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Original Article

Comparison between the application of dyed medical glue and hookwires for the localization of pulmonary nodules

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Abstract: *Objectives:* To compare the efficacy and safety of the localization of small pulmonary nodules (sPNs) with dyed medical glue (DMG) and hookwires prior to video-assisted thoracoscopic surgery (VATS). *Materials and methods:* A total of 344 patients were enrolled in this single-center retrospective cohort study between January 2018 and May 2022. There were 184 patients who underwent localization with DMG. From this amount, 160 patients underwent localization with hookwires. The localization success rate, localization-VATS interval time (LVIT), surgical resection time (SRT), and complications of the two groups were assessed. *Results:* VATS was successfully performed in all cases without conversion to thoracotomy. The localization success rate showed that the DMG group (100%, 184/184) had better results than the hookwire group (91.3%, 146/160) (P=0.004). The dyed glue group had a longer LVIT (P < 0.001) and shorter SRT (P=0.042). The rates of pulmonary hemorrhage (P < 0.001) and overall complications (P=0.009) in the DMG group were significantly lower than those in the hookwire group. An increased number of needle adjustments in the lung was associated with an increased incidence of pneumothorax (P=0.005), pulmonary hemorrhage (P=0.037), and overall complications (P=0.001). The prolonged time required for positioning was associated with an increased incidence of chest pain (P=0.002). *Conclusions:* Localization using DMG and hookwires is equally safe and effective for sPNs prior to resection with VATS. DMG localization was associated with fewer complications and resulted in a longer LVIT.

Keywords: Localization, dyed medical glue, hookwire, pulmonary nodule

Introduction

Small pulmonary nodules (sPNs) are the major manifestation of early-stage lung cancer. Surgical resection should be preferred for lung nodules highly suspected of lung cancer (continuing to exist or enlarge, solid components increase, malignant imaging signs such as burrs, and lobules appear in follow-up) [1, 2]. Video-assisted thoracoscopic surgery (VATS) is widely used in the diagnosis and treatment of sPNs due to its advantages of minimal invasiveness and low complication rate. For small nodules with a smaller diameter, insufficient solid composition, and positioned far from the pleura, it is often difficult to be accurately located only by observation and touch under thoracoscopy. This can lead to prolonged operation time, transfer thoracotomy, or even failure of resection. For pure ground glass nodules, intraoperative positioning is more difficult due to the lack of solid components. It is important to mark and locate the lung nodules before VATS. Studies suggest preoperative positioning technology can effectively improve the success rate of VATS lesion resection and shorten the pathologist's time to find the lesion [3, 4]. A variety of localization methods have been reported. Localization with a hookwire is the oldest and the most common method of nodule localization [5-7]. Its high rate of complications and dislocation have always been criticized. Dyed medical glue (DMG) localization is a new type of technique (mixes medical glue and methylene

blue in a proportion) have been considered a safe and effective preoperative localization method for sPNs. Its unique advantages have received attention [8, 9]. Since 2018, our center has successively used hookwire and DMG for the positioning of small pulmonary nodules guided by CT. Both have achieved good results. In this study, we retrospectively analyzed preoperative localization cases of our center, compared the safety and effectiveness of two different localization methods, and analyzed the advantages and application value of both.

Materials and methods

Patients

Consecutive patients in our hospital who underwent CT-guided preoperative pulmonary nodule localization with a hookwire or DMG from January 2018 to May 2022 were enrolled in the present study (January 2018 to July 2019 only the hookwire was used, August 2019 to May 2022 only the DMG was used). Patients who simultaneously localized multiple sPNs were excluded. The necessity and feasibility of the preoperative localization of each pulmonary nodule were confirmed by thoracic surgeons and interventional radiologists before the localization procedure. The positioning of sPNs should meet the following requirements: (i) age ≥ 18 years, (ii) sPNs that persistent and suspected malignant sPNs, 5.0 mm ≤ the long-axis diameter ≤ 20 mm, and the shortest distance to the pleura ≥ 5.0 mm; (iii) non-hilar nodules; (iv) the cardiopulmonary function could tolerate surgery; and (v) there was no contraindication to puncture (such as coagulopathy; a previous history of chest surgery that may have affected the localization process; or severe emphysema, pulmonary hypertension, or pulmonary interstitial fibrosis). This study was approved by the Institutional Ethics Committee and conducted in accordance with the Declaration of Helsinki. All patients consented to the localization and VATS procedures (Project Number: S2021070).

Material

Hookwire group: Hookwire (10 cm × 20 G, C. R. Bard, Inc.), $100.

