



# Factors influencing the accuracy and safety of preoperative computed tomography (CT)-guided soft hook-wire localization for pulmonary nodules: a comprehensive analysis

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**Background:** The necessity of localization of pulmonary nodules lies in ensuring the ability to locate the nodule quickly and accurately during surgery, thereby improving the success rate of the operation. The accuracy and risk of preoperative localization of pulmonary nodules need further exploration. Therefore, the purpose of this study was to investigate the factors of accuracy and safety of computed tomography (CT)-guided localization of pulmonary nodules using a flexible wire hook positioner.

**Methods:** In this retrospective cross-sectional analysis, 281 patients with a single pulmonary nodule underwent video-assisted thoracoscopic surgery (VATS) following localization with a soft hook-wire guided by CT scan from January 2021 to July 2022 at Nanjing Drum Tower Hospital. The patients underwent VATS to remove pulmonary nodules within 24 hours after localization. The demographic, pulmonary nodule, and technical factors were analyzed retrospectively. Univariate and multivariate analysis were used to analyze the identified factors that influence pulmonary nodule localization accuracy and complications.

**Results:** Localization was successfully performed in 280 patients, with only 1 patient being excluded due to a displaced positioner and the hook wire failing to enter the lung parenchyma as a result of pneumothorax. Out of the total cases, 191 (68.2%) were accurately positioned in group G0, whereas 89 cases (31.7%) were inaccurately positioned in group G1. Hemorrhage and self-limited hemoptysis were observed in 64 patients (22.8%), whereas pneumothorax was observed in 84 patients (29.9%). There were no serious complications such as air embolism or death. The accuracy of localization was found to be influenced by both the depth of pulmonary nodules [odds ratio (OR) =22.610, 95% confidence interval (CI): 10.351–49.391, P=0.001] and the depth of the needle used (OR =0.322, 95% CI: 0.136–0.765, P=0.010). Additionally, postoperative hemorrhage was found to be affected by several important factors, including the diameter (P=0.036) and depth of the nodule (P=0.011), as well as the thickness of the chest wall (P=0.043) and the depth of the needle used (P=0.005).

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**Conclusions:** The CT-guided flexible wire hook positioner has been found to be a safe and effective device for locating pulmonary nodules. The depth of pulmonary nodules and needle penetration are key factors affecting the accuracy of lung nodule localization under CT guidance and are important factors affecting postoperative bleeding.

**Keywords:** Pulmonary nodule localization; computed tomography-guided (CT-guided); hook-wire localization; video-assisted thoracoscopic surgery (VATS)

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## Introduction

Lung cancer is a major contributor to cancer-related deaths globally, with an overall 5-year survival rate of 29.7%; however, early diagnosis allows an increase in the survival rate of up to 82% (1). Therefore, early detection of lung cancer, followed by timely surgery, is crucial for improving patient survival rates. Lobectomy is currently considered the most effective surgical treatment for early lung cancer. Further, a recent meta-analysis indicated that the long-term survival outcomes of lobectomy are comparable to those of extended segmentectomy for peripheral non-small cell lung cancer (NSCLC) (2-4). Nevertheless, computed tomography (CT)-guided preoperative positioning of lung nodules can be beneficial to ensure adequate margins and reduce the time required for surgery in patients undergoing segmentectomy (5).

Video-assisted thoracoscopic surgery (VATS) has several limitations in identifying and localizing small peripheral pulmonary nodules, particularly deep ground-glass nodules. To address this, preoperative positioning techniques have been developed to ensure accurate intraoperative identification and precise nodule removal. Currently, CT guidance is the most widely used method for percutaneous perthoracic localization. Several CT guidance techniques are currently available, including metal markers such as hooked wires and microcoils, or dye staining (6-10). Further, several methods can be used to achieve preoperative labeling of lung nodules, each with its own advantages and disadvantages. One such method is microcoil localization, which can achieve good accuracy and a high success rate. However, this method is relatively complex and carries the risk of displacement (11-13).

Our team utilizes a novel device comprising a flexible wire claw-hook positioner for preoperative lung nodule positioning. This device has a hook-claw device at the tip

and a soft wire at the tail, making it stronger and safer after release. The accuracy of CT-guided localization of lung nodules directly affects the surgical effect and intraoperative risk; therefore, it is necessary to analyze the factors influencing accuracy and post-localization complications (13,14).

