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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

CT-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture before video-assisted thoracic surgery

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PURPOSE

To retrospectively analyze the effectiveness and safety of computed tomography (CT)-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture prior to video-assisted thoracic surgery (VATS).

METHODS

One hundred thirty-eight patients with 138 pulmonary nodules were included in this single-center retrospective study. Among them, 110 patients who underwent CT-guided microcoil localization using the routine puncture technique formed the routine group; the other 28 patients who underwent the CT-guided microcoil localization using the penetrating lung puncture technique formed the penetrating lung group. The main outcomes were the success rate and complication rate of the two groups.

RESULTS

The localization success rate was 95.5% (105/110) in the routine group and 89.3% (25/28) in the penetrating lung group ($P = 0.205$). There was no statistical difference in any of the complications (pneumothorax, intrapulmonary hemorrhage, or moderate and severe chest pain) in both groups ($P = 0.178$, $P = 0.204$, $P = 0.709$, respectively). Localization procedure time was significantly increased in the penetrating lung group compared with the routine group (31.0 ± 3.0 min vs. 21.2 ± 2.8 min, $P < 0.001$).

CONCLUSION

CT-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture prior to VATS resection is effective and safe. However, the deployment of the microcoil using penetrating lung puncture required more time than the routine puncture method.

KEYWORDS

Computed tomography, hemorrhage, localization, pneumothorax, pulmonary

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With the widespread use of low-dose chest computed tomography (CT) screening, the detection rate of pulmonary nodules has gradually increased, allowing lung cancer to be discovered at an earlier, or possibly more curable, stage.[1] Complete resection by video-assisted thoracoscopic surgery (VATS) is the standard treatment for potentially malignant lung nodules, and VATS in pulmonary wedge resection is a highly effective, minimally invasive procedure under which nodules can be safely removed without a thoracotomy.[2] However, some pulmonary nodules become invisible or inaccessible during the operation because of their small diameter or soft texture, which makes it difficult to successfully remove the nodules. With the development of lung nodule localization technology, surgeons have gradually avoided "blindness" in VATS procedures, thus avoiding the application of thoracotomy.

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The method of CT-guided microcoil localization is a reliable and simple marker that effectively assists the surgeon in finding and resecting pulmonary nodules during VATS. The routine puncture technique is used to select an appropriate location and adopt the shortest needle insertion path, leaving one end of the microcoil on the pleural surface, which will provide a direct indication of the location of the VATS resected nodule.[3] Many studies have endeavored to confirm the feasibility and safety of microcoil localization for pulmonary nodules, and continuous improvement of this technique with better coordination of resection procedures has been made.[4-7] However, there are still technical challenges in the accurate localization of some pulmonary nodules in special anatomical positions, such as a scapula-blocked area. Xian et al.[8] proposed a trans-scapular approach to the pulmonary nodules underneath the scapula. Unfortunately, this method greatly increases the operational difficulty. In addition, the distance from the distal end of the coil to the pleura in the path should be as short as possible to preserve the lung parenchyma and protect the lung function during VATS. Sometimes, a viable puncture path without passing through the scapula requires a large angle to the left or right of the axial position, resulting in a significant increase in the distance from the lesion to the pleura.[9]

The authors attempted to locate the scapula-blocked pulmonary nodules using a penetrating lung puncture under CT guidance, retrospectively analyzed the localization parameters and complications of this technique, and compared the results with routine localization methods.

Main points

- The accurate localization of some pulmonary nodules in special anatomical positions, such as scapula-blocked areas, is still challenging.
- Computed tomography-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture prior to video-assisted thoracic surgery resection is effective and safe.
- The deployment of the microcoil using penetrating lung puncture required more time than the routine puncture method.