DMG group: Medical glue (α-cyanoacrylate; Baiyun Medical Adhesive Co.), methylene blue (Jichuan Pharmaceutical), and puncture needle (15 cm × 21 G, Hakko Co., LTD.), for a total of $25.

DMG localization procedure

The CT-guided lung nodule localization operation was performed by two interventional doctors in our department with more than 10 years of experience in lung needle biopsies. Suitable body positions were selected for the patient. A reasonable puncture path was planned with the information provided by the chest CT. After local anesthesia with 2% lidocaine hydrochloride, the tip of the puncture needle was placed step by step to within 1 cm of the nodule margin under a breath-holding state. We used a 1 ml syringe to draw 0.4 ml of methylene blue, removed the air, and drew 0.3 ml of medical glue and quickly shook to mix (based on repeated experiments and surgeon feedback, the recommend a ratio of methylene blue to medical glue was 4:3). We injected approximately 0.25 ml-0.3 ml of this mixed glue to the appropriate position around the nodules (**Figures 1A**, **2A**, **2B**). To make the positioning more accurate, the two-point method can be used. In this method, two puncture needles were used to puncture the medial and lateral of sPNs. The position of the puncture needle and the injection dosage of DMG was the same as those used in the one-point method (**Figure 1B**). A blue colloid can form in the medial and lateral regions of the nodule, and the nodule can be accurately resected (**Figure 3**). For deep-seated nodules, after completed the DMG injection within 1.0 cm around the nodule, the puncture needle can be quickly withdrawn to the subpleural area approximately 1.0 cm from the pleura. A small amount of DMG (≤ 0.1 ml) can be injected again to help the surgeon quickly find the location of the nodule and cut the lung tissue to find the deep stained colloid and accurately remove the lesion (**Figure 1C**). For superficial nodules a shorter distance from the pleura, physicians need to ensure that the puncture needle penetrates the pleura, and avoid injecting the DMG too fast or too much. After injection, the puncture needle was kept there for 20-30 seconds (the DMG was near solidification to avoid DMG leakage, causing unnecessary pleural adhesion and chest pain). At the end, another CT scan of the chest was taken to determine the positioning success and check the occurrence of related complications, includ-

