^[5] and dyes with potential diffusion risk^[9], PNLN exhibits distinct advantages in localization efficacy and better operational controllability.

Meanwhile, positioning depth was also correlated with safety, mainly reflected in postoperative pain, pneumothorax and hematoma incidence. Previous studies indicated that post-localization pain primarily stems from intercostal nerve irritation^[14]. Hu et al.^[15] reported that moderate to severe pain occurred in approximately 24.2% of patients after pulmonary nodule localization, with more intense pain observed in lateral chest wall puncture. Although Fan et al.^[16] demonstrated that pulmonary nodule localization needles yield superior patient tolerance compared with other positioning devices, moderate to severe pain was observed in 24.4% (83/340) of enrolled patients in this study. Pleural reaction occurred in 2 cases. Among patients with VAS score over 4, negative positioning depth was noted in 58.3% (21/36), indicating needle tips protruding beyond the visceral pleura. Accordingly, post-procedural pain may not solely originate from intercostal nerve stimulation. Friction between needle tail and parietal pleura also serves as a critical contributor, potentially triggering more severe pain.

Excessively shallow needle placement may not only aggravate pain but also induce pleural reaction. Two cases of post-localization pleural reaction were recorded, both occurring in Group A with negative positioning depth. One patient presented with chest pain, chest tightness and shortness of breath, and was immediately transferred for emergency surgery. The other patient fainted while walking back to the ward voluntarily. Instant fingertip blood glucose was within normal range, ruling out hypoglycemia. The parietal pleura is abundant in vagal nerve endings. Mechanical irritation of the metallic needle tail against the parietal pleura during respiration triggers vagal reflex, ultimately resulting in pleural reaction.

Post-procedural pneumothorax and hematoma are vital safety indicators of localization^[17]. A total of 69 pneumothorax cases (19.2%) and 73 pulmonary hematoma cases (20.3%) were observed, consistent with findings reported by Dendo^[18] and Hsu^[19]. In Group-C, pneumothorax occurred in 8 cases and hematoma in 3 cases. In Group-D, pneumothorax was observed in 61 cases and hematoma in 70 cases. Chi-square test showed no significant differences in the incidence of pneumothorax and hematoma between the two groups. Most pneumothorax and hematoma cases presented no obvious clinical symptoms, without sequelae or increased medical costs. The incidence of these complications remained clinically acceptable, indicating favorable overall safety and controllable risks of this

localization method. It exerts no substantial adverse impacts on subsequent thoracoscopic surgery and postoperative recovery.

Nevertheless, several limitations exist in this study. Firstly, it was a single-center retrospective investigation with inherent restrictions. Secondly, this study mainly analyzed safety hazards caused by excessively shallow positioning, while risks of overly deep placement were not explored. Thirdly, only one type of localization needle was adopted. Needles with similar designs may differ in material, leading to varied mechanical stimulation to pleura. Further studies involving multiple needle types are warranted for verification.

Conclusion

Pulmonary nodule localization needle serves as a safe and effective minimally invasive positioning device in clinical practice. Insufficient positioning depth may lead to protrusion of the metallic tail end beyond the visceral pleura, which consequently elevates the risks of postoperative pain and pleural reactions.

Abbreviations

PNLN	pulmonary nodule localization needle
VATS	video-assisted thoracoscopic surgery
VAS	visual analogue scale
NSCLC	non-small-cell lung cancer
CT	computed tomography
pGGNs	pure ground-glass nodules

Declarations

Ethics approval and consent to participate: this retrospective study was approved by the Ethics Committee of Hangzhou Fuyang First People's Hospital (Ethics Approval No. 2025-KY-038), and informed consent was waived by the ethics committee. All clinical procedures were performed in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its subsequent amendments.

Consent for publication: all authors have agreed to the publication of this manuscript and confirm that the work is original, has not been published previously, and is not under consideration for publication elsewhere.

Availability of data and materials: the datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request. All relevant data are included within the

article.

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Authors' contributions:

