The utility of simultaneous CT-guided localization for multiple pulmonary nodules using microcoil before Video-Assisted Thoracic Surgery

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Abstract

Background: To evaluate the feasibility and safety of microcoil in simultaneous localization for multiple pulmonary nodules before video-assisted thoracic surgery (VATS).

Methods: Twenty-eight consecutive patients (26 two-nodule, 2 three-nodule; totally 58 nodules; Group A) underwent simultaneous CT-guided localization for multiple pulmonary nodules before VATS using microcoil. Successful targeting, localization, and VATS were defined as implantation of microcoil at the target site on CT image obtained immediately after the marking procedure, visualization of nodule location, and complete resection of the target nodule with adequate margin, respectively. Meanwhile, the clinical characteristics, localization procedure-related variables of the nodules and procedure-related complication in group A were also assessed and compared with those in a control group (221 single-localization procedures in 221 patients; Group B).

Results: The similar rates of success targeting, localization and VATS were observed in group A and B (96.6% *vs* 98.2%; 91.4% *vs* 91.0%; 100% *vs* 99.1%). Although the rate of overall complications (including localized pneumothorax and intrapulmonary hemorrhage) was a bit higher in group A than that in group B (32.8% *vs* 30.8%, p=0.771), only minor complications were observed in the subjects of the two groups with no need for further treatment. In addition, the duration of simultaneous localization procedures was significantly longer than that of single localization ones (24±7.5 *vs* 13±6 min, p<0.001).

Conclusions: CT-guided simultaneous microcoil localization for multiple pulmonary nodules before VATS was clinical feasible and safe with acceptable increasing the procedure time. Compared with localization for a single pulmonary nodule, simultaneous microcoil localizations for multiple nodules were prone to the occurrence of pneumothorax and hemorrhage. However, no statistically significant differences were observed between the two groups.

Background

Owing to the worldwide concerning about lung cancer screening and the improvement of imaging modalities, the detection for small pulmonary nodules is increasing, especially the rate of simultaneous multiple nodules in a single patient [1–2]. In a study conducted by Marjolein et al [3], the baseline nodule count (the number of nodules per screen) was not associated with the lung cancer probability and each nodule should be assessed separately.

For the indeterminate nodules, excision biopsy, which removes the entire nodule at one setting, is an available solution either for patients or physicians, especially for the anxious patients [4]. And a preoperative tumour localization can greatly improve the accuracy of resection and decrease the rate conversion to thoracotomy [5–14]. CT-guided microcoil localization for pulmonary nodule before video-assisted thoracic surgery (VATS) has been considered as a safe and accurate technique with a high success rate and low complication rate [5–14]. However, considering the procedure time, possible

changes in body position, potential morbidity and complications, it is still a challenge to perform simultaneous localization for multiple nodules in one procedure.

Although the simultaneous localization has been performed or mentioned in prior studies [15–19], few studies have focused on the microcoil utility in simultaneous localization before VATS [19]. Thus, we retrospectively summarized the experiences of CT-guided microcoil localization in lung nodules and evaluated the efficacy and safety of microcoil utility in simultaneous localization.

Methods

The institutional review board of our hospital approved the present retrospective study and waived the requirement for informed consent for collecting data from the related patients. Written informed consent for CT-guided percutaneous localization has been obtained from all patients prior to performing the procedure.

Study Subjects

From June 2016 to March 2019, 249 consecutive patients (90 males, 159 females) with 279 pulmonary nodules underwent CT-guided microcoil localization prior to VATS at our radiology department were enrolled in this study. Exclusion criteria for CT-guided microcoil localization were the following: 1) nodules adjacent to the hilum or apparent vascular structure; 2) lesions located in the bronchi; 3) patients who refused to microcoil localization or VATS resection.