Methods

Patient population

This study was approved by the Institutional Review Ethics Committee of Qinhuangdao First Hospital on June 2, 2021 (protocol no: 202106B003), and written informed consent was obtained from all participants. Data were obtained from a single medical center. A total of 161 patients were recruited between June 2020 and June 2021 into the routine group, and 28 patients were recruited between January 2019 and June 2021 into the penetrating lung group. At least 12 months of follow-up with CT or positron emission tomography/CT or suspicion of malignant nodules by radiologists with more than 10 years of experience had been employed to initially obviate the possibility of a benign nodule. The necessity and feasibility of preoperative localization of each pulmonary nodule were confirmed in an interdisciplinary meeting involving thoracic surgeons and interventional radiologists before the localization procedure. The primary reason for inclusion in the penetrating lung group was that the pulmonary nodules were shadowed by the scapula, and the nodules could not be coil-localized through the most direct needle path. Demographic, imaging, and surgical data were collected from these patients. Due to multiple pulmonary nodules, 51 patients were excluded from the study. Finally, 138 patients with 138 pulmonary nodules were included in this single-center retrospective study. Among them, 110 patients who underwent the CT-guided microcoil localization using the routine puncture technique formed the routine group; the other 28 patients who underwent the CT-guided microcoil localization using the penetrating lung puncture technique formed the penetrating lung group (Figure 1). Reviewing the preoperative images, the distribution of nodules was different between the two groups. In the routine group, the pulmonary nodules might appear in any lobe, and the suitable shortest path could be determined. In the penetrating lung group, the nodules were only located in the upper or lower lobe of the area shadowed by the scapula.

Localization procedure

Two interventional radiologists with at least 10 years of experience performed all the CT scans and localization procedures with the use of a 16-slice multidetector CT (GE Healthcare, Milwaukee, WI, USA). The main parameter settings for CT included the following: scanning method, helical acquisition mode; tube current, 100 mA; tube voltage, 120 kV; rotation speed, 0.8 seconds;

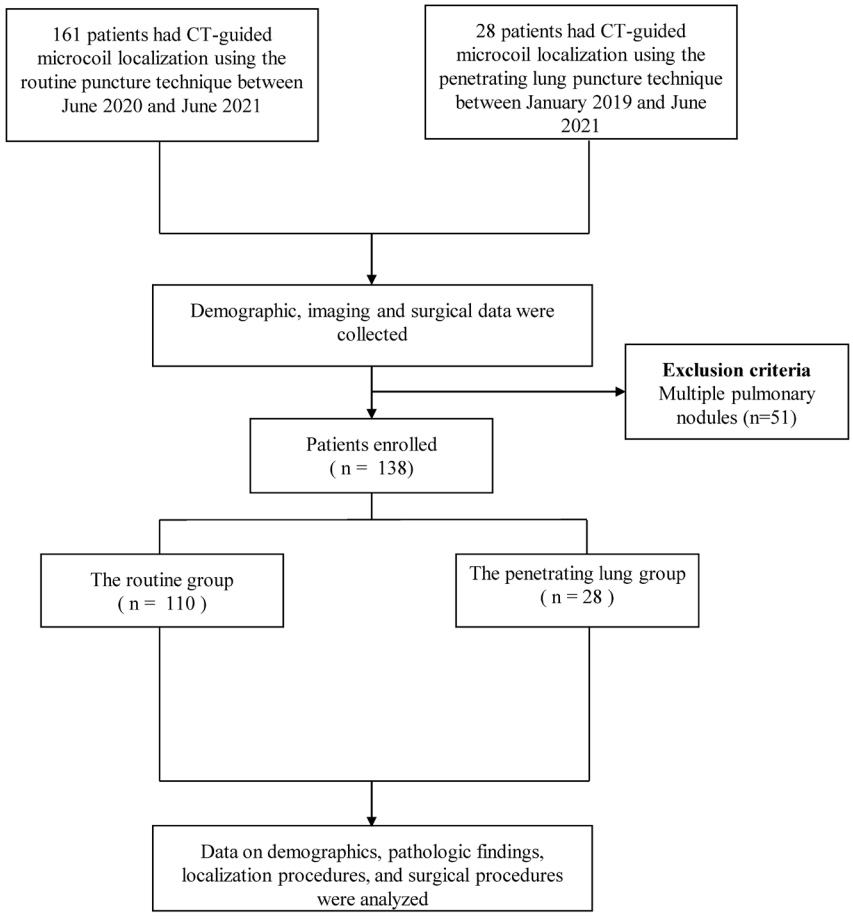

Figure 1. Flow chart showing the inclusion and exclusion criteria for the study.