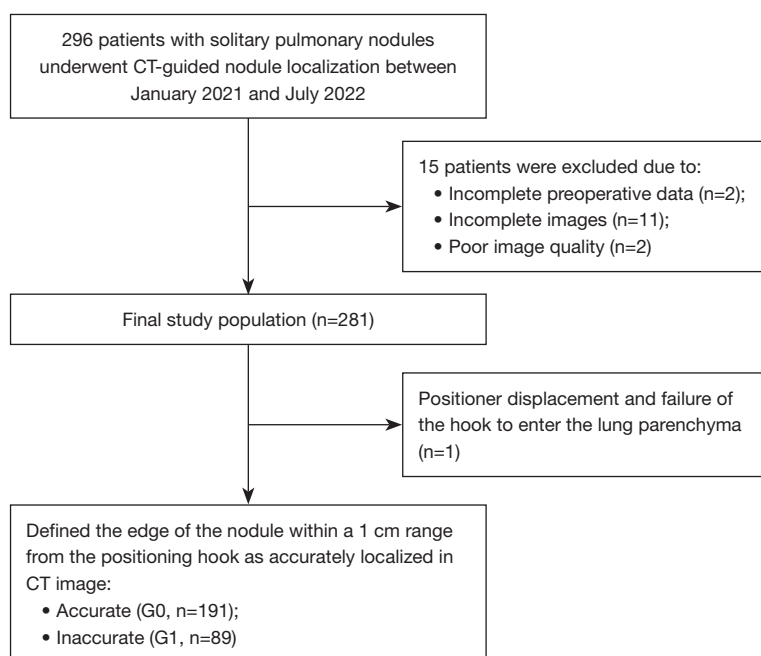
Herein, we analyzed the outcomes of 281 patients who underwent resection with a soft wire claw-hook to locate pulmonary nodules, to identify the factors affecting the accuracy of marking and the incidence of complications. We present this article in accordance with the STROBE reporting checklist (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1272/rc>).

## Methods

This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Nanjing Drum Tower Hospital. Written informed consent was provided by all patients prior to performing the CT-guided percutaneous localizations procedure.

### *Study participants*

Between January 2021 and July 2022, 281 patients with solitary pulmonary nodules underwent CT-guided nodule localization using a soft hook-wire and subsequent VATS resection in our institute. The decision to request preoperative nodule localization was made at the discretion of the referring thoracic surgeon. CT morphology and location were the primary factors used to identify eligible lesions. Ground-glass opacities that were unlikely to be palpable during surgery, pulmonary nodules smaller than 3 cm in diameter, nodules located less than 3 cm



**Figure 1** The flowchart of the inclusion and exclusion criteria. CT, computed tomography.

from the nearest pleural surface, biopsy-confirmed malignant nodules, and malignant nodules with suspicious morphological and septal changes were all considered eligible. Preoperative nodule localization was performed in patients who met the following criteria: no history of extrathoracic malignant tumors, VATS resection performed within 24 hours of localization, accurate resection, and clear postoperative pathological results. A total of 2 cases were excluded due to incomplete preoperative data, 11 cases were excluded due to incomplete images, and 2 cases were excluded due to poor image quality caused by difficulties in ensuring breathing coordination (*Figure 1*).

Demographic information, including sex, age, and smoking history, was recorded. Additionally, a preoperative comprehensive assessment of the heart, lung, and coagulation functions were recommended in patients before VATS (15). Prior to the CT scan, patients were instructed to perform and maintain calm breathing.

### **Preprocedure image analysis**

Preoperative images were acquired using a Spectral CT scanner (IQon Spectral CT, Philips Healthcare, Best, Netherlands) with the following scan parameters: tube current, 50–250 mAs; tube voltage, 120 kV; pitch factor, 1.2–1.5; reconstruction algorithm, Y-Detail; reconstruction

