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Comparison of cyanoacrylate and hookwire for localizing small pulmonary nodules: A propensity-matched cohort study

Jian Wang[a], Ju Yao[a], Lei Xu[a], Limei Shan[a], Rong Zhai[a], Libing Gao[b], Liang Liu[b], Fei Yao[a,*]

[a] *Department of Thoracic Surgery, The Affiliated Jiangning Hospital of Nanjing Medical University, Nanjing, Jiangsu, China*
[b] *Department of Radiology, The Affiliated Jiangning Hospital of Nanjing Medical University, Nanjing, Jiangsu, China*

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ABSTRACT

Background: Localizing small pulmonary nodules (SPNs) is a challenge during thoracoscopic resection, but preoperative computed tomography (CT)-guided localization using either cyanoacrylate or hookwire can be helpful. This study compared the safety, efficiency, and operability of the two techniques.
Methods: From September 2013 to November 2018, 269 patients (269 SPNs) who underwent preoperative CT-guided SPN localization were enrolled. A propensity-matched analysis, incorporating 13 variables, was performed to control potential selection bias.
Results: All the patients were divided into two groups: CT-guided cyanoacrylate localization group (Group C, n = 149) and CT-guided hookwire localization group (Group H, n = 120). Eighty-six patients were propensity-matched in each group. All SPNs were successfully removed thoracoscopically, and no conversion was required. Localization-related complications in the two groups were similar, including intrapulmonary focal hemorrhage ($p = 0.823$), pneumothorax ($p = 1.000$), or hemoptysis ($p = 0.121$). For pain assessment and management, the cyanoacrylate localization saw a lower pain score ($p < 0.001$) and less morphine use ($p < 0.001$). In Group H, the localization took a significantly longer time ($p < 0.001$). Covering only the patients in Group C, the sub-analysis found that cyanoacrylate localization on the day before surgery did not compromise the accuracy of intraoperative targeting or increase the incidence of complications, compared with the localization on the day of surgery (all $p > 0.05$).
Conclusion: Compared to hookwire localization, CT-guided cyanoacrylate localization decreased pain and morphine use and allowed flexible surgical schedules, suggestive of its preferability for the resection of SPNs.

1. Introduction

Low-dose thoracic computed tomography (CT), a useful tool for screening early lung cancer in high-risk patients, can reduce mortality by 20% [1]. Due to the widespread use of low-dose CT, small pulmonary nodules (SPNs) were increasingly identified in the screened population, and some suspected to be malignant may require further investigation [2]. Unfortunately, benign-malignant SPN differentiation is sometimes thorny just based on CT or positron emission tomography/CT [3,4]. Video-assisted thoracoscopic surgery (VATS), which allows complete removal of the entire nodule at one setting, provides a minimally invasive method for simultaneously diagnosing and treating SPNs. However, unguided VATS is often powerless for detecting small and/or deeply located SPNs, especially those with ground-glass opacity (GGO) component or surrounded by pleural adhesions [5].

To facilitate thoracoscopic resection of SPNs, various preoperative localization techniques have been developed. CT-guided localization using hookwire is the most appropriate method owing to its high efficiency and operability [6]. Besides, localizing SPNs with cyanoacrylate has also been developed as a simple method unrestricted by special equipment [7]. Although the previous study showed the feasibility of the CT-guided cyanoacrylate localization [8], its safety and efficacy have been seldom compared with those of hookwire localization [9]. Therefore, we performed a propensity-matched analysis evaluating the safety, efficiency, and operability of the two techniques at a single academic center.

2. Patients and methods

Written informed consent for preoperative localization was

* Corresponding author. Division of Thoracic Surgery, The Affiliated Jiangning Hospital of Nanjing Medical University, No. 168, Gushan Road, Jiangning District, Nanjing, 211100, Jiangsu Province, China.
E-mail address: yaofei@njmu.edu.cn (F. Yao).

