Original Article

The effectiveness and safety of computed tomography-guided hook-wire localization for secondary video-assisted thoracoscopic surgery: a retrospective study

Tian Xia[1,2#]^, Ziyue Zhou[1,2#], Ziyao Fang[1], Zhuolin Xie[1], Ziqing Shen[1], Cheng Ding[1,2], Haitong Huang[1], Yicheng Zhang[1], Shu Pan[1,2], Jun Zhao[1,2]

[1]Department of Thoracic Surgery, The First Affiliated Hospital of Soochow University, Suzhou, China; [2]Institute of Thoracic Surgery, The First Affiliated Hospital of Soochow University, Suzhou, China

Contributions: (I) Conception and design: T Xia, Z Zhou; (II) Administrative support: S Pan, J Zhao; (III) Provision of study materials or patients: Z Fang, Z Xie, H Huang, Y Zhang; (IV) Collection and assembly of data: T Xia, Z Zhou; (V) Data analysis and interpretation: T Xia, Z Shen, Z Fang, C Ding; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Jun Zhao, MD; Shu Pan, PhD. Department of Thoracic Surgery, The First Affiliated Hospital of Soochow University, 899 Pinghai Road, Suzhou 215000, China; Institute of Thoracic Surgery, The First Affiliated Hospital of Soochow University, Suzhou 215000, China. Email: zhaojia0327@126.com; panshusz@126.com.

Background: Computed tomography (CT)-guided hook-wire localization is currently the most commonly used technique for preoperative localization of pulmonary nodules in clinical practice. With the increasing incidence of multiple primary lung cancers and the increasing occurrence of second primary lung cancers or local recurrences after lung cancer surgery, some patients need to undergo an ipsilateral or contralateral second pulmonary resection. In order to reduce the surgical difficulty of the second operation and accurately guide the surgical resection, preoperative localization of some nodules is necessary. This study retrospectively analyzed the CT-guided hook-wire localization information of patients undergoing a second ipsilateral or contralateral video-assisted thoracoscopic surgery (VATS), discussed the safety and effectiveness of hook-wire localization for ipsilateral and contralateral surgeries, and analyzed the risk factors for complications after localization.

Methods: This study retrospectively collected data from 113 patients with isolated solitary pulmonary nodules who underwent a second pulmonary resection and completed CT-guided hook-wire localization at The First Affiliated Hospital of Soochow University from January 2020 to June 2024. The patients were divided into contralateral surgery group and ipsilateral surgery group to compare clinical characteristics, localization time, incidence of complications, and other information between the two groups. Logistic regression analysis was used to identify the risk factors for complications associated with the localization methods in each group.

Results: Compared to the contralateral group, the ipsilateral group had a longer interval between the two surgeries, which was 28.0±9.3 months (P<0.001). The maximum diameter of nodules in the ipsilateral group was 10.8±1.7 mm, higher than that in the contralateral group (P<0.001). There were no statistical differences between the two groups in terms of localization time, number of CT scans, depth of the release position, and incidence of complications. In the contralateral group, 25 patients (30.5%) developed pneumothorax, while in the ipsilateral group, there were 2 cases (6.5%), showing a statistically significant difference (P=0.008). In the contralateral group, 3.7% patients developed hemopneumothorax, while the incidence in the ipsilateral group was as high as 16.1% (P=0.04). Localization time [odds ratio (OR) =1.306, P=0.006] and depth of the release position (OR =1.202, P<0.001) were independent risk factors for the overall occurrence of

^ ORCID: 0009-0004-3376-9040.

complications and pneumothorax, while thoracic adhesions (OR =4.115, P=0.03) was an independent risk factor for hemopneumothorax. History of localization (OR =0.109, P=0.02) was identified as a protective factor for pneumothorax.

Conclusions: CT-guided hook-wire localization can effectively complete the localization of isolated nodules on the ipsilateral or contralateral side in patients requiring a second pulmonary resection, with similar safety. In the future, it is more advisable to promote more precise and personalized localization methods for different patients in clinical practice.

Keywords: Pulmonary nodule localization; video-assisted thoracoscopic surgery (VATS); hook-wire; secondary surgery

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Introduction

Lung cancer remains one of the malignancies with the highest mortality rate worldwide, posing a significant threat to public health (1). In the early stages of lung cancer, many patients present as pulmonary nodules smaller than 3 cm. With the widespread adoption of regular check-ups and low-dose chest computed tomography (LDCT), the detection rate of early lung cancer has significantly improved, especially in high-risk populations (2). Early detection of lung cancer and timely surgery are essential for improving patient survival rates (3).