Of these, 28 patients (male/female: 10/18; mean age: 57.7 ± 8.0 years) underwent simultaneous localization for multiple pulmonary nodules (26 two-nodule, 2 three-nodule, total 58 nodules; Group A), and the other 221 patients (male/female: 80/141; mean age: 57.3 ± 11.3 years) underwent localization procedures for 221 nodules (Group B). None of them has received the examination of needle biopsy for the current pulmonary lesions before. The median interval between CT interventional procedure and VATS was 27.8 hours (range, 0.9∽95.7 hours). The clinical characteristics of the patients were summarized in Table 1.

Table 1
The clinical information of the patients underwent CT-guided microcoil localization

Variable		Different groups		*p*-value
		Group A	Group B	
Patients No.		28	221	-
Nodule No.		58	221	-
Age (y)	Mean ± SD(range)	57.7 ± 8.0 (39∽77)	57.3 ± 11.3 (26∽81)	0.825
	≤ 55/ >55	13/15	94/127	0.695
Gender	Male/ Female	10/18	80/141	0.960
Smoking status	Ex- or current/ Never	2/26	28/193	0.546
Cancer history	Primary lung/ Extra-pulmonary/ No	0/2/26	10/18/193	-
Previous thoracic operation	Yes/ No	0/28	10/211	-
$FEV_{1.0}$/FVC (%)	Mean ± SD (range)	74.3 ± 9.9 (44.6∽91.5)	77.2 ± 7.4 (52.9∽91.5)	0.061
Localization procedure time (min)	Median ± IQR (range)	24 ± 7.5(13–45)	13 ± 6(5–52)	< 0.001
The time to the operation (hour)	Median ± IQR (range)	19.2 ± 16.9 (0.9∽72.6)	20.0 ± 12.7 (1.0∽95.7)	0.202
	≤ 24/ >24	21/7	144/77	0.299

Abbreviation: $FEV_{1.0}$/FVC, forced expiratory volume at 1 second/forced vital capacity; SD, standard deviation; IQR, interquartile range.

Ct-guided Microcoil Localization

Before CT-guided localization procedures, patients were trained to hold the breath for 5–10 seconds at the end of inspiratory. All the planning and localization CT scans were carried out using the same 16-detector-row scanner (Aquilion 16;Canon Medical Systems, Japan). The following parameters for the planning CT: scanning method = helical acquisition mode; tube currents = 50mAs; tube voltage = 120kVp; rotation time = 0.5 sec; imaging FOV = 400; slice thickness = 5 mm, the following parameters for the localization CT: scanning method = axial acquisition mode; tube currents = 50mAs; tube voltage = 120kVp; rotation time = 0.5 sec; imaging FOV = 400; slice thickness = 4 mm. The limited slices were scanning including lesion and microcoil for saving radiation dose.

A planning CT scan was performed before percutaneous needle insertion. An appropriate puncture point on a patient's skin was marked to get the shortest needle entry route meanwhile avoiding the inclusion of bullae and vessels structures. Embolization microcoil (Cook Incorporated, Bloomington, IN 47404, USA) was selected as a localization marker with a wire diameter of 0.018 inches and a length of 7 cm. After local anaesthesia with 2% lidocaine, an 18G/10 cm percutaneous introducer needle (Cook Incorporated, Bloomington, IN 47404, USA) was then advanced to puncture from the marked point on the skin without penetrating the parietal pleura. After confirming the direction of the tip of the puncture needle by the second CT scan, further insertion into the normal lung parenchyma around the lesions (within 5 mm) was carried out. Then the third CT scan was performed to confirm the final position of the tip of the needle before connecting the loading cannula of the microcoil to the needle. Our method for deploying the microcoil was a modified procedure from Powell's method [5]. The microcoil was implanted adjacent to nodule within 5 mm instead of nodule penetration, which may incite hemorrhage or inflammation in the nodule and then affect histopathologic assessment [20]. The intention of our method was to leave the proximal end of the microcoil on the visceral pleura, which will be a direct clue for nodule's position during VATS resection and significantly improve the efficiency of surgery [14].