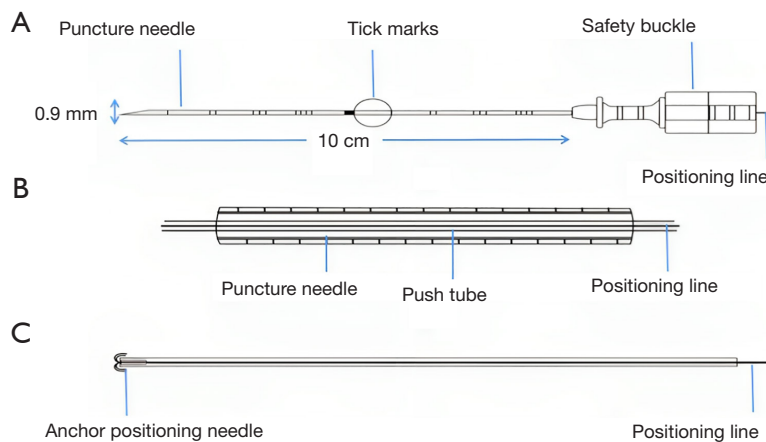
slice thickness, 1 mm; interval, 1 mm; and field of view (FOV), 350×350 mm. Indices were measured at the lung window [window width, 1,500 Hounsfield units (HU); window level, 600 HU].

Then, 2 radiologists, one (Q.F.) with 5 years of experience in interventional thoracic radiology and the other (J.Z.) with 8 years of experience in thoracic radiology, reviewed the last diagnostic CT scan obtained prior to CT-guided placement. During the measurement process, researchers remained blind to the patients' clinical and surgical details, as well as to the pathological outcomes. In case of any disagreement, a radiologist with 14 years of experience (L.C. and W.K.) performed the final review.

Preoperative images were carefully analyzed and recorded to determine the location, size (maximum diameter), and nature (ground-glass, mixed ground-glass, or solid) of the pulmonary nodules. These measurements were performed to better understand the characteristics of the nodules prior to surgery.

### **CT-guided soft hook-wire localization**

All surgeries were performed with the patient awake and quiet. All CT scans were performed using an IQon Spectral CT Scanner (Philips, Netherlands) at 100 kV, 120 mAs, 1 mm thickness. We evaluated nodule location on the



**Figure 2** The structure and labeling principle of the lung nodule localization needle. (A) The puncture needle consists of a needle tube, puncture needle handle, and safety buckle. (B) The push device is made up of a push tube and push tube handle. (C) The far end of the positioning line is connected to the anchor positioning needle.

lung window image. We selected the optimal route, and confirmed the position away from the blood vessel along the puncture route. Generally, this method allows selection of the shortest route for needle entry from the skin to a pulmonary nodule. Ideally, the marking position should be 1 cm from the edges of the pulmonary nodules. The positioning line provided by the scanner is used to mark the patient's body surface. Local subcutaneous infiltration of 3–5 mL of 2% lidocaine was applied as anesthesia. A soft-wire hook puncture needle (20 G × 100 mm; Ningbo Shengjiekang Biotechnology Co., Ltd., Ningbo, China) was used for nodule localization. The structure and positioning principle of the needle are shown in *Figure 2*. The locating needle comprised 5 main parts: a puncture needle, push device, anchor positioning needle, positioning line, and protection tube. The puncture needle comprised a needle tube, puncture needle handle, and safety buckle (*Figure 2A*). The push device was composed of a push tube and push tube handle (*Figure 2B*). The far end of the positioning line was connected to an anchor positioning needle (*Figure 2C*). The positioning line extended from the proximal end of the push device through the interior and outside of the push tube, and was marked with a tick at the distal end, measuring 10–15 cm in length and 0.9 mm in diameter.

Under CT guidance, a wire hook was advanced into the lung parenchyma surrounding the nodules. Once the positioner was released, the operator removed the positioning needle and bandaged the puncture points. A repeat CT scan was performed immediately to confirm that the soft-line hook had been properly placed in the