Video-assisted thoracoscopic surgery (VATS), particularly single-port thoracoscopy, has gained widespread adoption in the surgical management of pulmonary diseases in recent years due to its benefits, including minimal trauma, improved aesthetics, and rapid postoperative recovery (4). However, identifying ground-glass or solid nodules beneath the pleura during VATS presents a challenge as these lesions are hard to detect visually or by touch during the procedure. Surgeons may need to remove more lung tissue or resort to open thoracotomy when unsure of complete nodule excision, introducing unnecessary risks. Hence, precise and safe preoperative individualized localization is essential in thoracoscopic surgery for the successful removal of nodules (5).

Numerous techniques have been developed and implemented for preoperative localization of pulmonary nodules (6). Computed tomography (CT) localization is the most widely used localization method at present (7). Common CT-guided localization methods include: hook-wire, microcoil, liquid fluorescent dyes [indocyanine green (ICG) and methylene blue], medical adhesive or radioactive isotopes, etc. (8-10). The safety, effectiveness, operability, and even patient comfort of localization methods are important topics of concern. CT-guided hook-wire localization is the most commonly used technique for pulmonary nodule localization in clinical practice due to its advantages of short operation time, simple positioning, and high success rate (11). There have been numerous studies discussing the safety and effectiveness of hook-wire localization (12,13). To our knowledge, most of these studies have focused on patients undergoing their first lung nodule surgery. However, with increasing incidence of multiple primary lung cancer, some patients may have bilateral lung nodules requiring surgical intervention. Furthermore, advancements in modern medical imaging and standardized patient follow-up have led to an increase in the occurrence of second primary lung cancers or local recurrences after lung cancer surgery. For these patients, if their cardiopulmonary function is sufficient to tolerate a second surgery, surgical resection is still a recommended treatment (14). To reduce the surgical difficulty of the second operation, guide precise surgical resection, and minimize the risk of complications, preoperative localization of some nodules is necessary.

For patients undergoing ipsilateral second pulmonary resection, the risks associated with CT-guided hook-wire localization may differ from those undergoing contralateral surgery due to thoracic adhesions, changes in lung anatomy, and alterations in respiratory mechanics caused by the initial surgery. There are no previous studies reporting on this. In this study, we retrospectively analyzed preoperative CT-guided hook-wire localization information of patients undergoing second ipsilateral or contralateral

VATS pulmonary resection, aiming to explore the safety and effectiveness of CT-guided hook-wire localization for ipsilateral and contralateral surgeries, and analyze the risk factors for complications after localization. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1342/rc).

Methods

Patient population and study design

This study retrospectively collected data from patients with solitary pulmonary nodules (SPN) who underwent a second pulmonary resection and completed preoperative CT-guided hook-wire localization at The First Affiliated Hospital of Soochow University from January 2020 to June 2024.

Highlight box

Key findings

- Computed tomography (CT)-guided hook-wire localization can effectively complete the localization of isolated nodules on the ipsilateral or contralateral side in patients requiring a second pulmonary resection, with similar safety.

What is known and what is new?

- CT-guided hook-wire localization is the most commonly used technique for pulmonary nodule localization in clinical practice due to its advantages of short operation time, simple positioning, and high success rate. There have been numerous studies discussing the safety and effectiveness of hook-wire localization. To our knowledge, most of these studies have focused on patients undergoing their first pulmonary resection. With the increasing incidence of multiple primary lung cancers and the increasing occurrence of second primary lung cancers or local recurrences after lung cancer surgery, some patients need to undergo an ipsilateral or contralateral second pulmonary resection.
- This study retrospectively analyzed the CT-guided hook-wire localization information of patients undergoing a second ipsilateral or contralateral video-assisted thoracoscopic surgery (VATS), discussed the safety and effectiveness of hook-wire localization for ipsilateral and contralateral surgeries, and analyzed the risk factors for complications after localization.

What is the implication, and what should change now?

- CT-guided hook-wire puncture localization is effective and safe for the localization of isolated nodules in patients requiring a second pulmonary resection. However, due to the different rates of pneumothorax and hemopneumothorax between the contralateral and ipsilateral groups, it is necessary to choose precise and personalized localization methods based on the actual condition of the patients.

Inclusion criteria were as follows: (I) aged between 18 and 80 years old; (II) previously underwent ipsilateral or contralateral pulmonary resection surgery; (III) confirmed by thin-section high-resolution CT (HRCT) scan, assessed by the lung tumor multidisciplinary committee as requiring VATS resection of the lung nodule; (IV) no significant large blood vessels, pulmonary emphysema, or other necessary tissue structures along the proposed puncture path; (V) normal coagulation function and overall health condition, able to tolerate VATS and performed in our hospital; (VI) inability to accurately identify the location of the lung nodule by intraoperative observation and palpation. Exclusion criteria were: (I) maximum nodule diameter >30 mm; (II) pneumothorax, pleural effusion unable to be completely localized; (III) presence of multiple distant metastases inside or outside the lung; (IV) presence of surgical contraindications (such as chronic obstructive pulmonary disease, severe bullae); (V) incomplete clinical or imaging data. The patient selection flowchart is shown in *Figure 1*. Before the localization procedure, each patient or their direct relatives signed a localization consent form. This study was a retrospective, single-center pilot study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of The First Affiliated Hospital of Soochow University (ethical approval No. 2024454) and individual consent for this retrospective analysis was waived.