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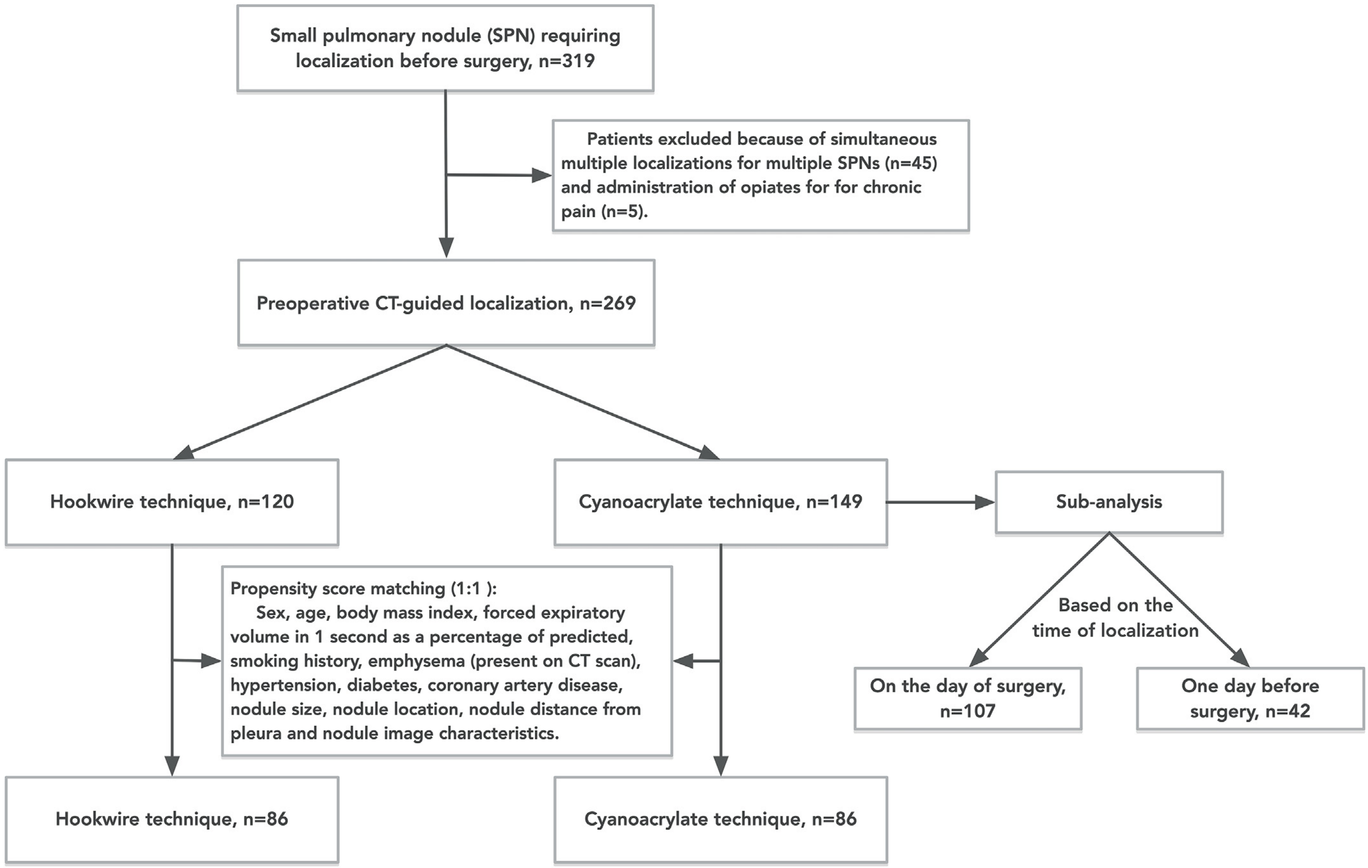

Fig. 1. Flowchart for propensity-score matching and subgroup analyses.

obtained from all participants. Our institutional review board approved this retrospective study and granted a waiver of informed consent. The study was conducted in accordance with the Declaration of Helsinki principles (Researchregistry 4874).

2.1. Patients

From September 2013 to November 2018, cyanoacrylate and hookwire were placed in 319 patients for preoperative SPN localizations at our institution. Of them, 45 patients were excluded because simultaneous localization of multiple SPNs was performed. Also excluded were 5 patients who had used opiates for chronic pain (defined by the International Association for the Study of Pain as having pain at the site of surgery more than 2 months afterward [10]). Thus, 269 patients with 269 SPNs were included (Fig. 1). The patients were assigned to two groups depending on the localization technique used: Group C (n = 149, 55.4%) comprised cyanoacrylate localization procedures, and Group H (n = 120, 44.6%) comprised procedures where hookwire localization was performed.

The main indications for preoperative CT-guided localization included (i) presence of small lesions (< 10 mm in maximal diameter) and/or (ii) deeply located pulmonary nodules (the distance to the nearest point on visceral surface > 10 mm). To determine the characteristics of the nodules, all the patients received a thin-slice chest CT, which was assessed by two experienced radiologists.