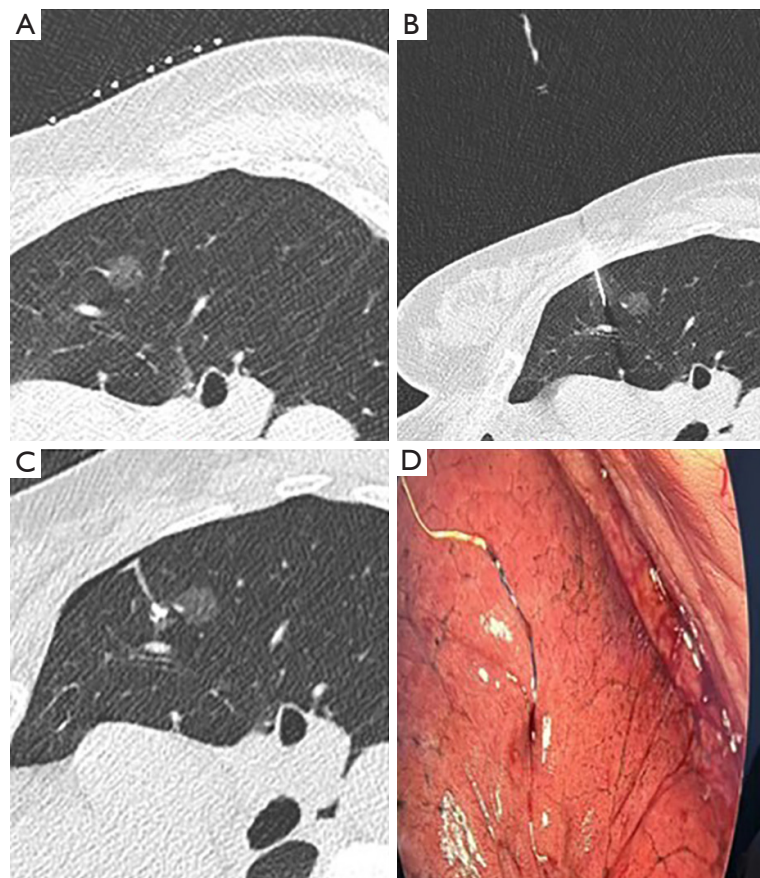
lung parenchyma. This step is crucial to assess the relative position of the hook claw to the target nodule and pleural surface, as well as to identify any possible complications, such as hemorrhage or pneumothorax (*Figure 3*).

### *Postprocedure image analysis*

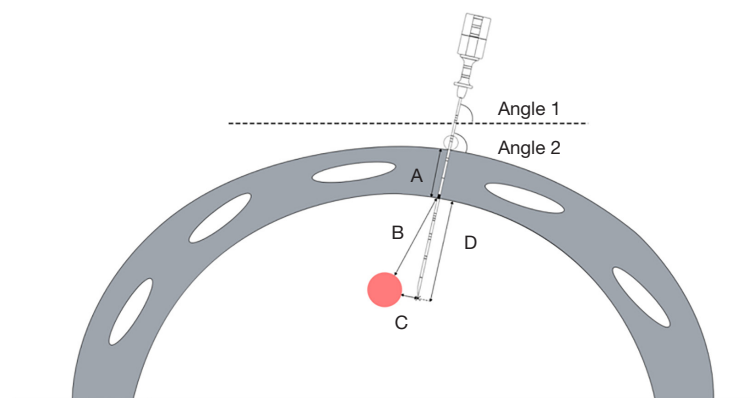
The CT-guided puncture localization-related images were retrospectively analyzed by 2 attending physicians (Q.F. and J.Z.) with 5 and 8 years of experience in radiology. Any disagreements were resolved by the chief physician with 14 years of experience in radiology who reviewed the images again. Based on the CT images, the puncture position (supine, prone, left, right, oblique), side of the nodule (left or right), and location of the pulmonary nodule (upper, middle, or lower lobes) were documented. We measured various parameters related to the pulmonary nodule, including its maximum diameter, the shortest distance from the outer edge of the nodule to the point at which the puncture needle enters the lung (known as the nodule depth), the thickness of the chest wall where the needle was inserted, the depth of the needle in the lung, the angle at which the puncture needle entered the chest wall (angle 1), and the angle between the puncture needle and the horizontal plane (angle 2) (*Figure 4*).

### *Surgical resection and pathological outcomes*

The decision to perform VATS within 24 hours after positioner placement was made at the discretion of a



**Figure 3** Schematic diagram of the process of marking lesions with a soft wire claw locator. (A) A 59-year-old woman with 1.2 cm GGN in left upper lobe of the lung in a left lateral position. (B) CT-guided soft wire claw locator was used to locate the pulmonary nodules. (C) The anchoring needle was released when the needle tip approached the lesion site. (D) The tail end of the line exposed outside the pleura was visible during VATS. GGN, ground-glass nodule; CT, computed tomography; VATS, video-assisted thoracoscopic surgery.



**Figure 4** Technical factors analyzed to determine which were related to successful CT-guided nodule localization. The red circle represents pulmonary nodules. (A) The thickness of the chest wall. (B) The depth of the needle in the lung. (C) The distance between the tip of the localization needle and the pulmonary nodule. (D) The puncture needle enters the lung (known as nodule depth). (Angle 1) The angle at which the puncture needle enters the chest wall. (Angle 2) The angle between the puncture needle and the horizontal plane. CT, computed tomography.