CT-guided localization with hook-wire

The necessity and feasibility of preoperative localization of each SPN were assessed by the lead surgical team. All patients underwent localization in the CT room before VATS, performed by experienced thoracic surgeons. Based on the target lesions in previous CT images, the patient was positioned in the appropriate posture (prone, supine, or lateral). A non-radiopaque grid was placed on the body surface. A 1 mm-thick CT scan was performed in the designated area, and the puncture point was marked at the intersection of the laser and the non-radiopaque grid. After routine disinfection and local anesthesia with 2% lidocaine, a puncture needle (18 G × 10 cm, BLR18/10, Gallini S.R.L, Mantova, Italy) was inserted to the chosen depth at the selected puncture level, angle, and position according to the CT images. The anchor hook was released after proper adjustment of the hook-wire in the repeated CT scan, and the puncture site was disinfected and covered with gauze.

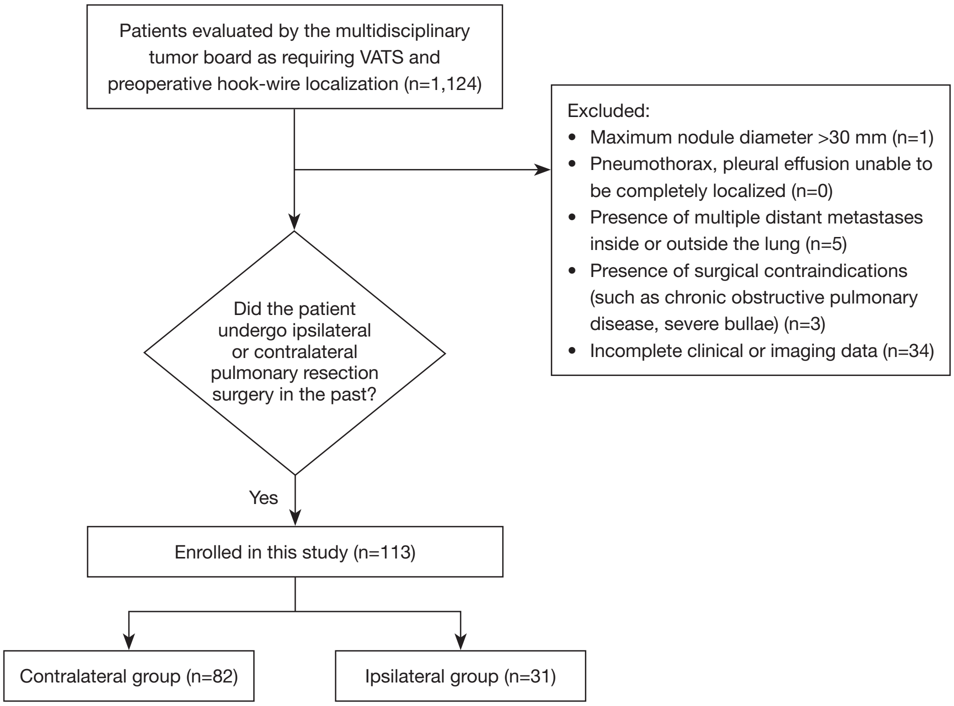

Figure 1 Patient selection flowchart. VATS, video-assisted thoracoscopic surgery.

Finally, a CT scan was performed to evaluate complications such as dislocation, pneumothorax, pulmonary hemorrhage, hemopneumothorax or any presence of air in the blood vessels (*Figure 2*). In this study, successful localization was defined as the final CT scan confirming the presence of the hook-wire in the lung and the surgical team being able to resect the nodule based on the hook needle position during the surgical procedure, while unsuccessful localization meant this could not be achieved. After localization, the patient, in a pillow-free and appropriate posture, was transferred onto a flatbed stretcher and wheeled into the operating room within 15 minutes for immediate anesthesia and surgery. During the waiting period, the patient was instructed to remain calm and breathe quietly.

VATS procedure

After the placement of a double-lumen endotracheal tube for general anesthesia, the patient was positioned in the lateral decubitus. A skin incision of approximately 3 cm was made along the anterior axillary line at the fourth or fifth intercostal space according to the lesion location identified by hook-wire localization. The target lesion was confirmed by hook-wire localization, and resection was performed using a stapler. If pleural adhesions are encountered, carefully and meticulously separate them using an electrocautery hook or ultrasonic scalpel. Rapid pathological examination was conducted on all nodules post-resection, and in cases where infiltrative components were reported in the frozen section biopsy, a standardized anatomical resection was performed, including segmentectomy or lobectomy with mediastinal lymph node dissection. To confirm the effective resection of the nodule in the excised specimen, tactile examination or rapid frozen section pathology is performed.