slice thickness, 1.25 mm; and reconstruction interval, 1.25 mm. The procedure used a 0.018-inch-diameter, 40-to-70-mm-long (chosen according to the distance from the pulmonary nodule to the pleura) platinum microcoil (Cook Medical, Bloomington, IN, USA), which was originally designed for blood vessel embolization, as well as a 15-cm, 21-G Chiba puncture needle with a coaxial core (Cook Medical, Bloomington, IN, USA). Each patient was placed on the CT scanning bed in a suitable position (prone, supine, or lateral decubitus) according to the location of the targeted lesions. Microcoil localization within the routine group was a modified method based on the procedure reported by Powell et al.[10] First, the location of the lesion and the most direct needle path to the lesion were determined according to the preoperative CT data. After routine disinfection, surgical dressings were placed, and 2% lidocaine was applied for local anesthesia. The patient was instructed to hold their breath after drawing in approximately 50% of the maximum inspiration during needle insertion in order to reduce the effects of respiratory movements and the risk of air embolism. Percutaneous access to the lung followed the planned path with a Chiba needle, advancing the needle tip into the normal lung parenchyma to within 10 mm of the lesions using CT guidance (Figure 2b). The distance from the needle tip to the pleura was measured using the electronic caliper function available on the CT scanner console. With the loading sleeve tightly connected to the puncture needle, the microcoil was pushed into the needle cavity, and the loading sleeve was removed from the needle. The coaxial needle core was used to release the microcoil into the lung tissue adjacent to the nodule. The puncture needle was slowly withdrawn, with the coaxial needle core remaining stationary until the tail of the microcoil remained outside the pleura (Figure 2c). The needle was removed, and then CT scanning was performed to confirm a satisfactory position of the microcoil and to observe for complications (Figure 2d).

The CT scan parameters and the interventional equipment in the penetrating lung group were the same as those in the routine group. The specific steps for penetrating the lung group were as follows: (1) the intersection point between the reverse extension line of the shortest path from the nodule to the pleura and the chest wall was used as a puncture point. (2) A Chiba needle was percutaneously inserted across long-distance lung tissue along the planned path under the guidance of CT, advancing the needle tip into normal lung parenchyma to within 10 mm of the lesion (Figure 3b) and continuing to penetrate the lung tissue to advance the needle tip into the pleural space. A CT scan was performed to determine that the needle tip reached the appropriate position. (3) With the microcoil loading sleeve tightly connected to the puncture needle, the distal end of the coil was first released to the pleural surface using a coaxial needle core. The puncture needle was slowly withdrawn, with the coaxial needle core remaining stationary until the tail of the microcoil remained near the nodule (Figure 3c). (4) The needle was removed, and a CT scan was also performed to confirm the coil position and any complications.

VATS procedure

The VATS procedure was performed under single-lung ventilation with a double-lumen endotracheal tube and general anesthesia. The location of the pulmonary nodule was determined using preoperative microcoil localization and thoracoscopic guidance. If the tail of the microcoil was not exposed outside the pleura, its position was ascertained by palpation of the coil or by finding the puncture point. Once the nodule location was determined, wedge resection was performed under microcoil guidance. The complete microcoil and nodules were carefully excised