2.2. Localization procedure

All localization procedures were performed with a multi-detector scanner (Siemens Healthcare, Forchheim, Germany). Before June 2016, hookwire insertion was the main localization method used at our institution. In June 2016, cyanoacrylate localization technique was introduced as an alternative and has gradually become more preferable ever since.

2.2.1. Cyanoacrylate localization

The procedures of CT-guided cyanoacrylate approach have been detailed in one previous study [8]. Briefly, the patient was placed in a position allowing for the shortest insertion route of the introducer needle. After local anesthesia, a 22-gauge introducer needle was advanced into the lung parenchyma at least 5 mm beneath the visceral pleura. The position of the needle tip was monitored with another CT scan. Thereafter, 0.2 ml of a mixture containing 0.15 ml of cyanoacrylate (Beijing Fuaile Medical Adhesive Co., Beijing, China) and 0.05 ml of methylene blue was injected. The introducer needle was then completely removed from the chest wall, followed by a postprocedural CT scan to define the final location of the cyanoacrylate as well as the possible postprocedural complications (Fig. 2C). The patient was then sent back to the general ward.

2.2.2. Hookwire localization

After determining the appropriate puncture path, local anesthesia was performed with lidocaine. An introducer needle housing the hookwire (Argon Medical Devices, Athens, TX, 21G) was then inserted by > 10 mm into the lung parenchyma [11]. Once the needle tip was placed in the proper position, the hookwire was released. As the cyanoacrylate localization did, a whole-chest CT scan was performed to identify the location of the hookwire and related complications (Fig. 2A). The distal end of the hookwire was trimmed at the skin level. The patient was then transferred back to the general ward before surgical procedure.

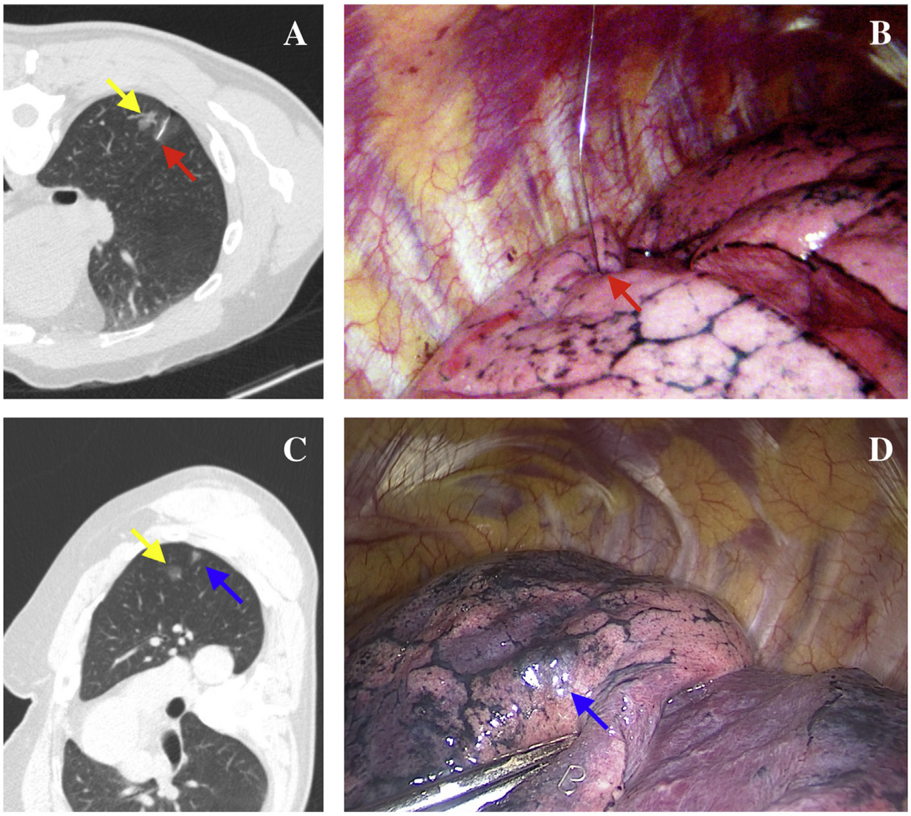

Fig. 2. (A) and (C) Computed tomography-guided hookwire placement and cyanoacrylate injection; (B) and (D) thoracoscopic view of the two makers. Red arrow indicates hookwire, blue arrow indicates cyanoacrylate marker, and yellow indicates nodule. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2.3. Surgical procedure

VATS resection and localization procedure were performed on the same day in all, except 42 patients in Group C who received VATS on the day after localization. VATS resection was performed under general anesthesia with single-lung ventilation. After localizing the target nodule, wedge resection or segmentectomy was performed (Fig. 2B, D). If the SPN could not be localized with thoracoscopy, the surgical procedure was converted to a VATS anatomic resection (segmentectomy or lobectomy) or an open thoracotomy. The resected specimen was intraoperatively evaluated by frozen-section pathological analysis to confirm a complete nodule excision with negative surgical margins. Additionally, if an infiltrating carcinoma presented, a formal lobectomy with systemic mediastinal lymph node dissection was conducted.