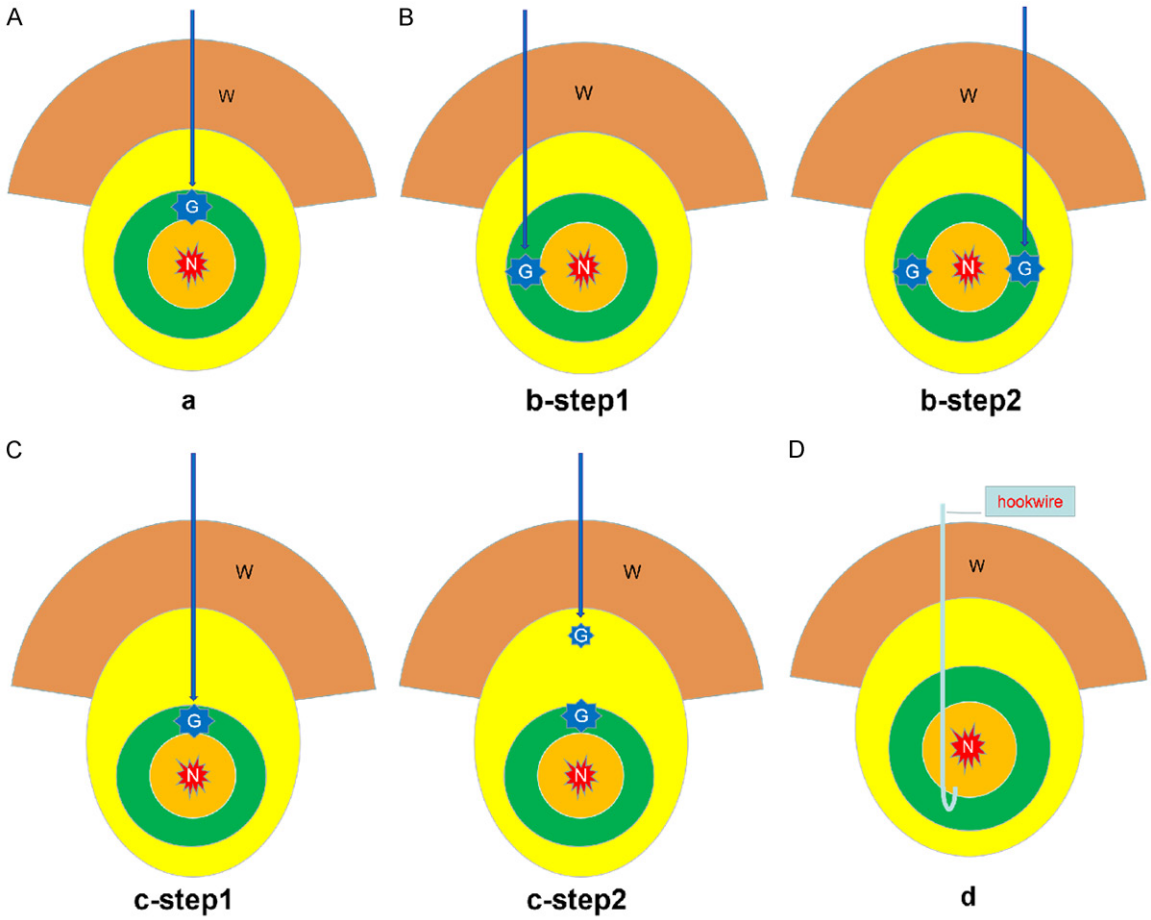

Figure 1. Schematic diagram of localization. (subfigures A) One-point method for DMG localization; (subfigures B-step1 and B-step2) two points method for DMG localization (B); (subfigures C-step1 and C-step2) deep pulmonary nodules for DMG localization; (subfigures D) hookwire localization. DMG = Dyed medical glue, W = chest wall, N = pulmonary nodules, G = Dyed medical glue. Green area on the figure represents the 0.5-1.0 cm area around the pulmonary nodules, which was the most suitable release location of the DMG or hookwire.

ing pneumothorax and pulmonary hemorrhage, to evaluate whether to administer appropriate treatments. A successful positioning standard was defined as CT visualization of the small nodular ground glass shadow (DMG) in the subpleural area within 1.0 cm around the nodule (**Figure 1B**), without fatal complications such as allergies, pleural reactions, air, or dyeing medical glue embolization.

Hookwire procedure

After using 2% lidocaine 5 ml to induce local anesthesia in the chest wall and pleura of the puncture point by following the preset puncture path, we used a 10 cm × 20 G hookwire component to puncture to within 1.0 cm around the lung nodules in a step-by-step manner (far away from the pleura is better). We released the hookwire, and pulled out the trocar (**Figure 1D**). We performed a low-dose CT scan of the chest again to check whether the hookwire release position was good, whether the hookwire had fallen off, and whether any related complications occurred. A successful positioning standard was defined as CT visualization of the hookwire within 1.0 cm beside the nodules, without fatal complications, no intraoperative hookwire dislocation occurred. **Figure 4A-C** presents images of a typical hookwire application procedure.

Surgical procedures

All patients were included if they were operated on by two thoracic surgeons in our hospital with more than 10 years of experience in VATS. This arrangement helped to determine start time

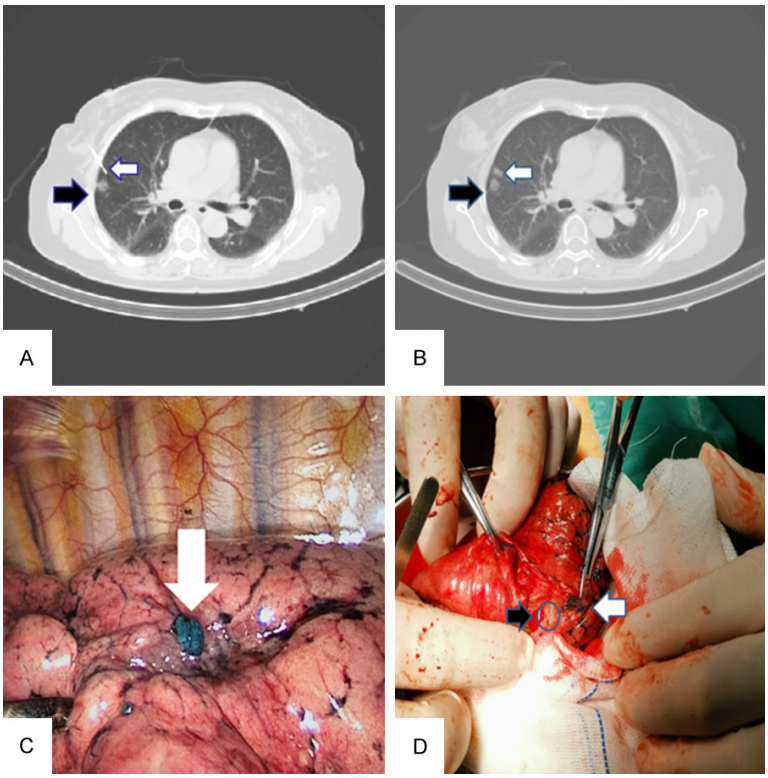

Figure 2. A 74-year-old woman with a pulmonary nodule in the right upper lobe that was localized with the dyed medical glue, and was diagnosed with invasive adenocarcinoma. A-D. Pulmonary nodule (black arrow). B-D. Dyed medical glue (white arrow).