**Table 1** Patient and nodule characteristics

Variables	Value
Age (year)	53.5±12.5
Gender (female/male)	187 (66.5)/94 (33.5)
Smoking status (ex-or current/never)	106 (37.7)/175 (62.3)
History of emphysema (yes/no)	82 (29.2)/199 (70.8)
History of extrathoracic malignancy (yes/no)	5 (1.8)/275 (98.2)
Nature (pure GGO/part solid/solid)	153 (54.4)/108 (38.4)/19 (6.8)
Location (upper lobe/middle lobe/lower lobe)	143 (50.9)/22 (7.8)/115 (40.9)
Surgery (VATS wedge resection/segmentectomy/lobectomy/conversion to thoracotomy)	52 (18.5)/186 (66.2)/43 (15.3)/0 (0)

Continuous variables are presented as mean ± SD and categorical variables are presented as numbers (%). GGO, ground-glass opacity; VATS, video-assisted thoracoscopic surgery; SD, standard deviation.

thoracic surgeon. Surgery was often performed relatively early in patients who were elderly, had difficulty tolerating the condition, or had a massive pneumothorax. During VATS, the thoracic surgeons were able to directly observe the line outside the pleura and manually palpate the focus.

After identifying the localization marks, the thoracic surgeon resected the corresponding lung tissue along with the localization of the claw hooks and specimens. All the resected specimens were promptly sent for histopathological examination. The surgeon decided whether to perform segmentectomy or lobectomy immediately after wedge resection based on the results of the intraoperative frozen section and/or lymph node sampling.

### Statistical analysis

In VATS, the surgeon considers the positioning needle technically successful when the tail positioning line of the device can be directly observed after entering the chest cavity. Nodules located within 1 cm of the positioning hook on CT images were classified as accurately positioned (G0), whereas those located outside of this range were classified as inaccurately positioned (G1). All factors that may affect the positioning accuracy were included in the statistical analysis. These included demographic factors, such as age, sex, history of emphysema, and history of extrapulmonary malignancies; nodule factors, including size (maximum diameter), solidity, density, location, and depth; and technical factors, including patient position, interlobar fissure, thoracic wall thickness, needle depth, the angle between the needle and pleura (angle 1), and the angle between the needle and horizontal plane (angle 2).

During surgery, we considered that there was an increased risk of puncturing the bronchial artery when the depth of the pulmonary nodule was greater than 2.5 cm. Therefore, depth of the pulmonary nodule beyond 2.5 cm was treated as a separate influencing factor.

Data analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Continuous variables, including age, nodule size, and distance from the nodule to the pleura, are presented as means ± standard deviation (SD), with ranges in parentheses. We used 2-sample *t*-tests to compare continuous variables. Categorical variables, such as sex and nodule location, were presented as counts or counts with percentages in parentheses. Chi-squared and Fisher's exact tests were used to compare categorical variables. Linear and multivariate logistic regression analyses were performed, using all of the aforementioned variables. Statistical significance was set at  $P < 0.05$ . We conducted a 2-sided test for the *P* values.

## Results

### Demographics of the study cohort

A total of 281 patients (187 women and 94 men) aged 53.5±12.5 years (range, 21–81 years) underwent CT-guided soft wire hook placement. One patient was excluded from the study because of positioner displacement and failure of the hook to enter the lung parenchyma resulting from a pneumothorax. All patients were subsequently followed up using VATS. The characteristics of all patients and pulmonary nodules are listed in *Table 1*. Postoperative pathological examination revealed that 53 cases (18.9%)

**Table 2** Pathological results

Pathologic finding	Value
Benign	53 (18.9)
Malignancy	227 (81.0)
Adenocarcinoma <i>in situ</i>	64 (22.8)
Minimally invasive adenocarcinoma	113 (40.2)
Invasive adenocarcinoma	43 (15.3)
Squamous cell carcinoma	2 (0.71)
Metastasis	5 (1.78)

Data are shown as counts with percentages in parentheses.

were benign and 227 (81.0%) were malignant (*Table 2*).