2.4. Evaluation of clinical outcomes

Baseline data, imaging data, and localization procedure and surgical data were collected from our medical record system. The SPNs were classified as pure ground glass opacity (GGO), mixed GGO or pure solid nodule based on their appearance on the thin-slice CT scan [12]. Localization procedural time was defined as the period between the first localization CT scan and the last CT scan. Insertion depth of the needle was defined as the length of the introducer needle inserted into the lung parenchyma measured on the CT scan. Successful targeting during localization was defined as the CT-scanned presence of the marker at the target site. Duration from localization to surgery was defined as the period between the last localization CT scan and the first skin incision. Conversion was defined as conversion to VATS anatomic resection or open thoracotomy due to failure to locate the nodule. Successful targeting during operation was defined as the presence of the nodule in the operative field under the guidance of the marker.

For localization-related pain assessment, we used the 11-point visual analogue scale (VAS), with a score ranging from 0 (no pain) to 10 (the worst pain imaginable) [13]. The pain was scored 30 min after the patient returned from the localization procedure to the ward. The pain scores were evaluated by an attending nurse blind to the study. When the VAS score was higher than 5, the patient was given additional analgesics (5 mg intramuscular morphine, up to 3 doses per day). The attending nurses (8 nurses) who had performed pain assessments for both localization techniques were given a questionnaire assessing their views on patient comfort between the two methods.

2.5. Statistical analysis

To minimize selection bias, a propensity-matched analysis was performed. Propensity scores were generated by using a logistic model including the following variables: sex, age, body mass index, forced expiratory volume in 1 s as a percentage of predicted, smoking history, emphysema (present on CT scan), hypertension, diabetes, coronary artery disease, nodule size, nodule location, nodule distance from pleura and nodule image characteristics. The 1:1 match was achieved by using the nearest neighbor matching algorithm. Patients were considered being matched if the absolute difference in their propensity scores was ≤ 0.05. A sub-analysis was performed for patients receiving CT-guided cyanoacrylate localization, who were further divided into two subgroups based on the time of localization: on the day of surgery or one day before surgery.

Variables were analyzed as proportions and percentages, mean ± SD, or median with interquartile range, as appropriate. Categorical variables were analyzed using Pearson's χ^2 test or Fisher's exact test. Continuous variables were compared using unpaired Student's *t*-test or Mann-Whitney *U* test. Two-sided *p* values less than 0.05 were considered significant for all tests. Data analysis was conducted using IBM SPSS for Mac (version 22.0, IBM, New York, USA). The work and results were reported in line with the STROCSS criteria [14].

Table 1
Characteristics of patients and nodules.