Statistical analysis

The data were analyzed using SPSS software (SPSS 25.0, Chicago, IL, USA). Continuous variables were presented as mean ± standard deviation (SD), while categorical variables were presented as numbers and percentages. Continuous variables were compared using Student's *t*-test or Mann-Whitney *U* test, and categorical variables were compared using χ^2 test and Fisher's exact test (as appropriate). Logistic univariate regression analysis was performed on factors possibly related to post-localization complications, with variables with P<0.05 in univariate analysis included in

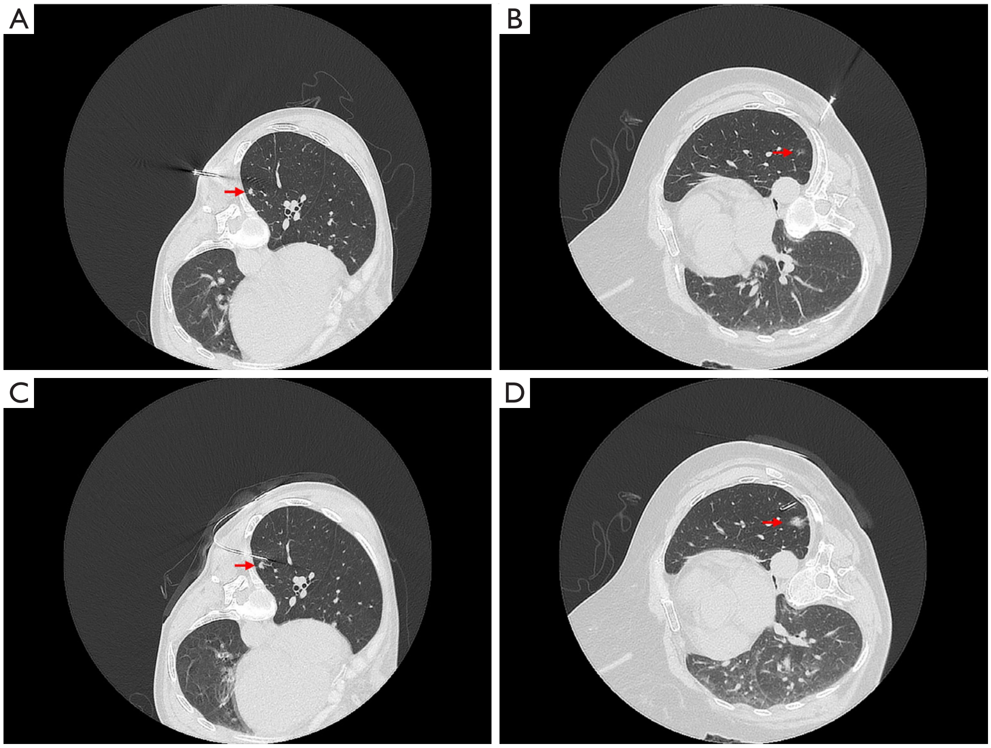

Figure 2 The CT-guided hook-wire localization of pulmonary nodule. The area indicated by the arrow shows the pulmonary nodule. (A) The process of hook-wire puncture in the contralateral surgery group. (B) The process of hook-wire puncture in the ipsilateral surgery group. (C) Release of the hook-wire in the contralateral surgery group. (D) Release of the hook-wire in the ipsilateral surgery group. CT, computed tomography.

logistic multivariate analysis to assess the influencing factors of postoperative complications. A P value <0.05 was considered statistically significant.

Results

Characteristics of the patients and nodules

The clinical characteristics collected during the research process were summarized based on patients (*Table 1*) and based on nodules (*Table 2*). A total of 113 patients were included (49 males, 64 females) who underwent VATS resection of nodules after localization. Among them, in 82 patients, the second surgery was contralateral, while in 31 patients, it was ipsilateral. Baseline information such as age, gender, smoking history, localization history, distance between nodules and pleura, nodule location, etc., compared between the two groups of patients showed no statistically significant differences (P>0.05). The interval between the two surgeries in the contralateral surgery group was 11.2±9.7 months, while it was longer in the ipsilateral surgery group, at 28.0±9.3 months (P<0.001). The maximum nodule diameter in the ipsilateral surgery group was 10.8±1.7 mm, which was higher than that in the contralateral surgery group (P<0.001). In the contralateral surgery group, six patients (7.3%) underwent lobectomy during the second surgery, and 76 patients (92.7%) underwent sublobar resection, including segmentectomy and wedge resection. In the ipsilateral surgery group, one patient (3.2%) underwent lobectomy, and 30 patients (96.8%) underwent sublobar resection. Due to the previous surgery, in the ipsilateral surgery group, 30 patients (96.8%) experienced varying degrees of pleural adhesions during the second surgery, while in the contralateral surgery group, only 16 patients (19.5%) had pleural adhesions (P<0.001). The pathological diagnoses of the 113 nodules are as follows: 7 benign nodules, 17 adenocarcinoma in situ (AIS), 70 minimally invasive adenocarcinoma (MIA), and 19 invasive adenocarcinoma (IAC).