(VATS was performed immediately if the patient developed intolerable chest pain, a large amount of pneumothorax, or hemothorax while waiting to undergo surgery). In the DMG group, the surgeon could easily find the location needed to resect the sPNs through the conspicuous, blue-stained hard nodes in the subpleural area (**Figures 2C**, **2D**, **3D**). In the hookwire group, the location was confirmed by pulling the hookwire (**Figure 4D**). Upon hookwire dislocation, the localization of the nodule was guided by the hematoma at the puncture site. Wedge resection of all nodules was performed. The nodule was sent immediately for intraoperative frozen pathological examination. Segmental resection and regional lymph node dissection were performed if a nodule was diagnosed as invasive/microinvasive adenocarcinoma. Each nodule underwent a final histopathological examination after the surgery.

Data collection and assessment

The basic characteristics of all patients, nodules, relevant data during localization, and surgical procedures were collected. Localization to VATS interval time (LVIT), surgical resection time (SRT), pathological result, complications, and their influencing factors from the two groups were evaluated. Pneumothorax and hemorrhage were assessed by CT, and graded according to the major/minor criteria of the Society of Interventional Radiology [10]. Chest pain was evaluated using a numerical rating scale based on the patient's verbal [11].

Statistical analysis

Statistical analysis was performed using SPSS 22.0 Software (IBM). Data are primarily presented as the mean ± standard deviation (SD), range, or n (%). The two groups of data were compared using student's t test or the chi-square test, and related variables of important concern were analyzed using multivariate logistic regression model. A result was considered to be significant at $P < 0.05$.

Results

Patient and nodule characteristics

During the study period, 378 patients underwent CT-guided preoperative pulmonary nodule localization with a hookwire or DMG. A total of 34 patients who simultaneously localized multiple PNs were excluded. There were a total of 344 patients included in this single-center retrospective nonrandomized cohort study: 184 patients (52 males and 132 females, age 53.2±11.0 years) underwent DMG localization, and 160 patients (46 men and 114 women, age 51.8±10.0 years) underwent hookwire localization. Patient and nodule characteristics are listed in **Table 1**. There were no significant differences in age, sex, smoking history, nodule type, nodule location, nodule short diameter, puncture path length, or shortest distance from the nodule to the pleura between the two groups (all $P > 0.05$).

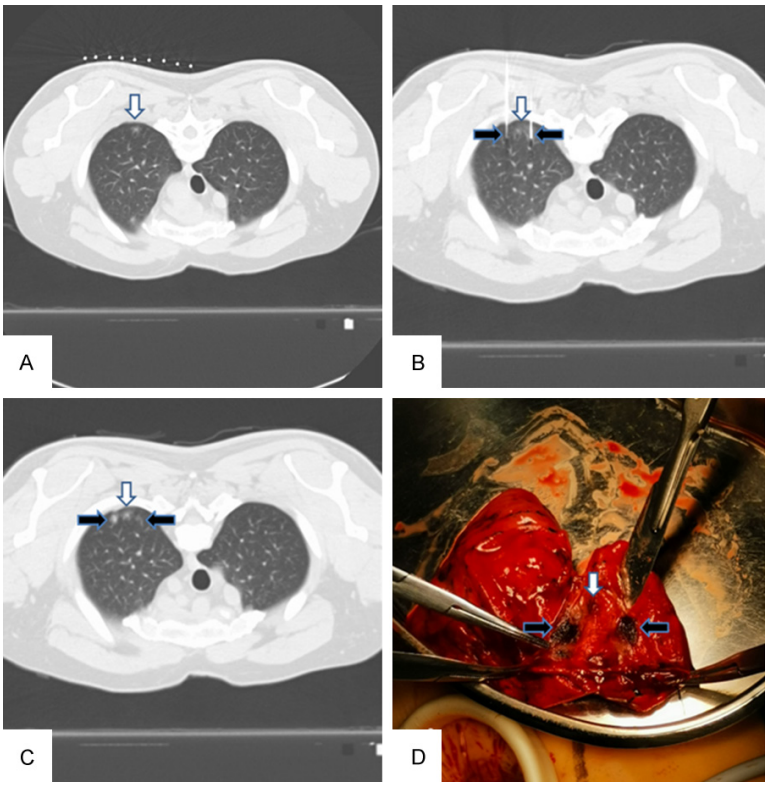

Figure 3. A 48-year-man with a pulmonary nodule in the left upper lobe that was localized with the dyed medical glue (two points method), and was diagnosed with chronic inflammation. A-D. Pulmonary nodule (white arrow). C, D. Dyed medical glue (black arrow).