Variables	All patients			Propensity-matched Patients		
	Group H (n = 120)	Group C (n = 149)	p Value	Group H (n = 86)	Group C (n = 86)	p Value
Age, y	55.4 ± 11.0	54.9 ± 11.3	0.667	54.1 ± 11.6	54.9 ± 10.0	0.662
Sex			0.275			0.528
Men	48 (40.0)	50 (33.6)		30 (34.9)	34 (39.5)	
Women	72 (60.0)	99 (66.4)		56 (65.1)	52 (60.5)	
BMI, kg/m^2	23.2 ± 3.0	23.7 ± 3.0	0.188	23.1 ± 3.0	23.7 ± 3.0	0.199
% Predicted FEV1	93.3 ± 14.2	95.6 ± 13.2	0.169	94.3 ± 14.2	95.6 ± 14.8	0.556
Smoking history			0.050			0.952
Never	102 (85.0)	140 (94.0)		79 (91.9)	78 (90.7)	
Former, quit > 30 d	5 (4.2)	3 (2.0)		2 (2.3)	2 (2.3)	
Active smoker	13 (10.8)	6 (4.0)		5 (5.8)	6 (7.0)	
Emphysema (present on CT scan)	5 (4.2)	5 (3.4)	0.756	2 (2.3)	2 (2.3)	1.000
Preoperative comorbidity						
Hypertension	9 (7.5)	9 (6.0)	0.643	5 (5.8)	5 (5.8)	1.000
Diabetes	5 (4.2)	2 (1.3)	0.248	3 (3.5)	2 (2.3)	1.000
CAD	1 (0.8)	2 (1.3)	1.000	1 (1.2)	1 (1.2)	1.000
Nodule size, mm	9.8 ± 3.3	8.0 ± 3.0	< **0.001**	8.7 ± 2.9	8.6 ± 3.5	0.775
Nodule location			0.426			0.875
Upper/Middle lobe	75 (62.5)	86 (57.7)		53 (61.6)	54 (62.8)	
Lower lobe	45 (37.5)	63 (42.3)		33 (38.4)	32 (37.2)	
Nodule distance from pleura, mm	10.8 ± 8.0	9.9 ± 7.6	0.349	10.0 ± 7.5	10.8 ± 7.8	0.455
Nodule image characteristics			< **0.001**			0.793
Pure GGO	68 (56.7)	119 (79.9)		63 (73.3)	60 (69.8)	
Part-solid GGO	24 (20.0)	15 (10.1)		13 (15.1)	13 (15.1)	
Solid	28 (23.3)	15 (10.1)		10 (11.6)	13 (15.1)	

Data are presented as mean ± standard deviation or number (proportion).
FEV1, forced expiratory volume in 1 s; CT, computed tomography; CAD, coronary artery disease; GGO, ground glass opacity.

3. Results

3.1. Patient and nodule characteristics

Between September 2013 and November 2018, 269 of 319 patients who were potentially eligible for the study were selected. The inclusion criteria and propensity scores are shown in Fig. 1. Before matching, significant differences in nodule size ($p < 0.001$) and nodule image characteristics ($p < 0.001$) were observed between Group H and Group C. After propensity matching, 86 well-matched pairs were identified, and the two variables did not show a significant difference. Details of patient and nodule characteristics before and after matching are described in Table 1.

3.2. Localization procedure

Table 2 provides the detailed outcomes of two localization techniques. Localization was achieved either by hookwire or cyanoacrylate and successfully performed in all cases (successful targeting during localization: 100%). After matching, Group C was associated with shorter localization procedural time ($p < 0.001$), shorter needle-insertion depth ($p < 0.001$), and longer duration from localization to surgery ($p < 0.001$) as compared with the Group H. The localization-related pain score was 4.7 ± 1.6 in Group H and 3.5 ± 1.3 in Group C ($p < 0.001$). Supplemental morphine was used in 36 (41.9%) patients in Group H, and 9 patients (10.5%) in Group C ($p < 0.001$). Eight nurses completed the questionnaire on patient comfort between the two localization techniques. All eight nurses indicated that the cyanoacrylate technique significantly reduced the pain of patients as compared with the hookwire technique.

Regarding localization-related complications, there were no statistical differences between the two groups in intrapulmonary focal hemorrhage ($p = 0.823$), pneumothorax ($p = 1.000$), or hemoptysis ($p = 0.121$). We further classified the amount of pneumothorax based on the longest distance from the collapsed lung to the chest wall [15]. All the pneumothorax observed in this study was classified as small pneumothorax (the distance was less than 2 cm). All the complications were observed and did not require additional treatment.

Table 2
Localization-related variables.

Variables	All patients			Propensity-matched Patients		
	Group H (n = 120)	Group C (n = 49)	p Value	Group H (n = 86)	Group C (n = 86)	p Value
Localization procedural time, min	15.1 ± 5.8	10.9 ± 2.9	< **0.001**	15.3 ± 6.3	10.9 ± 3.0	< **0.001**
Insertion depth of needle, mm	23.5 ± 7.4	13.8 ± 5.0	< **0.001**	22.7 ± 7.0	14.0 ± 4.9	< **0.001**
Successful targeting during localization	120 (100)	149 (100)	–	86 (100)	86 (100)	–
Duration from localization to surgery, min	146 ± 66	441 ± 444	< **0.001**	145 ± 68	238 ± 239	**0.001**
Localization-related complications						
Intrapulmonary focal hemorrhage	17 (14.2)	12 (8.1)	0.108	12 (14.0)	11 (12.8)	0.823
Pneumothorax	25 (20.8)	27 (18.1)	0.575	18 (20.9)	18 (20.9)	1.000
Hemoptysis	4 (3.3)	1 (0.7)	0.176	4 (4.7)	0 (0)	0.121
Dislodgement	2 (0.7)	0 (0)	0.198	2 (2.3)	0 (0)	0.497
Pain score	4.7 ± 1.6	3.2 ± 1.3	< **0.001**	4.7 ± 1.6	3.5 ± 1.3	< **0.001**
Morphine use	51 (42.5)	13 (8.7)	< **0.001**	36 (41.9)	9 (10.5)	< **0.001**

Data are presented as mean ± standard deviation or number (proportion).