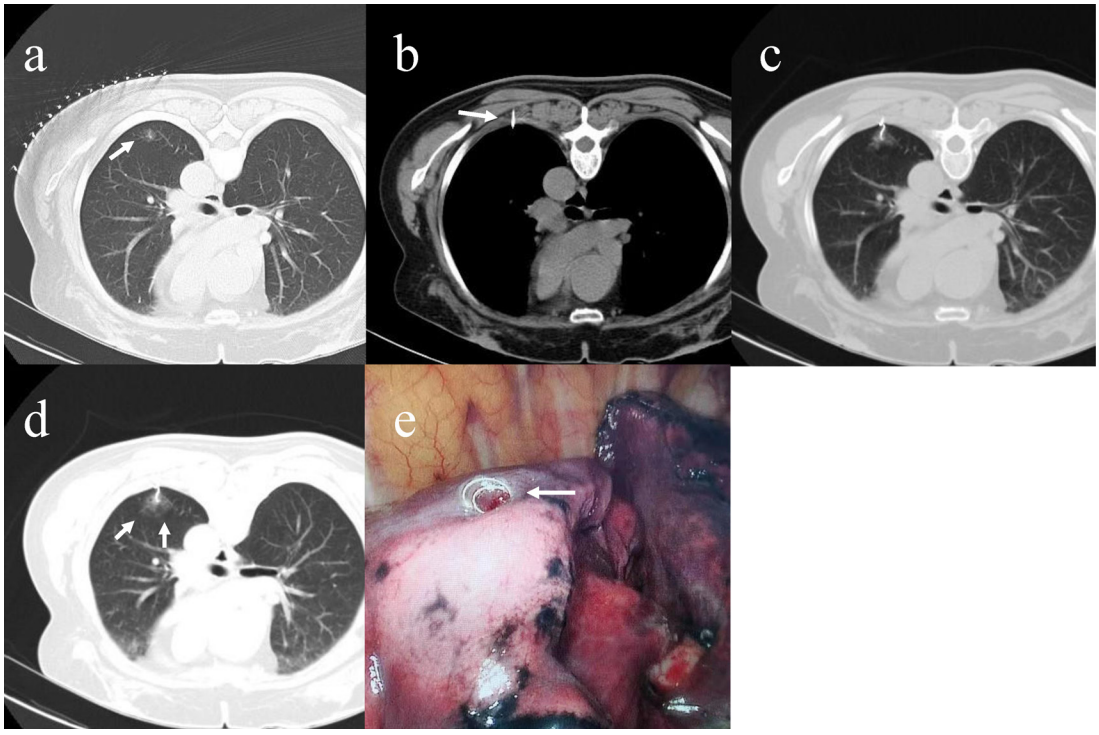

Figure 2. A 62-year-old male with a pulmonary nodule in the left lower lobe. **(a)** Axial CT image showing lesion (arrowhead) in the left lower lobe. **(b)** Needle tip (arrowhead) was advanced into the normal lung parenchyma to within 10 mm of the lesions. **(c)** The microcoil was released with the superficial end of the microcoil beyond the visceral pleura and the distal end coiled in the lung parenchyma adjacent to the nodule. **(d)** A repeat CT scan indicated a satisfactory localization, with new shadows (arrowhead) around the lesion suggestive of intrapulmonary hemorrhage. **(e)** The superficial end of the microcoil (arrowhead) was visualized using a thoracoscope to guide wedge resection. CT, computed tomography.

by the thoracic surgeons, and the specimen was sent immediately for frozen section. The frozen sections were used to assess whether the lesion had been completely removed or whether extended resection was necessary. There was no difference in the VATS procedure between the two groups.

Data collection

The following information was extracted from the medical records and radiology information systems: gender, age, nodule position, nodule maximal diameter, nodule to pleural distance, nodule density, patient position, complications of the localization procedure, localization procedure time, surgical operation time, localization success rate, and postoperative pathological diagnosis. Pneumothorax and intrapulmonary hemorrhage complications were confirmed using a CT scan after localization was completed and based on the common terminology criteria for adverse events (CTCAE).[11] A numerical rating scale was used to evaluate chest pain grade.[12]

Statistical analysis

Continuous variables were summarized using mean ± standard deviation, and categorical variables using frequency and percentage. Student's t-test was used for normally distributed continuous variables, and Pearson's chi-square test or Fisher's exact test was used for categorical variables. The software SPSS version 25.0 for Windows (IBM, Armonk, NY, USA) was used for all statistical analyses, and a P value of <0.05 was considered statistically significant.