Localization, pathological, and surgical results

The localization success rate was 100% (184/184) in the dyed glue group and 91.3% (146/160) in the hookwire group (14 cases had failed localization due to hookwire dislocation). The localization success rate showed that the dyed glue group was better than the hookwire group (P=0.004) (**Table 2**). As showed in **Table 2**, there was no significant difference in the time required for positioning (P=0.206) and the number of needle adjustments in the lung (P=0.125) between the two groups. VATS was successfully performed in all cases, without conversion to thoracotomy. For 14 cases of failed localization of sPNs in the hookwire group (hookwire dislocation), segmentectomy was performed and guided by the hematoma at the puncture site. Wedge resection and segmentectomy were performed in 96 (52.2%) and 88 (47.8%) nodules, respectively, in the dyed glue group. A total of 82 (51.2%) and 78 (48.8%) nodules in the hookwire group were treated with wedge resection and segmentectomy, respectively. Surgical methods showed no difference between the two groups (P=0.904). The DMG had a longer LVIT (31.6±28.7 h vs. 2.8±2.8 h, P < 0.001) and shorter SRT (87.6±27.0 min vs. 108.9±46.6 min, P=0.042) (**Table 2**). All PNs in the two groups were successfully resected. The pathology is shown in **Table 4**. The final pathological result was in agreement with the pathological results of intraoperative frozen sections in all instances.

Complications

Some patients in the two groups had minor complications. All complications in both groups were mild or asymptomatic (SIR grade I). They did not require active treatment, without fatal complications (such as allergy, air, or DMG embolization, and pleural reaction). Four patients in the hookwire group who had an operation in advance due to intolerable chest pain after localization did receive treatment. Six patients in the hookwire group experienced both mild pneumothorax and mild pulmonary hemorrhage (CT showed patchy ground glass exudation around the puncture path and anchor, 1.0 cm ≤ the maximal short-axis diameter ≤ 3.0 cm). The dyed glue group had two cases. Pulmonary hemorrhage (6.5% vs. 15.7%, P < 0.001) and overall complications (22.8% vs. 47.5%, P=0.009) in the DMG group were significantly lower than those in the hookwire group. In terms of coughing, pneumothorax, and chest pain, there was no significant difference between the two groups (all P > 0.05) (**Table 3**). The use of a hookwire (P=0.002) and an increased number of needle adjustments in the lung were associated with an increased incidence of pulmonary hemorrhage (P=0.037). The location of sPNs (P=0.041) and the number of needle adjustments in the lung (P=0.005) were associated with pneumothorax occurrence. A prolonged time required for positioning

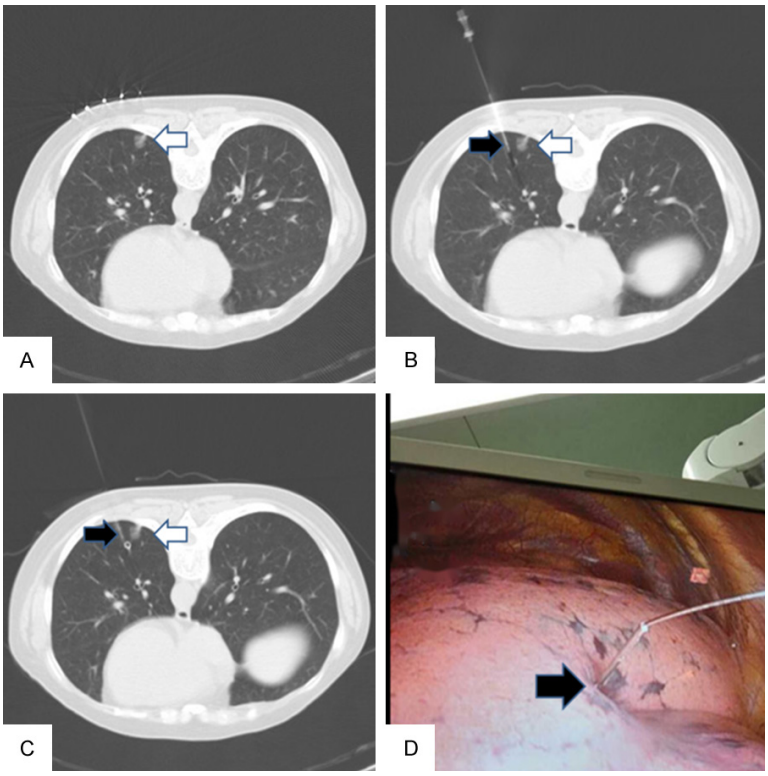

Figure 4. A 54-year-old woman with a pulmonary nodule in the left lower lobe that was localized with the hookwire, and was diagnosed with invasive adenocarcinoma. A-C. Pulmonary nodule (white arrow). B-D. Hookwire (black arrow).