### **Factors influencing successful localization**

During VATS, the location of the hook wire and pulmonary nodules were explored and removed. The CT scan image after localization was used to define the edge of the nodule within a 1 cm range from the positioning hook as accurately localized. Of the 280 patients, 191 (68.2%) were classified as accurate (G0) and 89 (31.7%) were classified as inaccurate (G1).

Univariate analysis revealed that demographic factors and nodule properties such as size and density had no significant impact on accurate nodule localization. However, nodule location, depth, and needle depth were identified as crucial factors influencing precise localization, as shown in *Table 3*. Further, we found that nodule depth was significantly different between the accurate (1.01 cm) and inaccurate (2.24 cm) groups ( $P < 0.001$ ). Specifically, when the nodule depth was less than 2.5 cm, the localization accuracy was 67.5%; however, when the nodule depth was greater than 2.5 cm, the localization accuracy decreased significantly to only 0.7% ( $P < 0.001$ ). This result indicates that needle depth is a significant factor influencing accurate localization. The average distance in the accurate group was 0.9 cm, whereas the average distance in the inaccurate group was 1.1 cm ( $P < 0.001$ ). Thoracic wall thickness, the angle between the needle and pleura, and the angle between the needle and horizontal plane were not important factors for positioning accuracy. Multivariate regression analysis comprehensively assessed all the important factors (including demographics, nodule factors, and technical factors). Overall, nodule depths [odds ratio (OR) =22.610, 95% confidence interval (CI): 10.351–49.391,  $P = 0.001$ ] and needle depths (OR

=0.322, 95% CI: 0.136–0.765,  $P = 0.010$ ) were identified independent factors associated with accurate localization (*Table 4*).

### **Factors influencing the risk of complications**

Of the 281 patients, 64 (22.8%) experienced self-limiting bleeding, such as needle-tract bleeding and hemoptysis. Fortunately, none of these cases escalated to the point where thoracotomy was required (*Table 5*). According to the results of the univariate analysis, several factors, including nodule diameter, nodule depth, chest wall thickness, and needle depth, showed a significant causative link with bleeding. The mean nodule diameter in the bleeding group was 1.99 cm, which was significantly higher than the mean nodule diameter of 0.84 cm in the non-bleeding group ( $P = 0.036$ ). The mean nodule depth was 1.64 cm in the bleeding group and 1.33 cm in the non-bleeding group ( $P = 0.011$ ). Further, the mean chest wall thickness was 3.91 cm in the non-bleeding group and 4.26 cm in the bleeding group ( $P = 0.043$ ). The mean needle insertion depth was 1.01 cm in the non-bleeding group and 1.18 cm in the bleeding group ( $P = 0.005$ ).

Of the 281 patients analyzed, 84 (29.9%) experienced pneumothorax, and 5 had to undergo early surgery. The incidence of pneumothorax was not associated with demographic or nodular factors. Patients with pleural reactions were administered oxygen inhalation and 5% glucose solution infusion, and were closely monitored and treated. No other interventions were administered.

### **Discussion**

Our study comprehensively analyzed the factors affecting the accuracy of pulmonary nodule localization before VATS, and discussed the influencing factors of complications.

VATS has recently emerged as the preferred surgical approach for the diagnosis and treatment of early lung cancer (16). Surgeons often face challenges in accessing and visualizing pulmonary nodules located deep within the lung parenchyma, as well as for small ground-glass nodules. Preoperative localization of these nodules with VATS enables chest surgeons to achieve precise resection, thereby minimizing the need for extensive surgery, and promoting the use of minimally invasive treatments. Consequently, it is crucial to assess the factors that affect the success rate, safety, and risks associated with the preoperative localization of pulmonary nodules.