Basing on the learning curve analysis described by Chao et al [21], the over-33-month (from June 2016 to March 2019) operational process of the interventional radiologists could be divided into two stages: the initial 16-month and the later 17-month. In the initial 16-month, the radiologists were with limited experience for evaluating microcoil dislodgement or migration (localization failure) on CT scans and the microcoil implantation used to be given only once for one nodule, while in the later 17-month, a repeated localization procedure would soon be done if the radiologists predicted the proximal end of the first microcoil was likely to dislodge or detach from the visceral pleura on post-procedural CT images. And the procedure-related complications were evaluated based on the Society of Interventional Radiology Standards of Practice Committee Classification [12].

Surgical Procedure

VATS was performed under single-lung ventilation with a double-lumen endotracheal tube and general anaesthesia. The patient was placed in the lateral decubitus position, with the involved lung in the superior location. According to preoperative images, a thoracoscopic port inserted into the pleural cavity through appropriate intercostal space. The other two ports were placed to insert a grasping instrument and a linear stapling device.

Under the guidance of VATS and preoperative localization CT (Fig. 1a-e), the excision of the complete microcoil and nodule was carefully performed and the specimen was immediately sent for frozen section. The frozen sections were used to evaluate whether the extended resection was necessary and/or the lesion was completely resected. Completion lobectomy was performed unless the lesion was found to be noninvasive cancer, or the patient had an inadequate cardiopulmonary reserve, or the patient had lung resection before, or the patient declined to extended resection.

Assessment

The successful targeting rate, localization rate, VATS rate, and procedure-related complications rate were calculated based on the total number of the nodules [11, 22]. Successful targeting was defined as implantation of microcoil at the target site adjacent to a nodule on CT image obtained immediately after the marking procedure and the rate was calculated as follows: (number of successful targeting procedures/number of all localization procedures in each group)x100; successful localization was defined as detection of nodule location and the rate was calculated as follows: ([number of successful targeting procedures-number of dislodgements or misses under the thoracoscope]/number of all localization procedures in each group)x100; successful VATS was defined as complete resection of the target nodule with adequate margin and the rate was calculated as follows: ([number of successful VATS /number of all localization procedures in each group)x100. The severity of procedural complications was also recorded according to the Society of Interventional Radiology Standards of Practice Committee classification of complications [12].

In addition, all preoperative CT data was transmitted to the picture archiving and communication system (PACS) and scanner workstation. Nodules were classified as solid, part-solid and ground-glass opacity (GGO) according to their density on CT images with a lung window setting (level:-450HU; width: 1300HU). One nodule was defined as GGO when it had increased attenuation relative to parenchyma but was not as dense as soft tissue density (such as the parenchymal vessels). Part-solid nodule contained some areas with solid attenuation component. The nodule characteristics and localization procedure-related variables, including nodule location, size, type, depth from pleura (the shortest vertical distance), presence of emphysema (around the needle insertion pathway), patient position for localization procedure (prone or supine), needle-pleural angle, pleura-microcoil distance (along the needle insertion pathway), presence of “pleural indentation” (defined as the manifestation that the pleura was not penetrated by the needle and protruded towards the nodule, resulting in a tent-shaped appearance of the pleura), scapulae-covered sign (nodule was shadowed by the scapulae), presence of procedure-related complications (pneumothorax or pulmonary hemorrhage), localization procedure time (defined as the interval time between the initial CT scan scout film before puncture and last CT scan followed localization procedure) as well as the time to the operation (defined as the interval time between the termination of the postprocedural CT scan in the interventional unit and the start of the general anaesthesia in the operating room) were measured and recorded. The comparison of clinical characteristics and procedure-related variables between Group A and B were recorded in Tables 1 and 2.