Feng Kan: Conceptualization, Writing – Original Draft

Sun Jiewei: Validation, Supervision, Quality Control

Zhu Yufeng, Lu Yong: Data Curation

Bao Keyu: Visualization

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Figures

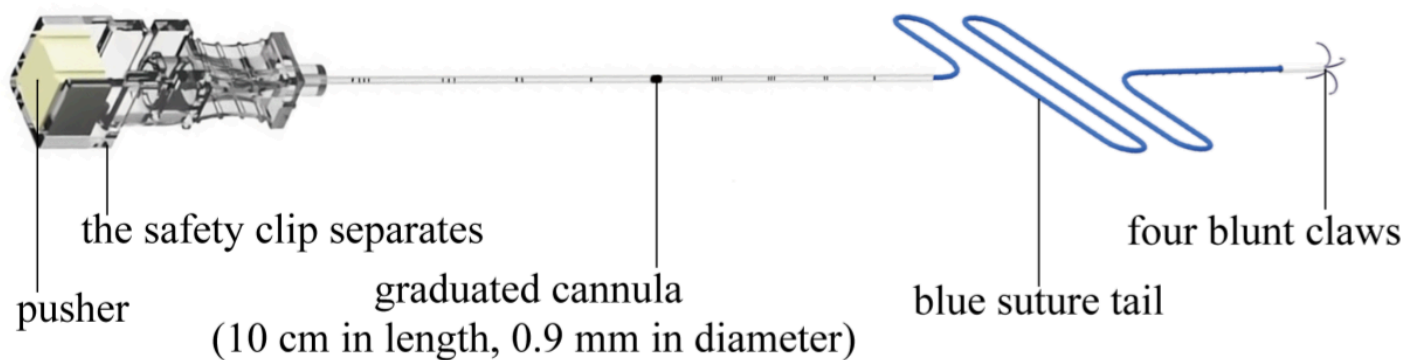


Figure 1

Pulmonary Nodule Localization Process

The procedure was mainly performed by one experienced thoracic surgeon, assisted by another thoracic surgeon for localization, and one radiologist responsible for CT scanning. All CT scans were conducted on a Siemens 64-slice CT scanner with a scanning voltage of 100 kV, current of 120 mA, slice thickness of 1.25 mm, window width of 1500 HU, and window level of -500 HU.

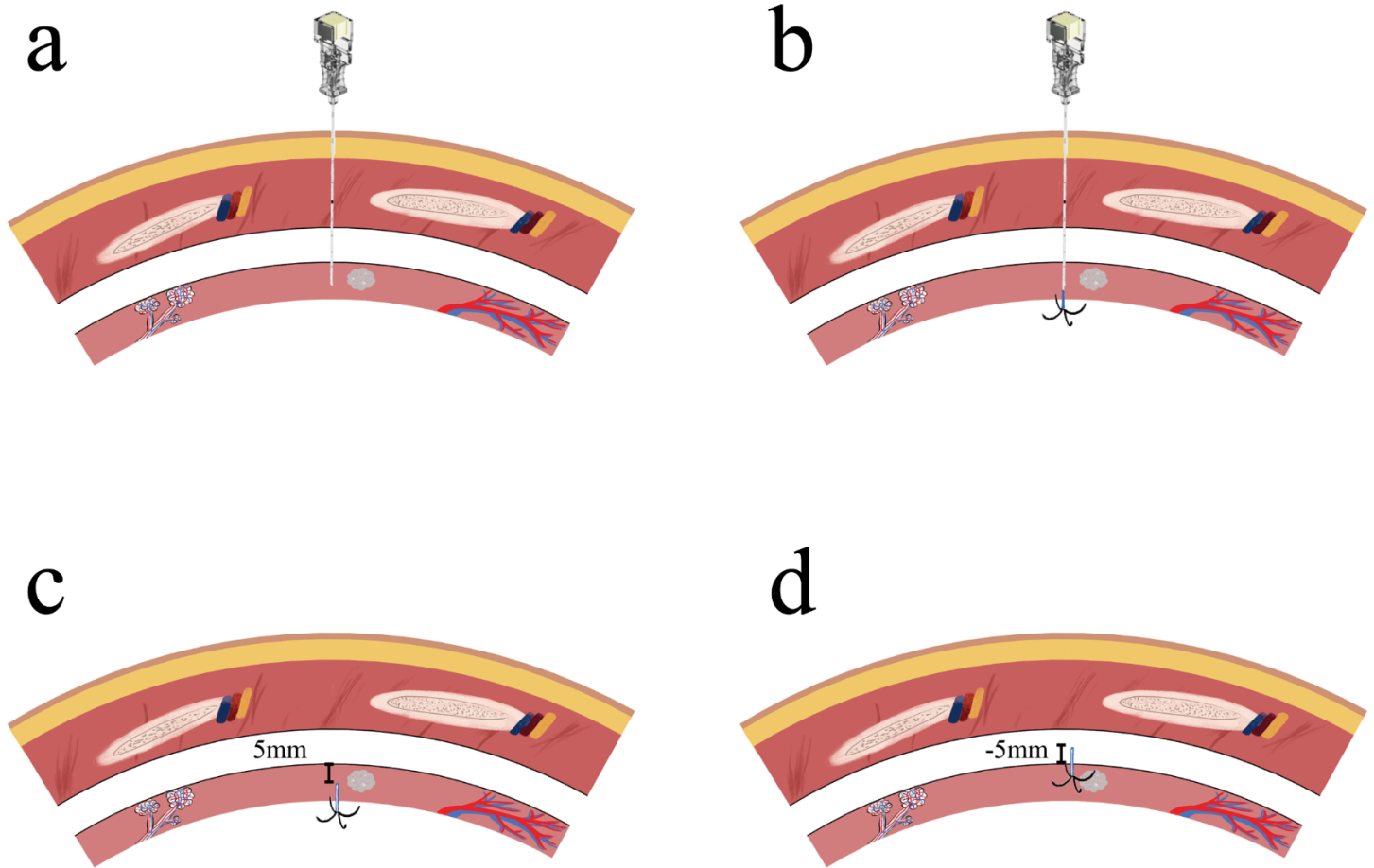


Figure 2

After pulmonary nodule localization, the patient was transferred to the bedside by wheelchair with assistance from family members and medical staff. The patient was instructed to lie supine for rest, receive supplemental oxygen appropriately, refrain from excessive speaking, and await surgical notification.