Results

A total of 138 patients with 138 pulmonary nodules were enrolled in the study, including 110 patients in the routine group and 28 patients in the penetrating lung group. Age, gender, nodule to pleural distance, maximal diameter, nodule density, and nodule position did not differ significantly between the two groups (P = 0.547, P = 0.791, P = 0.116, P = 0.173, P = 0.756, and P = 0.223, respectively). However, the penetrating lung group had more supine positioning than the routine group (89.9% vs. 41.0%, P < 0.001). The baseline characteristics of the patients and nodules are summarized in Table 1.

Localization procedure time was significantly increased in the penetrating lung group compared with the routine group (31.0 ± 3.0 min vs. 21.2 ± 2.8 min, P < 0.001) (Table 2). A CTCAE grade of 3 or above for adverse events did not occur during the localization procedure of the two groups, and no additional intervention was required in all cases. There was no statistical difference in any of the complications (pneumothorax, intrapulmonary hemorrhage, or moderate and severe chest pain) in both groups (P = 0.178, P = 0.204, P = 0.709, respectively).

In all cases, VATS was performed with a success rate of 100%. No statistical difference was observed in surgical operation time between the two groups (P = 0.414). The localization success rate was 95.5% (105/110) in the routine group and 89.3% (25/28) in the penetrating lung group (P = 0.205). In two of the five failed nodules in the routine group, the microcoil was attached to the thoracic wall muscle, with the distal end of the microcoil pulled out of the lung. Under these circumstances, the surgeons needed to carefully examine the needle track on the lung surface to locate the nodule, and VATS was successfully performed. The superficial end of the microcoil was not exposed in the pleural surface in three of the five failed cases in the routine group, and palpation of the microcoil finally located the nodules. Three nodule localization failures were found in the penetrating lung group. In these cases, the superficial end of the coil did not appear in the pleural cavity. All three patients developed pneumothorax on their last CT scan after localization, and localized pulmonary nodules were finally palpated.

There were 71 patients with benign lesions and 39 patients with malignant lesions in the routine group. Among the 28 patients in the penetrating lung group, 17 were benign, and 11 were malignant lesions. The postoperative pathological diagnoses of the nodules are listed in Table 3.

Discussion

This study retrospectively describes the effectiveness of CT-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture. When performing CT-guided pulmonary interventional procedures, bony structures such as the scapula have the potential to obstruct the needle path, thereby increasing the difficulty