Table 2
Summary of nodule characteristics

Variable		Different groups		*p*-value
		Group A	Group B	
Nodule size (mm)	Median ± IQR (range)	7.1 ± 3.6 (2.3∽18.9)	9.8 ± 5.8 (2.8∽26.8)	< 0.001
	≤ 5 mm	10	12	< 0.001
	> 5∽10 mm	38	106	
	> 10∽15 mm	9	74	
	> 15 mm	1	29	
Nodule location	Right/ Left side	39/19	131/90	0.268
	RUL/RML/RLL	21/0/18	86/14/31	0.011
	LUL/LLL	10/9	63/27	
Nodule type	Solid/Part-solid/GGO	20/12/26	36/33/152	0.002
Depth from pleura (mm)	Median ± IQR (range)	12.6 ± 13.6 (0.0∽44.4)	10.3 ± 16.7 (0.0∽53.1)	0.781
	≤ 5 mm	14	52	0.159
	> 5∽10 mm	12	57	
	> 10∽15 mm	13	25	
	> 15 mm	19	87	
Presence of emphysema	Yes/ No	4/54	6/215	0.224
Position for localization procedure	Supine/ Prone	24/34	108/113	0.309
Needle-pleura angle (°)	Mean ± SD(range)	64.0 ± 14.0 (32.4∽88.9)	61.2 ± 15.7 (21.1∽89.8)	0.225
	≤ 30°	0	8	0.410
	> 30∽60°	23	93	
	> 60°	35	120	

Variable		Different groups		*p*-value
Pleura-microcoil distance▼(mm)	Mean ± IQR (range)	35.2 ± 9.4 (4.0∽57.8)	34.07 + 10.3 (1.0∽55.9)	0.378
	≤ 10 mm	2	11	0.211
	> 10∽20 mm	0	13	
	> 20∽30 mm	11	43	
	> 30 mm	45	154	
Presence of pleural indentation	Yes/ No	10/48	60/161	0.121
Presence of the scapulae-covered	Yes/ No	4/54	42/179	0.027
Procedure-related complications	Yes/ No	19/39	68/153	0.771
Pneumothorax	Yes/ No	16/42	67/154	0.686
Intrapulmonary haemorrhage	Yes/ No	7/51	26/195	0.949
Surgical procedure	Wedge resection/ Anatomic resection●/ Open thoracotomy	46/12/0	134/85/2	-
Pathologic result▼▼	Primary lung cancer/ metastasis/ Benign lesion	37/0/21	175/3/43	-

Abbreviation: IQR, interquartile range; SD, standard deviation; GGO, ground glass opacity; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

Note:

"" The emphysema region was around the needle insertion pathway.

"▼" Pleura-microcoil distance was measured along the needle insertion pathway.

"●"Anatomic resection included lobectomy and segmentectomy.

"▼▼"Detailed pathologic results were summarized in the Table 3.

Statistical analysis

Statistical analysis was performed using SPSS 17.0 software (SPSS 17.0 for Windows, Chicago, IL). The Kolmogorov-Smirnov test for normality was performed on continuous variables and the graphical spread of the data was visually inspected. Descriptive statistics were shown as mean ± standard deviation (SD)

or median ± interquartile range (IQR) for continuous variables, and as frequency and percentage for categorical variables.

The comparison of clinical characteristics and microcoil localization procedure-related variables between group A and group B were analyzed by Independent-samples *t*-test/Mann-Whitney U test, and the chi-square test/Fisher exact test. A two-sided *p*-value less than 0.05 was considered statistically significant.

Results

The successful targeting, localization, and VATS rate for group A and B

For group A (multiple nodules per person), according to the CT scan obtained immediately after the marking procedure, two microcoils were implanted into the pleural surface and did not reach the target regions in parenchymal (one of the nodules was performed in early-stage without repeated puncture, the other was given repeated puncture), thus the successful targeting rate was 96.6% (56/58).Three microcoils dislodged into the thoracic cavity after initial deflation of the lung, thus the successful localization rate was 91.4% (53/58).

For group B (single nodule per person), four microcoils did not reach the target region in parenchymal on CT scan and repeated punctures were performed immediately, thus the initial successful targeting rate was 98.2% (217/221). 12 microcoils dislodged into the thoracic cavity, 3 hanged on the parietal pleural and 1 fell on the diaphragmatic surface when the targeted lung collapsed, thus the successful localization rate was 91.0% (201/221).

For most of the nodules with failed targeting or localization mentioned above, subpleural haemorrhage or puckering of the visceral pleura combined with intraoperative palpation served as additional guide for successful resection. Only two patients in group B were converted to open thoracotomy, one for diffuse pleural adhesion, the other for inability to perform bronchoplasty after nodule resection with a video-assisted thoracoscope. The success VATS rate of group A and B was 100%, 99.1%, respectively.