Table 1 Patient-based characteristics

Characteristics	Contralateral group (n=82)	Ipsilateral group (n=31)	P value
Age (years)	59.7±11.7	60.8±9.1	0.94
Gender			0.81
Male	35 (42.7)	14 (45.2)	
Female	47 (57.3)	17 (54.8)	
Smoking history	14 (17.1)	4 (12.9)	0.78
Interval time (months)	11.2±9.7	28.0±9.3	<0.001
Localization history	22 (26.8)	7 (22.6)	0.65
First operative procedure			0.79
Lobectomy	15 (18.3)	5 (16.1)	
Sublobar resection	67 (81.7)	26 (83.9)	
Second operative procedure			0.67
Lobectomy	6 (7.3)	1 (3.2)	
Sublobar resection	76 (92.7)	30 (96.8)	
Thoracic adhesions in the second surgery			<0.001
None adhesion	66 (80.5)	1 (3.2)	
Mild adhesion	12 (14.6)	11 (35.5)	
Severe adhesion	4 (4.9)	19 (61.3)	

Data are presented as mean ± standard deviation or n (%).

Table 2 Nodule-based characteristics

Characteristics	Contralateral group (n=82)	Ipsilateral group (n=31)	P value
Lesion location			0.19
Left upper lobe	19 (23.2)	4 (12.9)	
Left lower lobe	13 (15.9)	6 (19.4)	
Right upper lobe	27 (32.9)	9 (29.0)	
Right middle lobe	6 (7.3)	1 (3.2)	
Right lower lobe	17 (20.7)	11 (35.5)	
Maximum diameter (mm)	8.5±1.5	10.8±1.7	<0.001
Nodule-pleura distance (mm)	8.3±1.6	8.9±2.5	0.14
Histopathologic results			0.28
Benign lesion	5 (6.1)	2 (6.5)	
AIS	15 (18.3)	2 (6.5)	
MIA	49 (59.8)	21 (67.7)	
IAC	13 (15.9)	6 (19.4)	

Data are presented as mean ± standard deviation or n (%). AIS, adenocarcinoma in situ; MIA, microinvasive adenocarcinoma; IAC, invasive adenocarcinoma.

Table 3 Localization results in the two groups

Characteristics	Contralateral group	Ipsilateral group	P value
Localization time (min)	15.3±2.0	15.6±3.6	0.51
CT scan times	4.0±0.7	4.1±0.6	0.43
Depth of the release position (mm)	12.0±4.3	12.1±5.2	0.73
Complications	37 (45.1)	12 (38.7)	0.65
Pneumothorax	25 (30.5)	2 (6.5)	0.008
Pulmonary hemorrhage	8 (9.8)	6 (19.4)	0.20
Hemopneumothorax	3 (3.7)	5 (16.1)	0.04
Hook-wire dislodgement	5 (6.1)	1 (3.2)	0.55
SAE	0 (0)	0 (0)	>0.99

Data are presented as mean ± standard deviation or n (%). CT, computed tomography; SAE, systemic air embolism.

Localization of the nodules

There was no statistical difference in the duration of localization between the two groups. In the contralateral surgery group, five cases (6.1%) experienced failed localization due to hook-wire dislodgement, while in the ipsilateral surgery group, only one case (3.2%) had a similar issue, with no statistical difference between the groups (P=0.55). There were no statistical differences in the CT scan times, and depth of the release position between the two groups. Among the 113 patients, 37 patients in the contralateral surgery group experienced complications, while 12 patients in the ipsilateral surgery group had complications (P=0.65). The main complications were pneumothorax, pulmonary hemorrhage, hemopneumothorax, and hook-wire dislodgement. In the contralateral surgery group, 25 patients (30.5%) suffered from pneumothorax, while in the ipsilateral surgery group, there were two cases (6.5%), showing a statistical difference between the groups (P=0.008). All patients with pneumothorax in both groups had mild symptoms and did not require chest tube drainage. The incidence of pulmonary hemorrhage in the contralateral surgery group was 9.8%, compared to 19.4% in the ipsilateral surgery group, with no statistical difference between the two groups (P=0.20). Notably, three cases (3.7%) in the contralateral surgery group experienced hemopneumothorax, while the incidence in the ipsilateral surgery group was as high as 16.1% (P=0.04). There were no deaths or severe complications, such as pleural reactions and systemic air embolism (SAE), in either group during the localization process (*Table 3*). None of the patients experienced any cases of unexplained cerebral infarction or myocardial infarction within three months postoperatively.