(P=0.002) was associated with an increased incidence of chest pain (**Table 5**).

Discussion

Pulmonary nodules with small diameters are often tough to touch during surgery, and ensuring the scope of resection and shortening the time of finding nodules often rely on the accurate positioning of sPNs. Various localization methods have been reported. Hookwire is the most widely used positioning method. The wire is retained in the chest wall. Patients must be operated immediately after positioning. Frequent dislocation can lead to positioning failure [12]. Some scholars have tried to use medical glue or methylene blue for the localization of pulmonary nodules. Neither of these have had dislocation troubles and have been considered safe and effective [13-15]. The shortcomings of methylene blue are easily absorbed and readily diffuses. Medical glue is colorless, transparent, and not easy to observe during surgery. DMG is a mixture of the above two materials in a proportion. This combines the advantages of methylene blue and medical glue in the localization of lung nodules and avoids the shortcomings of both. As a novel positioning technology, the use of DMG has rarely been reported. In this study, we found that both positioning methods had localization success rates higher than 90%. This demonstrated that the use of DMG positioning and hookwire localization was equally effective in guiding VATS pulmonary nodule resection. The DMG group had better results than the hookwire group in terms of the localization success rate (100% vs. 91.3%). We considered that dislocation was the reason for the relatively low localization success rates of the hookwire group. Many reports believe that due to its lack of anti-shedding mechanism. The occurrence of hookwire dislocation is inevitable. It occurs in between 0.7% and 7.3% of cases [16-20]. Even though all the nodules in which the two localization methods were used successfully resected without conversion to thoracotomy. For 14 nodules with hookwire dislocation (failed positioning), segmentectomy was performed directly, increasing the scope of normal lung tissue resection and the time of finding sPNs during VATS. DMG positioning has no trouble with dislocation, and only needs the accuracy of puncture for the operator and the control of the injection dose.

Pneumothorax, hemorrhage, chest pain, and coughing were the most common complications after localization [15]. By studying published reports, we found that the proportion of pneumothorax is 21.8%-39% for the hookwire method [16-20]. Jiang et al. reported a proportion of pneumothorax of 4.6% using DMG [8]. Compared with hookwire localization, pneumothorax should theoretically be less likely due to the puncture needle path plugged by DMG. There was no significant difference between them in this study. The incidence of pneumo-

Table 1. Characteristics of patients and nodules, n (%)

Parameter	Hookwire (n=160)	Dyed medical glue/DMG (n=184)	*P* Value
Age (y)			0.520
Range/(Mean)	31-76/(51.8±10.0)	24-76/(53.2±11.0)	
Sex			0.943
Male/Female	46 (28.7)/114 (71.3)	52 (28.3)/132 (71.7)	
Smoking history			0.868
Yes/No	28 (17.5)/132 (82.5)	34 (18.5%)/150 (81.5)	
Puncture position			0.514
Prone/Supine	100 (62.5)/60 (37.5)	106 (57.6%)/78 (42.4)	
Nodule type			0.374
Ground glass nodules/Semisolid/Solid	114 (71.3)/28 (17.5)/18 (11.2)	142 (77.2)/30 (16.3)/12 (6.5)	
Nodule location			0.151
Right lung	90 (56.3)	92 (50.0)	
Upper/middle/lower lobe	58 (36.3)/4 (2.5)/28 (17.5)	58 (31.5)/10 (5.5)/24 (13.0)	
Left lung	70 (43.7)	92 (50.0)	
Upper/lower lobe	32 (20.0)/38 (23.7)	64 (34.8)/28 (15.2)	
Nodules diameter (mm)			0.242
Range/(Mean)	3-14/(7.4±3.2)	3-20/(7.7±3.4)	
Mean puncture path length (mm)	60.7±17.3	61.6±15.4	0.086
Mean shortest distance from the nodule to the pleura (mm)	10.6±9.8	9.8±8.6	0.722

Comparison between the 2 groups was according to t test or chi-square test.