Localization Procedure Time And Procedure-related Complication Rates

Although the nodules in the patients of group A were all in the unilateral lung distribution, twelve patients (12/28; 42.9%) have changed body positions during interventional procedures. The procedure time of group A was significantly longer than that of group B (24 ± 7.5 *vs* 13 ± 6 min, $p < 0.001$).

With respect to procedure-related complications, only minor complications (including localized pneumothorax and intrapulmonary haemorrhage; class A/B) were observed in the subjects of the two

groups with no need for further treatment. Furthermore, there was no significant difference in the rates of overall procedure-related complications between the two groups (32.8% *vs* 30.8%, $p = 0.771$).

Pathological Result

The detailed pathological results for the nodules were summarized in Table 3. Over half of the nodules in both groups were confirmed as malignant lesions (63.8% *vs* 80.1%). The pathological results of multiple nodules in one same patient were inconsistent, which was revealed in half of the patients with multiple nodules (14/28).

Table 3
Summary of pathology in two groups

Pathologic process		Incidence	
		Group A (n = 58)	Group B (n = 221)
Malignant	Invasive adenocarcinoma	16 (27.6%)	104(47.1%)
	Minimally invasive adenocarcinoma	15 (25.9%)	58(26.2%)
	Adenocarcinoma in situ	3 (5.2%)	10(4.5%)
	Squamous cell carcinoma	1 (1.7%)	1(0.5%)
	Metastases	0	3(1.4%)
	Pulmonary carcinoid	2 (3.4%)	1(0.5%)
Benign	Atypical adenomatous hyperplasia	6 (10.3%)	10(4.5%)
	Minute pulmonary meningothelial-like nodules	0	2(0.9%)
	Nodular lymphoid hyperplasia	3 (5.2%)	4(1.8%)
	Benign intraparenchymal lymph node	2 (3.4%)	4(1.8%)
	Localized pneumonitis	3 (5.2%)	13(5.9%)
	Cryptococcosis	2(3.4%)	3(1.4%)
	Tuberculosis	0	2(0.9%)
	Granulomas	2 (3.4%)	1(0.5%)
	Sclerosing hemangioma	0	1(0.5%)
	Fibrotic nodule	3 (5.2%)	4(1.8%)

Discussion

Results of the current study indicate that preoperative microcoil localization technology is a safe and effective method for simultaneous multiple nodules as well as a single pulmonary nodule, with similar successful targeting (96.6% *vs* 98.2%) and localization rates (91.4% *vs* 91.0%). Meanwhile, the rates of overall procedure-related complications showed no statistically significant differences between the two groups (32.8% *vs* 30.8%, $p = 0.771$). The high success rate of final VATS further confirmed the feasibility of microcoil preoperative localization for simultaneous multiple nodules.

Actually, with respect to simultaneous localization of multiple pulmonary nodules, the potential challenges and problems have been well described in previous studies [15–19], even though a different localization technique-hook wire has been adopted. Compared to single localization, simultaneously targeting multiple nodules means repetitive procedures in a short time, which is not only associated with potential increased risk of failure and complication but also a tough process both for operators and patients.

An integrated and ideal process of microcoil localization in our interventional unit is “one line with two dots”, which means two ends of the microcoil tightly deploy in lung parenchyma and the pleural surface, respectively. In our opinion, the main reason for targeting failure may be attributed to the insufficient depth of insertion. The pleura was protruded to nodule direction presenting as the tent shape rather than being penetrated by the puncture needle (the presence of pleural indentation). In such cases, the needle tip is only close to the nodule on images rather than reaching the desired region actually. In other words, it is targeting failure. The flexibility of microcoil makes it easy to curl and retract once it is pushed out of the puncture needle. If there is no enough distance between the two ends of the microcoil to resistant its own elastic recoil force, it would retract into the parenchymal or deploy on the pleural surface. And in the latter situation, microcoil often dislodged from the pleural when the targeted lung collapsed, which is localization failure. In the current study, either” presence of pleural indentation” or, “pleura-microcoil distance” showed no significant differences between group A and B. Therefore, it is a bit reasonable to observed the similar success rates of targeting and localization in two groups (96.6% *vs* 98.2%; 91.4% *vs* 91.0%).