Multivariate logistic regression analysis

Multivariable logistic regression analysis showed that the localization time [odds ratio (OR) =1.306, P=0.006] and depth of localization needle release (OR =1.202, P<0.001) were independent risk factors for the occurrence of overall complications. For pneumothorax caused by localization, the localization time (OR =1.617; P<0.001) and depth of localization needle release (OR =1.364, P<0.001) were identified as independent risk factors. It is worth mentioning that a history of localization (OR =0.109; P=0.02) was found to be a protective factor against pneumothorax, and similarly, ipsilateral localization (OR =0.023; P=0.003) was also identified as a protective factor for pneumothorax. Regarding hemopneumothorax, univariate analysis showed that the presence of pleural adhesions during the second surgery (OR =3.987; P=0.006) and ipsilateral localization (OR =5.064; P=0.03) were risk factors. However, including both in a logistic regression model for multivariate analysis revealed that pleural adhesions (OR =4.115; P=0.03) were independent risk factors for hemopneumothorax. For pulmonary hemorrhage and hook-wire dislodgement, no independent factors related to them have been identified (*Tables 4-8*).

Discussion

With the continuous development of minimally invasive techniques, VATS, which has the advantages of small trauma

Table 4 Logistic regression analysis of potential risk factors for the occurrence of total complications

Risk factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender	0.774 (0.365–1.639)	0.50	–	–
Age	0.997 (0.964–1.031)	0.85	–	–
Localization history	0.607 (0.253–1.461)	0.27	–	–
Thoracic adhesions in the second surgery	1.062 (0.669–1.686)	0.80	–	–
Maximum diameter	0.829 (0.669–1.026)	0.08	–	–
Nodule-pleura distance	1.013 (0.831–1.236)	0.89	–	–
Localization time	1.178 (1.003–1.382)	0.045	1.306 (1.078–1.583)	0.006
Depth of the release position	1.152 (1.052–1.262)	0.002	1.202 (1.086–1.332)	<0.001
Localization lateral	1.301 (0.560–3.026)	0.54	–	–

OR, odds ratio; CI, confidence interval.

Table 5 Logistic regression analysis of potential risk factors for the occurrence of pneumothorax

Risk factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender	0.775 (0.326–1.847)	0.57	–	–
Age	1.009 (0.969–1.050)	0.68	–	–
Localization history	0.174 (0.039–0.792)	0.02	0.109 (0.017–0.697)	0.02
Thoracic adhesions in the second surgery	0.572 (0.306–1.072)	0.08	–	–
Maximum diameter	0.825 (0.636–1.069)	0.15	–	–
Nodule-pleura distance	0.946 (0.747–1.197)	0.64	–	–
Localization time	1.202 (1.018–1.420)	0.03	1.617 (1.237–2.116)	<0.001
Depth of the release position	1.164 (1.059,1.280)	0.002	1.364 (1.166–1.597)	<0.001
Localization lateral	0.157 (0.035–0.710)	0.02	0.023 (0.002–0.267)	0.003

OR, odds ratio; CI, confidence interval.

and fast postoperative recovery, has gradually replaced traditional open chest surgery (15). Research indicates that in the hands of a proficient surgeon, performing secondary ipsilateral VATS on lung cancer patients with a history of prior pulmonary resection is both viable and safe (14,16). Similar to the first surgery, it is difficult for surgeons to determine the exact location of small nodules beneath the pleura. Patients undergoing a second pulmonary resection may have poorer lung function and higher surgical risks, making precise preoperative localization more critical. CT-guided hook-wire localization technique, as a low-cost, safe, effective, and operable method, has been widely studied and applied, but specific analyses on the safety of localization for patients undergoing a second pulmonary resection are still lacking.

Our study comprehensively analyzed the effectiveness and safety of preoperative pulmonary nodule localization for ipsilateral and contralateral second lung VATS, and discussed the factors influencing complications. Secondary ipsilateral nodules mainly manifest as local recurrence and second primary lung cancer (14). In this study, nodules in the ipsilateral surgery group may represent recurrent tumors untreated in the initial surgery or local recurrence or metastasis of the initial lesion, with a usually slow disease

Table 6 Logistic regression analysis of potential risk factors for the occurrence of pulmonary hemorrhage

Risk factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender	0.530 (0.171–1.644)	0.27	–	–
Age	1.001 (0.951–1.053)	0.97	–	–
Localization history	1.736 (0.530–5.683)	0.36	–	–
Thoracic adhesions in the second surgery	1.193 (0.609–2.336)	0.60	–	–
Maximum diameter	0.959 (0.703–1.307)	0.79	–	–
Nodule-pleura distance	1.211 (0.914–1.607)	0.18	–	–
Localization time	0.994 (0.796–1.241)	0.96	–	–
Depth of the release position	1.123 (1.005–1.255)	0.04	–	–
Localization lateral	2.220 (0.702–7.022)	0.17	–	–

OR, odds ratio; CI, confidence interval.