Table 2. Localization and surgical procedure, n (%)

Parameter	Hookwire (n=160)	DMG (n=184)	*P* Value
Successfully marked nodules	146 (91.3)	184 (100.0)	0.004
Hookwire dislocation	14 (8.7)		
The number of needle adjustments in the lung (time)			0.152
Range/mean	1-4/(1.3±0.1)	1-4/(1.2±0.1)	
Needle adjustments 1/2/3/4 times	126/22/8/4	154/28/0/2	
Duration for localization procedure (min)			0.206
Range/(Mean)	8-27/(15.0±4.2)	8-30/(14.3±3.7)	
Operative procedure			0.904
Wedge resection	82 (51.2)	96 (52.2)	
Segmentectomy	78 (48.8)	88 (47.8)	
Localization to Video-assisted thoracoscopic surgery interval time/LVIT (h)			0.000
Range/(Mean)	1-8/(2.8±2.8)	1-96/(31.6±28.7)	
Surgical resection time/SRT (min)			0.000
Range/(Mean)	50-370/(108.9±46.6)	40-310/(87.6±26.9)	

Comparison between the 2 groups was according to t test or chi-square test.

Table 3. Comparison of complications between the two groups, n (%)

Parameter	Hookwire (n=160)	DMG (n=184)	*P* Value
Overall complications	70 (47.5)	40 (22.8)	0.009
Cough	4 (2.5)	6 (3.3)	0.767
Pneumothorax	18 (11.3)	20 (10.9)	0.937
Hemorrhage	42 (26.2)	12 (6.5)	0.000
Chest pain	12 (7.5)	4 (2.1)	0.098
Allergy or pleural reaction	0 (0.0)	0 (0.0)	1.000
Air or DMG embolization	0 (0.0)	0 (0.0)	1.000

Comparison between the 2 groups was according to chi-square test.

Table 4. Pathologic result, n (%)

Parameter	Hookwire (n=160)	DMG (n=184)	*P* Value
Pathologic result			0.513
Benign	36 (22.5)	34 (18.5)	
Precancerous lesions and cancer	124 (77.5)	150 (81.5)	
Adenocarcinoma in situ	36 (22.5)	46 (25.0)	
Minimally invasive adenocarcinoma	26 (16.3)	28 (15.2)	
Invasive adenocarcinoma	52 (32.5)	60 (32.6)	
Atypical adenomatous hyperplasia	8 (5.0)	16 (8.7)	
Metastases	2 (1.2)	0 (0.0)	

Comparison between the 2 groups was according to chi-square test.

thorax in the two groups was similar. The incidence in the hookwire group was significantly lower than the average reported in the literature. The reason for this result may be related to the choice of puncture path and surgical proficiency. For chest pain, there was no significant difference between the two groups. Hookwire group pain scored higher than the DMG group. Four patients chose VATS in advance due to their intolerance of chest pain after hookwire positioning, disrupting the operation plan and partly shortening the localization-VATS interval time. This was because the metal wire retained in the chest wall is hard and is poor in tissue compatibility. After losing efficacy of local anesthesia, the pain of the patient may be worse. This positioning method requires VATS immediately. In this study, we found that the rates of overall complications (22.8% vs. 47.5%) and pulmonary hemorrhage (6.5% vs. 26.2%) were significantly lower than those in the hookwire group. By multivariate logistic regression analysis, we verified that pulmonary nodule localization using a hookwire was associated with increased pulmonary hemorrhage and overall complications. All patients with pulmonary hemorrhage had minimal hemorrhage, asymptomatic or mild symptoms, and required no additional treatment. The possible explanations are as follows: (i) The DMG may plug the bleeding vessel and the puncture needle path during the hardening process. This reduces the incidence of bleeding and pneumothorax and prevent them from deteriorating. (ii) The thinner puncture needle used in the dyed glue group may help reduce the incidence of hemorrhage. (iii) The hookwire may continue to stimulate the chest wall and pleural nerve, leading to a higher incidence of chest pain. (iv) Fewer intrapulmonary needle adjustments with the use of DMG than with a hookwire can reduce lung tissue and pleura damage and obtain a shorter positioning time. This reduces the chance of pulmonary hemorrhage, pneumothorax, and chest pain. Using multivariate logistic regression analysis, we found that an increased number of needle adjustments in the lung was associated with increased pneumothorax, pulmonary hemorrhage, and overall complications. A prolonged time required for positioning was associated with increased chest pain. Nodule location was associated with the occurrence of pneumothorax. These conclusions were the same as Huang's comparative study of medical glue and hookwires [21]. Our research sample size was larger. A relatively large sample study comparing medical glue and hookwires did not produce such results [22]. In one study, the authors believed that complications were more related to the puncture procedure than to the marker. Our study confirmed that the complication rate increase was related to the puncture procedure (such as the number of needle adjustments in the lungs and positioning time). This was the same as the research results of Wang et al. [22]. We believe that the occurrence of complications was related to the positioning materials and the puncture procedure.