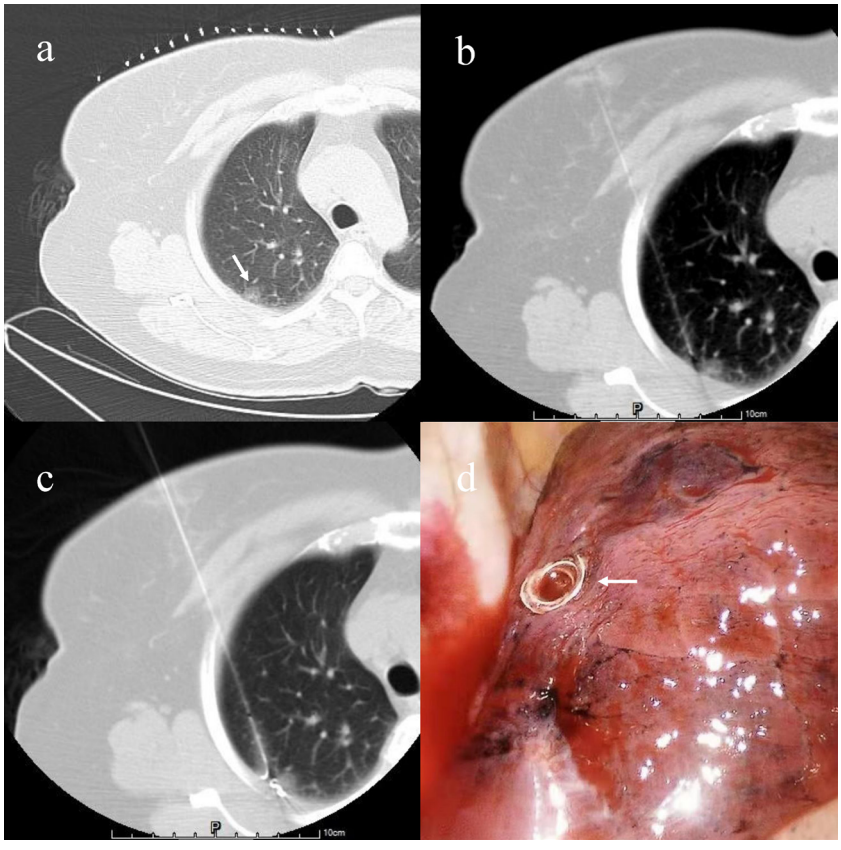

Figure 3. A 49-year-old female with a pulmonary nodule in the right upper lobe. **(a)** Axial CT image showing lesion (arrowhead) in the right upper lobe. **(b)** Needle tip was advanced into the normal lung parenchyma adjacent to the lesion and continued to advance to the pleural cavity. **(c)** The distal end of the coil was first released to the pleural surface, and the tail of the microcoil remained near the nodule. **(d)** The superficial end of the microcoil (arrowhead) was visualized using a thoracoscope to guide wedge resection. CT, computed tomography.

of manipulation.[13,14] Zhang et al.[15] attempted to apply a trans-scapular approach for preoperative CT-guided coil localization of scapula-blocked pulmonary nodules, achieving a technical success rate of 100% and pneumothorax in 9.1% of patients. In fact, avoiding bony structures is considered to be the optimal approach. In the present study, although there were a few unsuccessful localizations in both groups, VATS was successfully performed in all cases without breaking the scapula.

Although the localization success rate was lower in the penetrating lung group (89.3%) than in the routine group (95.5%), this difference was not significant. Consequently, CT-guided microcoil localization using the penetrating lung puncture technique is feasible. Xu et al.[3] considered that the presence of pleural indentation during the procedure was a significant risk factor contributing to microcoil pleura marking failure, which was positively correlated with the existence of pneumothorax. The removal of predisposing factors for pneumothorax (e.g., a reduction in the number of punctures) may contribute to an increased success rate. In the penetrating lung puncture group, localization failed in three cases because the distal end of the coil did not appear on the pleural surface, and all of these patients developed pneumothorax. In this case, the CT image provided misleading information to radiologists that the procedures had been successfully completed. In fact, as the lung tissue re-inflated during the positioning and VATS intervals, the ends of the microcoil retracted from the pleural surface, and eventually, the microcoil could not appear on the pleural surface. Fortunately, these nodules were all successfully localized under palpation by the surgeons and subsequently resected.

Table 1. Clinical characteristics in the routine group and the penetrating lung group

	Routine group	Penetrating lung group	*P* value
Number, n	110	28	
Age (year), mean ± SD	58.5 ± 9.9	57.1 ± 11.7	0.547
Gender, n (%)			0.791
Male	48 (43.6%)	13 (46.4%)	
Female	62 (56.4%)	15 (53.6%)	
Nodule to pleural distance (mm), mean ± SD	25.8 ± 13.5	21.6 ± 7.8	0.116
Maximal diameter (mm), mean ± SD	11.9 ± 5.5	13.9 ± 7.2	0.173
Nodule density, n (%)			0.756
Solid	28 (25.5%)	8 (28.6%)	
Part-solid	15 (13.6%)	5 (17.9%)	
Non-solid	67 (60.9%)	15 (53.6%)	
Patient position, n (%)			<0.001
Supine	45 (40.9%)	25 (89.3%)	
Prone	36 (32.7%)	0	
Lateral	29 (26.4%)	3 (10.7%)	
Nodule position, n (%)			0.223
Right lung	69 (62.7%)	21 (75.0%)	
Left lung	41 (37.3%)	7 (25.0%)	

SD, standard deviation.

Table 2. Comparison of complications, localization, and surgical procedure-related data between the groups

	Routine group	Penetrating lung group	*P* value
Number, n	110	28	
Pneumothorax, n (%)	19 (17.3%)	8 (28.6%)	0.178
Intrapulmonary hemorrhage, n (%)	12 (10.9%)	6 (21.4%)	0.204
Moderate and severe chest pain, n (%)	9 (8.2%)	3 (10.7%)	0.709
Localization procedure time (minutes), mean ± SD	21.2 ± 2.8	31.0 ± 3.0	<0.001
Surgical operation time (minutes), mean ± SD	118.4 ±14.3	121.0 ± 16.4	0.414
Success rate, n (%)	105 (95.5%)	25 (89.3%)	0.205

SD, standard deviation.