Table 7 Logistic regression analysis of potential risk factors for the occurrence of hemopneumothorax

Risk factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender	1.299 (0.295–5.722)	0.26	–	–
Age	0.978 (0.921–1.039)	0.47	–	–
Localization history	0.963 (0.183–5.060)	0.96	–	–
Thoracic adhesions in the second surgery	3.987 (1.499–10.603)	0.006	4.115 (1.174–14.421)	0.03
Maximum diameter	0.921 (0.611–1.388)	0.69	–	–
Nodule-pleura distance	0.757 (0.497–1.153)	0.20	–	–
Localization time	0.795 (0.544–1.161)	0.23	–	–
Depth of the release position	0.987 (0.839–1.160)	0.87	–	–
Localization lateral	5.064 (1.132–22.659)	0.03	0.924 (0.127–6.706)	0.94

OR, odds ratio; CI, confidence interval.

progression, while nodules in the contralateral surgery group are mostly primary lung cancers unrelated to the initial lesion. Therefore, the interval between the two surgeries is usually longer in the ipsilateral surgery group than in the contralateral surgery group. Considering the challenges and safety concerns of secondary ipsilateral lung surgery, some physicians may opt for conservative follow-up observation instead of immediate surgical treatment. This may result in larger nodule diameters in patients undergoing a second surgery in the ipsilateral surgery group compared to the contralateral surgery group. Currently, there are limited research data on whether to choose lobectomy or sublobar resection for the second lung surgery. Research by Yao *et al.* (16) showed that sublobar resection for the second pulmonary resection has better perioperative outcomes and survival benefits similar to lobectomy. In our study, 96.8% of patients in the ipsilateral surgery group underwent sublobar resection, while 92.7% of patients in the contralateral surgery group underwent sublobar resection, based on comprehensive considerations for postoperative lung function preservation, quality of life, and perioperative safety.

In this study, the success rate of localization in the contralateral surgery group was 93.9%, and in the ipsilateral

Table 8 Logistic regression analysis of potential risk factors for the occurrence of hook-wire dislodgement

Risk factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender	1.566 (0.275–8.924)	0.61	–	–
Age	0.986 (0.919–1.059)	0.71	–	–
Localization history	1.481 (0.257–8.547)	0.66	–	–
Thoracic adhesions in the second surgery	1.093 (0.403–2.971)	0.86	–	–
Maximum diameter	0.679 (0.374–1.234)	0.20	–	–
Nodule-pleura distance	1.218 (0.818–1.814)	0.33	–	–
Localization time	0.932 (0.648–1.337)	0.71	–	–
Depth of the release position	1.126 (0.964–1.316)	0.13	–	–
Localization lateral	0.513 (0.058–4.578)	0.55	–	–

OR, odds ratio; CI, confidence interval.

surgery group was 96.8%, indicating that preoperative localization can be effectively performed on the diseased side regardless of previous surgical resection. The incidence of complications was 45.1% and 38.7%, including pneumothorax, pulmonary hemorrhage, hemopneumothorax, and hook-wire dislodgement. There was no significant difference in the overall complication rate between the two groups (P=0.65), indicating overall comparable safety of localization. Both univariate and multivariate analyses showed that the time of localization and depth of the release position were independent risk factors for overall complications. Studies by Chai *et al.* (11) and Yin *et al.* (17) analyzing the risk factors of complications in hook-wire localization support our conclusions. However, the probability of pneumothorax in the contralateral surgery group was significantly higher than in the ipsilateral surgery group, likely due to various reasons. From one perspective, the presence of pleural adhesions may provide a protective effect against pneumothorax occurrence, although in our study, it was not an independent factor (18). For patients undergoing an ipsilateral surgery, varying degrees of pleural adhesions can be observed intraoperatively, with abnormal fibrous connections formed during the natural repair process predominantly originating from the damage from the first surgery (19). Patients without pleural adhesions may immediately face the risk of gas entering the pleural cavity and causing pneumothorax once the puncture needle penetrates the pleura and enters the lung tissue during localization, with the probability of this risk increasing with prolonged localization time (11). However, for patients with pleural adhesions, adhesion and closure of the visceral and parietal pleura layers along the puncture path may prevent or reduce the risk of gas entering the pleural cavity, thus decreasing the likelihood of pneumothorax. From another perspective, we believe that the difference in pneumothorax incidence between the two groups is also related to changes in respiratory mechanics and dynamics following pulmonary resection surgery. After pulmonary tissue resection, as the gas in the pleural cavity is expelled and the intrapleural pressure decreases, the remaining lung tissue may over-expand, while pulmonary compliance decreases (20,21). Zeng *et al.* (22) found that increased respiratory amplitude may result in more scans and prolonged localization time during CT-guided localization. Although we did not find differences in the localization time between the two groups in our study, we speculate that in patients of the ipsilateral surgery group, decreased lung compliance on the diseased side due to the previous surgery may lead to reduced respiratory amplitude during breathing, lowering the risk of gas entry post-puncture. However, further research is needed to confirm this. Interestingly, we found that a history of localization was a protective factor for pneumothorax occurrence. Based on our clinical experience, this could be due to patients undergoing repeated localization having lower anxiety and better compliance, reducing the risk of pneumothorax from patient movements, coughing, and deep breathing.