Table 5. Multivariate logistic regression of procedural success, pneumothorax, pulmonary hemorrhage, chest pain, and overall complications

Group	Procedural success		Pneumothorax		Pulmonary hemorrhage		Chest pain		Overall complications	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*P*	OR (95% CI)	*p*	OR (95% CI)	*P*
DMG	1	0.996	1	0.956	1	0.002	1	0.061	1	0.015
Hookwire	0.000 (0.000-0.000)		1.032 (0.339-3.143)		5.663 (1.898-16.900)		6.730 (0.919-49.314)		2.586 (1.200-5.575)	
Age (years)	0.959 (0.874-1.054)	0.388	1.005 (0.952-1.060)	0.862	1.035 (0.987-1.085)	0.158	0.993 (0.916-1.077)	0.867	1.032 (0.994-1.071)	0.104
Sex										
Female	1	0.843	1	0.206	1	0.200	1	0.613	1	0.668
Male	1.208 (0.185-7.914)		2.112 (0.662-6.731)		0.471 (0.149-1.489)		1.540 (0.289-8.192)		0.831 (0.357-1.935)	
Nodule location	1.086 (0.614-1.919)	0.777	1.565 (1.018-2.405)	0.041	0.790 (0.577-1.081)	0.141	0.804 (0.467-1.383)	0.430	1.056 (0.826-1.349)	0.664
Diameter (mm)	1.086 (0.713-1.653)	0.701	1.046 (0.872-1.254)	0.630	0.913 (0.759-1.098)	0.334	1.196 (0.994-1.438)	0.058	1.003 (0.892-1.127)	0.965
The number of nodules	5.554 (0.505-61.021)	0.161	0.704 (0.247-2.013)	0.513	0.902 (0.415-1.961)	0.795	0.455 (0.073-2.849)	0.400	1.038 (0.551-1.955)	0.908
Puncture path length (mm)	1.007 (0.955-1.062)	0.793	0.977 (0.938-1.018)	0.273	1.016 (0.986-1.047)	0.308	0.993 (0.945-1.044)	0.779	1.004 (0.980-1.028)	0.759
Shortest distance from the nodule to the pleura (mm)	1.078 (0.943-1.233)	0.269	1.012 (0.952-1.075)	0.707	1.007 (0.958-1.058)	0.789	0.944 (0.831-1.073)	0.378	0.998 (0.957-1.041)	0.927
The number of needle adjustments in the lung	0.516 (0.151-1.768)	0.292	3.581 (1.466-8.750)	0.005	2.274 (1.052-4.916)	0.037	0.522 (0.103-2.634)	0.431	4.198 (1.774-9.935)	0.001
Duration for localization procedure	0.841 (0.651-1.086)	0.184	1.002 (0.851-1.179)	0.985	1.012 (0.889-1.151)	0.862	1.362 (1.118-1.660)	0.002	1.020 (0.918-1.133)	0.717

Note-Factors affecting procedural success, pneumothorax, pulmonary hemorrhage, chest pain, and overall complications were analyzed by means of multivariate logistic regression analysis (forward) individually. P < .05 was significant. CI = confidence interval; OR = odds ratio.

We found that longer LVIT and less SRT can be obtained for lung nodules located by dyed glue. The longest LVIT in this group was 96 hours (The methylthionine's color is slightly lighter as the LVIT extends. This does not adversely affect the localization effect). A longer LVIT allows the interventional physicians to be more flexible when choosing the start time of the localization operation and helps to obtain sufficient preoperative preparation time. Carrying hookwire for a long time after positioning may increase the risk of dislocation and pneumothorax. The poor tolerance of human tissues to metal wire, leads to intolerable chest pain. Four patients in the hookwire group had to undergo VATS in advance due to intolerable chest pain after positioning. For patients after positioning with hookwire who undergo the VATS as early as possible is the priority selection. These reasons may lead to the LVIT being shorter in the hookwire group than in the DMG group. The relatively shorter SRT in the DMG group may have been caused by the presence of a certain proportion of hookwire dislocation in the hookwire group, increasing the time of finding nodules in surgery. DMG can reduce the patient's surgical exposure, save medical resources, and reduce the risk of complications.

Our research had a few limitations. This was a retrospective study. Selection bias in the results is inevitable. The study was a single-center study. Studies from multiple centers and prospectively are needed.

In summary, compared with hookwires, the use of dyed glue for localization was equally effective. There is no dislocation, allowing for a higher localization success rate and a reduction of the SRT. A longer LVIT can be obtained, allowing for more flexible localization and surgical arrangements. The DMG method is less expensive. We found that the localization of sPNs using DMG had a lower incidence of overall complications and intrapulmonary hemorrhage and is safer.

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Disclosure of conflict of interest

None.

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