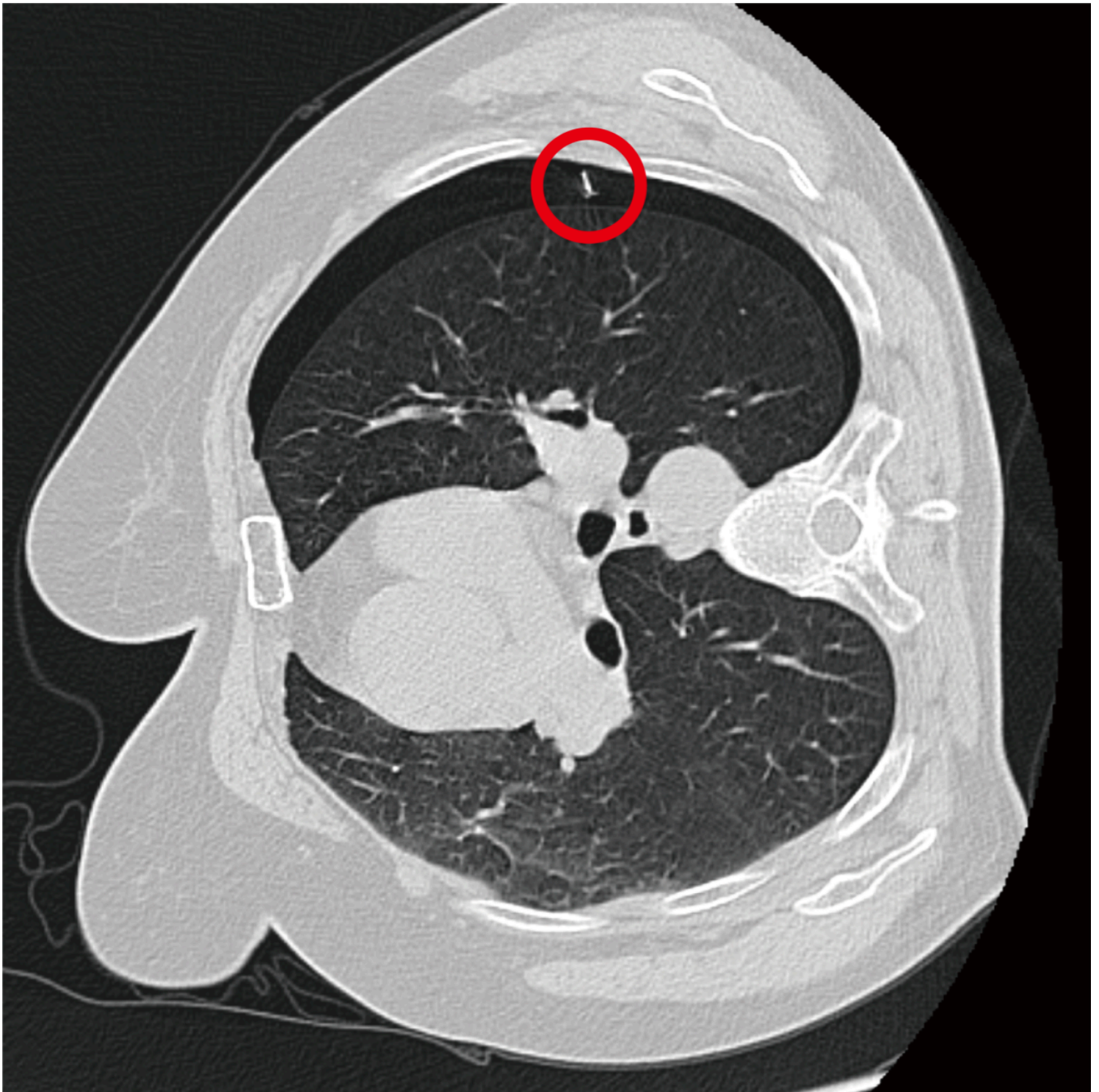


Figure 3

Evaluation of Localization Results

In this study, all 358 pulmonary nodules were successfully identified under VATS with preoperative localization, localization effectiveness rate 99.7% (358/359). One case with localization PNLN dislodgement underwent pulmonary wedge resection by referencing the relationship between the intrathoracic puncture site and the lung surface after lung inflation.