In our study, the probability of hemopneumothorax occurrence was higher in the ipsilateral surgery group than in the contralateral surgery group (P=0.04). Univariate analysis showed that pleural adhesions during the second surgery and ipsilateral localization posed as risk factors. However, as most patients in the ipsilateral surgery group (96.8%) had pleural adhesions, after removing confounding factors in multivariate analysis, only pleural adhesions were identified as an independent risk factor for hemopneumothorax in localization. Studies have reported that bleeding caused by pleural adhesion tearing is an important factor for hemopneumothorax (23-25). New tiny blood vessels may be present in dense pleural adhesions formed after secondary lung surgery, and when the puncture needle passes through, they may rupture and bleed. With a large volume of gas entering an adhesive pleural cavity, rapid lung collapse can lead to tearing of adhesive bands, resulting in hemopneumothorax. Undoubtedly, performing surgery in patients with extensive pleural adhesions under single-port thoracoscopy is challenging. Our experience provides insights into these surgeries, where judicious use of energy devices and cautious dissection are important measures to reduce bleeding. In a clinically significant observation in our center, when patients have extensive adhesions, there is a possibility that the hook wire may be wrapped in the adhesion bands, and upon separating the adhesions, the hook wire may be burnt into two fragments by the electrocoagulation hook, thereby increasing the difficulty and risks of the surgery. This phenomenon is not very common, but in clinical practice, it requires additional attention from the operating surgeon.

Although severe complications such as pleural reactions and SAE did not occur in our study, this stroke of luck does not mean that these fatal complications will not occur, especially SAE. SAE is a potential fatal complication of hook-wire localization, with an estimated incidence rate of 0–0.62% (26). This rare complication possibly associated with prone positioning, patient movement during the procedure, repositioning after placement, coughing, Valsalva maneuver, etc., may lead to the presence of asymptomatic intravascular air post-localization, and also potentially result in coronary artery embolism, cerebral infarction, or even death (27,28). In our study, all patients did not exhibit suspicious intravascular or intracardiac gas shadows, and there were no cases of unexplained cerebral infarction or myocardial infarction during the localization process and postoperatively. We believe this may be related to instructing the patients to remain still and breathe calmly during the procedure before localization. In our institution, the operating physicians performing localizations are required to ensure the correct needle path before entering the lung and to minimize multiple puncture adjustments, which may be an important factor in reducing the occurrence of SAE. Additionally, the disposable puncture needle we selected is relatively thin (18G), which may reduce the risk of gas entering during the puncture process.

This study has the following limitations: (I) this study is a retrospective single-center study, and the results may be influenced by selection bias; (II) due to the uniqueness of the cases, the sample size in this study is small, and further multicenter, large sample size prospective studies are needed to validate our clinical conclusions; (III) this study only focuses on the influencing factors of solitary nodule localization and does not consider the influencing factors of multiple nodule localization, which will be further explored in future studies.

Conclusions

Our study results indicate that CT-guided hook-wire localization can effectively locate solitary nodules on the same side or contralateral side for patients requiring a second pulmonary resection, with similar safety. The incidence of hemopneumothorax in the ipsilateral surgery group was higher than that in the contralateral group, but the incidence of pneumothorax was lower. The history of localization time and depth of the release position are independent risks factor for overall complications and pneumothorax, while pleural adhesions are an independent risk factor for hemopneumothorax, and the history of localization is a protective factor for pneumothorax. Increasing understanding of CT-guided hook-wire localization and implementing cautious, personalized localization measures can help reduce the occurrence of potential complications.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of the First Affiliated Hospital of Soochow University (ethical approval No. 2024454) and individual consent for this retrospective analysis was waived.

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