Table 3
Perioperative variables.

Variables	All patients			Propensity-matched Patients		
	Group H (n = 120)	Group C (n = 149)	p Value	Group H (n = 86)	Group C (n = 86)	p Value
Conversion	0 (0)	0 (0)	–	0 (0)	0 (0)	–
Successful targeting during operation	118 (98.3)	149 (100)	0.198	84 (97.7)	86 (100)	0.497
Type of resection			< **0.001**			**0.010**
Wedge resection	55 (45.8)	111 (74.5)		43 (50.0)	59 (68.6)	
Segmentectomy	26 (21.7)	28 (18.8)		21 (24.4)	19 (22.1)	
Lobectomy	39 (32.5)	10 (6.7)		22 (25.6)	8 (9.3)	
Pathologic diagnosis			< **0.001**			0.078
Atypical adenomatous hyperplasia	5 (4.2)	3 (2.0)		5 (5.8)	3 (3.5)	
Adenocarcinoma in situ	23 (19.2)	21 (14.1)		21 (24.4)	15 (17.4)	
Minimally invasive adenocarcinoma	33 (27.5)	98 (65.8)		31 (36.0)	46 (53.5)	
Invasive adenocarcinoma	36 (30.0)	9 (6.0)		19 (22.1)	9 (10.5)	
Benign	23 (19.2)	18 (12.1)		10 (11.6)	13 (15.1)	
Postoperative hospital stay, d	4.7 ± 1.1	4.5 ± 1.1	0.109	4.7 ± 1.1	4.5 ± 1.0	0.285
30-day mortality	0 (0)	0 (0)	–	0 (0)	0 (0)	–

Data are presented as mean ± standard deviation or number (proportion).

3.3. Perioperative outcomes

Upon thoracoscopic exploration, hookwire dislodgement was observed in 2 patients (1.7%, 2/120). No significant difference was found in rate of successful targeting during operation ($p = 0.198$). Hookwire dislodgement did not affect the success of VATS resection (guided by the small hematoma at the puncture site caused by the introducer needle), and no conversion was required. When a propensity-matched comparison was made between the two groups, there were no significant differences in pathologic diagnosis ($p = 0.078$) or postoperative hospital stay ($p = 0.285$). Wedge resection was performed in 43 (50.0%), segmentectomy in 21 (24.4%), and lobectomy in 22 (25.6%) of the patients in Group H; 59 (68.6%), 19 (22.1) and 8 (9.3%) of patients in Group C ($p = 0.010$) (Table 3).

3.4. Sub-analysis of the cyanoacrylate localization technique

According to when the localization was performed, the patients receiving CT-guided cyanoacrylate localization were sub-analyzed: 107 (71.8%) patients received cyanoacrylate localization on the day of surgery, whereas 42 (28.2%) patients on the day before the surgery (Table 4). There were no significant differences in all localization-related outcomes between the two groups (all $p > 0.005$).

4. Discussion

With the use of low-dose CT in early lung cancer screening, SPNs are increasingly detected in clinical practice. Complete resection via VATS is frequently required for SPNs highly suspected of malignancy. However, detection of these SPNs during VATS is challenging. Therefore, various preoperative nodule markers for VATS have been developed. Given its high efficacy and operability, CT-guided hookwire localization is the most commonly performed technique [16]. This method, however, still has limitations. The patient may feel discomfort brought by the rigid wire traversing the lung parenchyma and remaining in place until the surgical resection. In addition, localization-related complications, such as pneumothorax, dislodgement and focal hemorrhage, may get worse during the interval between localization and surgery [17]. Cyanoacrylate, a class of synthetic tissue sealants that can quickly polymerize on exposure to anionic material such as tissue fluid or blood [18], has been used for SPN localization in our institution since 2016. Although the use of the cyanoacrylate in our study is off-label, the procedure is technically feasible and safe. Previous research suggested that preoperative CT-guided localization using cyanoacrylate is a simple, safe, and efficient technique [8]. However, only one retrospective study, which included 19 patients in the hookwire group, has been conducted to compare the localization-related complications of the two localization techniques [9], meaning there may be more information to explore.