There was no statistical difference in the incidence of any complication between the penetrating lung group and the routine group, with complications of grade 1 or 2, demonstrating that CT-guided microcoil localization for pulmonary nodules using penetrating lung puncture is safe. Penetrating lung puncture inevitably led to a longer puncture path. Although it has been reported that a longer puncture path was linked with the incidence of pneumothorax and intrapulmonary hemorrhage during CT-guided lung biopsy,[16] no similar findings were seen in this study. This may be due to the use of a 21-G needle for the localization of pulmonary nodules, which is thinner than a biopsy needle. Al-Damegh[17] reported that the small needle size in their study was associated with the significant absence of post-procedural complications. The incidence of moderate and severe chest pain was comparable in both groups and not directly related to the penetrating lung puncture. Hu et al.[18] concluded that smaller diameter nodules contributed to the increased incidence of moderate or severe chest pain.

The location of the marking should be the shortest distance from the pleura to the nodule.[19] Considering the shadow effect of the scapula, more patients used the supine position in the penetrating lung group, which was determined by the shortest path from the pleura to the nodules, while no patients used the prone position. In the routine group, the most suitable body position should be determined according to the location of the nodules. This is used to explain why there is a significant difference in body position between the two groups.

The microcoil localization procedure time in the penetrating lung group was 31.0 ± 3.0 minutes, which was much longer than the time in the routine group. The possible reasons that contributed to the long procedure time are as follows: 1) the primary motivation for the penetrating lung puncture was scapular occlusion, which required a more complex path strategy during localization; and 2) a longer puncture path required the radiologist to adjust the insertion route and angle more frequently. In addition, the penetrating lung group first released the distal end of the microcoil on the pleural surface, and more precise adjustment of the posi-

Table 3. Postoperative pathology of the nodules in the two groups

Pathology	Routine group (n = 110)	Penetrating lung group (n = 28)
Malignant, n (%)		
invasive adenocarcinoma	41 (37.3%)	7 (25.0%)
Minimally invasive adenocarcinoma	22 (20.0%)	3 (10.7%)
Adenocarcinoma *in situ*	6 (5.5%)	5 (17.9%)
Squamous cell carcinoma	2 (1.8%)	1 (3.6%)
Metastatic carcinoma	0	1 (3.6%)
Benign, n (%)		
Atypical adenomatous hyperplasia	13 (11.8%)	4 (14.3%)
Tuberculosis	8 (7.3%)	2 (7.1%)
Lymphoid hyperplasia	5 (4.5%)	0
Localized pneumonitis	5 (4.5%)	1 (3.6%)
Fibrous tissue hyperplasia	3 (2.7%)	2 (7.1%)
Intrapulmonary lymph node	2 (1.8%)	0
Pulmonary hamartoma	2 (1.8%)	2 (7.1%)
Sclerosing hemangioma	1 (0.9%)	0

tion of the needle tip was required to reduce damage to the chest wall tissue caused by unnecessary puncture as compared with the routine group. The proximal end of the microcoil in the routine group could be placed within 10 mm of the extrapleural chest wall tissue since the needle had already passed through the chest wall tissue at that site. There was no significant difference in surgical time between the two groups, proving that different puncture methods of microcoil localization had no effect on VATS procedure time.

However, this study had some limitations. First, the sample size was relatively small, so future studies with larger sample sizes are required. Second, this was a single-center evaluation, and a future multicenter study may further confirm the findings. Moreover, it was not possible to evaluate unusual adverse events due to the fact that no such complications occurred in this study.

In conclusion, CT-guided microcoil localization for scapula-blocked pulmonary nodules using penetrating lung puncture prior to VATS resection is effective and safe. However, the deployment of the microcoil using penetrating lung puncture required more time than the routine puncture method.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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