**Table 3** Univariate analysis results

Characteristic	G0 (n=191)	G1 (n=89)	P value
<b>Demographic factors</b>			
Age (years)	53.9±12.5	52.6±12.3	0.85
Gender (female/male)	134 (70.2)/57 (29.8)	52 (58.4)/37 (41.6)	0.05
History of emphysema (yes/no)	62 (32.5)/129 (67.5)	19 (21.3)/70 (78.7)	0.05
History of extrathoracic malignancy (yes/no)	3 (1.6)/188 (68.4)	2 (2.2)/87 (97.8)	0.69
<b>Nodule characteristics</b>			
Size (cm)	1.1±4.6	0.9±0.7	0.42
Solidity (pure GGO/part solid/solid)	110 (57.6)/71 (37.2)/10 (5.2)	43 (48.3)/37 (41.6)/9 (10.1)	0.18
Density	-434.7±230.1	-427.1±235.6	0.82
Location (specific to the lobes)			0.16
Left upper/left lower	49 (25.7)/34 (17.8)	15 (16.9)/13 (14.6)	
Right upper/right middle/right lower	46 (24.1)/14 (7.3)/48 (25.1)	33 (37.1)/8 (9.0)/20 (22.5)	
Location (specific to the segment)	-	-	0.02
Nodule depth (>2.5/≤2.5 cm)	189 (99.0)/2 (1.0)	57 (64.0)/32 (36.0)	<0.001
<b>Technical factors</b>			
Patient position			0.44
Supine/prone/left lateral	47 (24.6)/65 (34.0)/19 (9.9)/	20 (22.5)/33 (37.1)/8 (9.0)	
Right lateral/oblique lateral	17 (8.9)/43 (22.5)	3 (3.4)/25 (28.1)	
Through the interlobar fissure (yes/no)	188 (98.4)/3 (1.6)	86 (96.6)/3 (3.4)	0.33
Nodule depth (cm)	1.01±0.5	2.24±0.8	<0.001
Thoracic wall thickness (cm)	3.8±1.1	4.2±1.2	0.71
Needle depth (cm)	0.9±0.3	1.1±0.5	<0.001
Angle between needle and pleura (angle 1)	75.9±9.2	75.3± 8.7	0.57
Angle between needle and horizontal plane (angle 2)	73.8±13.8	72.4±15.3	0.48

Continuous variables are presented as mean ± SD and categorical variables are presented as numbers (%). Nodule depth, distance from nodule to the pleura. Needle depth, distance from needle tip to the pleura. G0: the edge of the pulmonary nodule was less than 1 cm from the localization needle tip on CT. G1: the edge of the pulmonary nodule was more than 1 cm from the localization needle tip on CT. GGO, ground-glass opacity; SD, standard deviation; CT, computed tomography.

In the present study, successful localization was defined as having the locator positioned within the lung parenchyma, with the tail end of the cord visible on the skin surface or outside the lung pleura, and directly visible to the chest surgeon during surgery. To evaluate the accuracy of localization, we measured the shortest distance (1 cm) between the release position of the needle tip and the edge of the pulmonary nodule. This standard fully satisfies the requirements of VATS for lesion localization. During VATS, all localization markers, including the pulmonary

nodules, were removed and subsequently verified by pathological examination.

In our study, only 1 patient experienced claw dislodgement during repeated scans, whereas the remaining 280 positioned needles were successfully arranged. Previous studies have suggested that inserting a needle may cause the locator to shift, and it is therefore recommended to insert the cannula tip at least 1 cm below the pleural surface (13,14,17,18). Prior research has shown that the coil locator is more prone to displacement and detachment in cases



**Table 4** Multivariate analysis results

Variable	$\beta$ value	OR	95% CI	P value
Size (cm)	-0.030	0.966	0.866–1.076	0.526
Solidity	-0.010	0.999	0.997–1.001	0.180
Location	0.098	1.103	0.863–1.410	0.433
Patient position	0.066	1.068	0.837–1.364	0.595
Nodule depth (cm)	3.118	22.610	10.351–49.391	0.001
Needle depth (cm)	-1.132	0.322	0.136–0.765	0.010
Thoracic wall thickness (cm)	0.240	1.271	0.928–1.741	0.135
Angle between needle and pleura (angle 1)	-0.190	0.982	0.942–1.023	0.377
Angle between needle and horizontal plane (angle 2)	-0.160	0.984	0.959–1.010	0.225

OR, odds ratio; CI, confidence interval.

**Table 5** Procedure complications

Characteristic	Value
Pneumothorax (self-limiting/requiring chest tube or immediate surgery)	84 (29.9)/5 (1.8)
Hemorrhage or hemoptysis positioner displaced or dislodged	64 (22.8)

Data are shown as counts with percentages in parentheses.

where the distance between the coil and pleura is less than 20 mm (12,13). However, the locator used in our study had 4 fishhook-shaped claws at the tip, which provided a firmer grip on the adjacent lung parenchyma and prevented dislocation. Additionally, the tail of the positioning line was a soft wire that minimized friction with the adjacent tissues during respiratory movement, and the tension was relatively low. Therefore, we believed that placing the locator at a greater depth was unnecessary to prevent it from detaching. To ensure that the anchor does not shift due to the patient's own movement while waiting for surgery, we recommend performing repeated CT scans before release to confirm that the locator has successfully penetrated the pleura and entered the lungs.