The success rate of targeting during operation was 98.3% (118/120) in the hookwire group and 100% (149/149) in the cyanoacrylate group, suggesting that both techniques were highly effective in locating SPN during VATS. Regarding localization-related complications, unmatched and matched analyses found no statistical differences between the two groups. Huang et al. reported that preoperative localization by the cyanoacrylate method brought with fewer complications than that with the hookwire technique [9]. They suggested that the sealing effect of the cyanoacrylate on the needle trajectory played a crucial role in reducing complications. Our results did not demonstrate a significant reduction in complications in the cyanoacrylate group. One possible

Table 4
Sub-analysis of CT-guided cyanoacrylate localization technique based on the time of localization.

Variables	On the day of surgery (n = 107)	One day before surgery (n = 42)	p Value
Localization procedural time, min	10 (8–12)	10 (9–13)	0.514
Insertion depth of needle, mm	13.0 (10–17)	13.5 (12–16)	0.432
Localization-related complications			
Intrapulmonary focal hemorrhage	11 (10.3)	1 (2.4)	0.180
Pneumothorax	20 (18.7)	7 (16.7)	0.773
Hemoptysis	0 (0)	1 (2.4)	0.282
Pain score	3 (2–4)	3 (2–4)	0.345
Morphine use	9 (8.4)	4 (9.5)	0.759
Chest tube drainage	0 (0)	0 (0)	–
Successful targeting during localization	107 (100)	42 (100)	–
Successful targeting during operation	107 (100)	42 (100)	–

Data are presented as median with interquartile range or number (proportion).

explanation was related to the time of diagnosing the localization-related complications. For both localization techniques, CT scan was performed immediately after the placement of the marker to identify the final location of the marker as well as the possible complications. We believed that the complications diagnosed at this time were more related to the puncture procedure, rather than the marker. In our study, the puncture procedures in the two techniques were similar. Although cyanoacrylate localization technique did not reduce complications, we agree with Imperatori et al. in that it can prevent localization-related complications from getting worse by its sealing effect on the needle trajectory [19].

Effective pain control can reduce preoperative stress and anxiety and accelerate postoperative recovery. Huang et al. observed no statistical difference in chest pain generating from the two techniques [9]. However, their study lacked a clear definition of chest pain and a description of pain management. In the present study, we used the 11-point VAS to evaluate localization-related pain, which is globally accepted, and we standardized pain assessment and management. Moreover, to make the results more convincing, we excluded patients with simultaneous multiple SPNs localization and preoperative chronic pain. Our study found that cyanoacrylate localization was associated with a lower pain score and less morphine use. In addition, all the eight attending nurses involved in pain assessments for both localization techniques indicated that the cyanoacrylate technique significantly reduced the pain in SPN patients.

Hookwire is rigid and has a barbed tip which prevents it from falling out of the lung parenchyma. To reduce localization-related complications, we removed the portion of the hookwire that protruded from the chest wall, allowing the remaining part to slide freely in the chest wall [20]. However, the rigid wire, which slides inside the chest wall with the patient's normal breath, can cause significant chest pain that does not disappear until the wire is removed (Fig. 3A). In comparison, the cyanoacrylate is a liquid that quickly polymerizes into a small nodule after being injected into the lung parenchyma. The artificial nodule formed by the cyanoacrylate then firmly anchors in lung parenchyma and rarely causes pain (Fig. 3B). In the present study, the pain measured after cyanoacrylate localization was mainly caused by puncture injury and gradually decreased with time.

Both hookwire and cyanoacrylate localization techniques are performed under CT guidance and are highly dependent on CT. For the hookwire localization technique, several previous studies have suggested that the interval between localization procedure and surgery should be shortened as much as possible, as localization-related complications may get severer during this time [17,21]. However, this requires seamless cooperation between the CT suite and operating room. In comparison, the cyanoacrylate maker can reduce postprocedural pain and is tolerant well by patients. Additionally, the cyanoacrylate can completely seal the needle trajectory after the puncture, thus preventing the progression of localization-related complications [22]. These features give surgeons great flexibility to schedule CT and surgery. In our study, 42 of 149 patients who received cyanoacrylate localization were performed on the day before the surgery. To determine the optimal localization strategy, we performed a sub-analysis based on the time point of localization, which demonstrated that performing cyanoacrylate localization on the day before surgery did not compromise the accuracy of intraoperative targeting or increase the incidence of complications.