In the present study, we found that needle-tract bleeding occurred more frequently when the nodule size was >0.84 cm, the nodule depth was >1.33 cm, the thickness of the chest wall at the puncture point was >3.91 cm, or the needle insertion depth was >1.01 cm. We therefore recommend that the operator should pay special attention to avoid pulmonary arterioles in the puncture path as much as possible in such cases.

The incidence of pneumothorax after surgery was relatively high (29.9%) in our study, which may be related

to the CT slice thickness of 1 mm we used. A small amount of pneumothorax does not require special treatment. In our study, 1 patient developed pneumothorax and the positioner detached. This may be because the needle did not enter the lung parenchyma but did enter the thoracic cavity. Since lung tissue has a certain elasticity, the inner pleura may be compressed during puncture, but not be penetrated (13). In such cases, the surgeon should continue to insert the puncture needle to ensure that the needle tip enters the lung parenchyma.

In the present study, demographics, pulmonary nodules, and technical factors were found to have no significant impact on pneumothorax. In support of this, some studies have indicated that frequency is the only significant independent risk factor for pneumothorax (19-21). However, this study only considered patients with a single nodule, and excluded the possible impact of multiple injections. The positioning of 2 or more nodules may cause errors in measurement, which requires further study. The present cohort included patients across a wide age range (53.5±12.5 years, range 21–81 years), and our analysis indicated that age does not significantly affect the accuracy of localization or the occurrence of complications. Complications experienced by all patients were relatively

mild, and did not require specialized treatment. In cases where the patient is older, has comorbid emphysema, or has low pain tolerance, postoperative care involves rest in the supine position, administration of oxygen inhalation, or pain relief medication. If needed, surgery may be scheduled in advance to minimize patient waiting time.

In the present study, surgical records were used to confirm location markers. However, considering that the success of the operation may be affected by factors related to the surgeon and individual patient, it was impossible to determine a direct relationship between the success of the operation and CT-guided localization. Despite these limitations, we believe that the depth of pulmonary nodules and the depth of the localizer are factors that affect accurate localization and complications of hemorrhage after localization. Further, we also propose that it is not necessary to insert the locator too deeply to improve the success rate of targeting pulmonary nodules for subsequent VATS.

The flexible wire hook positioner offers several advantages over traditional positioning methods: First, it surpasses dye localization by providing highly accurate nodule positioning information. Surgeons can swiftly and precisely pinpoint lung nodules with the visual tail wire and anchored tip visible in CT images, minimizing surgical errors and uncertainties. Second, its flexible tail wire is less invasive than a metal one, reducing unnecessary incisions and trauma, thus enhancing safety. Third, compared to coil localization, this device is simpler and faster to operate, alleviating patient pain and discomfort. Consequently, the soft wire claw lung nodule locator excels in precision, visualization, safety, and user-friendliness, contributing to more accurate and safer lung nodule surgeries, shortening operation times, and lessening patient pain.

This study has several limitations which should be acknowledged. This study focused solely on the influencing factors of a single positioning and did not take into account the influencing factors of secondary or multiple positioning. However, these factors will be explored in future research. In our study, we evaluated accuracy based on CT image results rather than relying on surgical records. We believe that all data in the CT image is well preserved, allowing for a comprehensive and direct analysis of the factors influencing successful localization. Nevertheless, it is important to note that there are numerous other factors that can affect the success of surgery, and it is not possible to fully correlate the localization-related factors with the surgical success rate.

## Conclusions

Our results showed that the depth of the nodule and the depth of needle insertion are both important factors influencing the accuracy of soft wire claw hook positioning under CT guidance. Further, the size and depth of the pulmonary nodule, thickness of the puncture point, and depth of needle insertion affect bleeding after localization. Evaluation of these indicators should be considered when locating pulmonary nodules under CT guidance. These results will be helpful in improving the accuracy of puncture positioning, reducing repetitive operations and patient pain, and effectively reducing the operation time and postoperative risk.

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## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1272/rc>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1272/coif>). All 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 retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Nanjing Drum Tower Hospital. Written informed consent was provided by all patients prior to performing the CT-guided percutaneous

localizations procedure.

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