In this study, we also found that the cyanoacrylate technique was associated with a shorter localization duration. Considering that the implantation procedures of the two techniques are almost identical, we have no convincing explanation for this difference. But we speculate that it might be related to the insertion depth of the introducer needle. In the hookwire group, the insertion depth of the introducer needle was much larger than that in the cyanoacrylate group ($p < 0.001$), to minimize the risk of wire dislodgement. However, as the insertion depth increases, the probability of pulmonary vasculature injury increases too. To reduce the possible complications, interventional radiologists need to carefully select the puncture route, which is a time-consuming process.

This single institutional study had several limitations, including the retrospective design and the relatively small sample size. Furthermore, the study population consisted only of selected patients with a single SPN requiring localization. Finally, we used a propensity-matched analysis to balance observed baseline covariates between groups; however, there may be other important unmeasured characteristics and confounders not included in our database, thus leading to may also biase our results. Another limitation of propensity score methods is that the analysis does not "fix" other potential methodologic biases that may exist.

5. Conclusions

To our knowledge, this is the largest study comparing CT-guided cyanoacrylate localization technique with the hookwire localization technique for VATS resection of SPNs. Our results show that both techniques were highly efficient and fraught with similar localization-related complications. Considering that the cyanoacrylate technique demonstrated consistent efficacy, with both localization and operation successful targeting rates of 100%, decreased localization-related pain and morphine use, and allowed flexible surgical schedules, the data from this study suggest that cyanoacrylate localization technique is more preferable than hookwire localization for the resection of SPNs.

Provenance and peer review

Not commissioned, externally peer-reviewed.

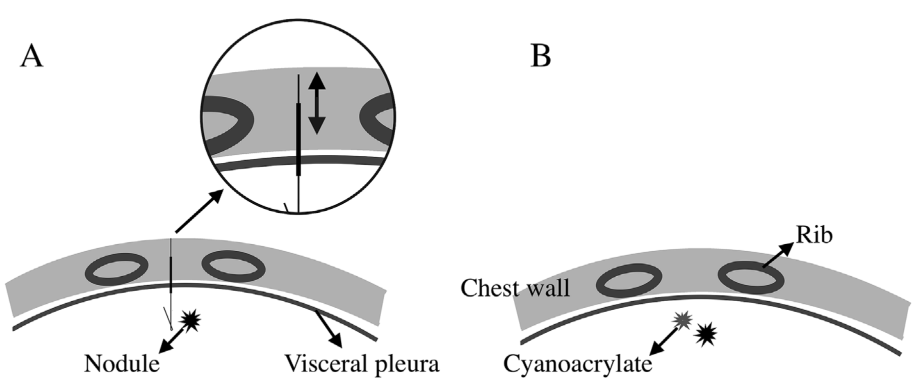

Fig. 3. Schematic diagram of the two localization techniques. (A) Hookwire sliding in the chest wall with the patient's normal breath, (B) Cyanoacrylate firmly anchored in lung parenchyma.

Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Data statement

Data is not publicly available as it is derived from patient records data, hence it is kept confidential. Data may be shared to researchers if approval is obtained from the institution.

Ethical approval

This study was approved by the Ethics Committee of the Affiliated Jiangning Hospital of Nanjing Medical University (Nanjing, China). All patient surgical data in the study were approved for extraction from the database.

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Author contribution

J. W. and F. Y. conceived and designed the study. J. W. and J. Y. wrote the paper. L. X. and R. Z. collected the data. F. Y. and L.-M. S. contributed to the analysis and interpretation. L. L. and L.-B. G. performed the localization procedures and collected the image data. F. Y. revised the paper.

Conflicts of interest

There is no conflict of interest in the submission of this manuscript.

Research registry number

1. Registry used: Research registry.
2. Unique Identifying number or registration: 4874.
3. Hyperlink to the registration (must be publicly accessible): https://www.researchregistry.com/browse-theregistry#home/registrationdetails/5cdd0c3c6d2f40000634f3b9/

Guarantor

Fei Yao (Department of Thoracic Surgery).

CRediT authorship contribution statement

Jian Wang: Conceptualization, Writing - original draft. **Ju Yao:** Investigation, Writing - original draft. **Lei Xu:** Data curation, Methodology. **Limei Shan:** Formal analysis. **Rong Zhai:** Data curation, Methodology. **Libing Gao:** Resources, Software. **Liang Liu:** Resources, Software. **Fei Yao:** Conceptualization, Formal analysis, Supervision, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.09.001.

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