Smaller nodule size and lower GGO rate were observed in group A (multiple nodules group). However, microcoil was implanted adjacent to lesion rather than through it, nodule size or type seemed to rarely influence the procedure progress. Although it was suggested a priority should be given to the most clinically significant nodule (such as the lesion difficult to locate or with malignant features) [15], we did not make such selection for puncture order when simultaneous localizations were performed. Although the rate of overall procedure-related complications was a bit higher in group A than that in group B (32.8% *vs* 30.8%, $p = 0.771$), only minor complications [12] (including localized pneumothorax and intrapulmonary haemorrhage; class A/B) were developed in the two groups. There are two inevitable factors associated with the higher rate of complications in multiple nodules group: 1) multiple punctures in the ipsilateral lung [23]; 2) position changes during the procedure. Hence, to some degree, the complication rate varied within a reasonable range. In addition, its flexible but firm quality avoids the

occurrence of parenchyma tear and its thrombogenic fiber coating reduces the risk of haemorrhage [13]. Therefore, in our opinion, it is a safe localization approach for simultaneous multiple nodules.

Considering the nodule number and possible position changes needed during the procedures, It is not hard to understand that the duration of the localization procedures was longer for multiple nodules localization (24 ± 7.5 *vs* 13 ± 6 min, $p < 0.001$). However, the procedure time could be greatly cut for unchangeable position (only 13 min needed in two patients with two-nodule) during the process, and similar results were observed in Iguchi et al [15] study with hook wire system. On the other side, even single nodule, the duration of the procedure would be delayed for variable factors, such as the shield of bone tissue nearby, unstable breathing movement of patients. A much higher incidence of “the scapulae-covered” was observed in group B (42/221; 19.0%), in which 5 patients with the procedure time over half an hour.

In addition, high rates of malignancy were demonstrated in both groups (63.8% [37/58] *vs* 80.5% [178/221]). Actually, most of the nodules were recommended to surgical treatment after the initial screening and follow-up period, which might account for the high malignant rate. Interestingly, it was observed that the multiple nodules in the same patient showed inconsistent pathological results, and the ratio of such patients was up to 50% (14/28) in group A, which in turn emphasized the importance of separate assessment for lung nodules and necessity for simultaneous localization.

There are several limitations to the current study. First, it is a retrospective study that only limited to a single center. Second, the total number of patients with multiple nodules was relatively small. Third, there is a potential selection bias in the choice of patients with multiple nodules localization. Even though certain patients with multiple nodules would opt to have the most suspicious nodules localized rather than simultaneous localization for various reasons, we have not encountered that yet in our center. In other words, all the patients with multiple nodules we encountered selected simultaneous localization and radical resection. Fourth, occasionally, the proximal end of the microcoil detached from the visceral pleural surface and curled into the lung parenchyma. However, the microcoil could still be observed under the fluoroscopy and offered important clues for nodules. The results for those part of nodules were counted in success localization in this study. Finally, only one localization technique was used in the study without comparison with other targeting techniques [11], such as hook wire localization, percutaneous injection of dyes, or intraoperative imaging.

Conclusions

In conclusion, CT-guided simultaneous microcoil localization for multiple pulmonary nodules before VATS was clinical feasible and safe with increasing certain acceptable procedure time. Compared with localization for a single pulmonary nodule, simultaneous microcoil localizations for multiple nodules were prone to the occurrence of pneumothorax and hemorrhage. However, no statistically significant differences were observed between the two groups.

Abbreviations

VATS =video-assisted thoracoscopic surgery; $FEV_{1.0}$/FVC =forced expiratory volume at 1 second/forced vital capacity; OR =Odds ratio; SD =standard deviation; IQR =interquartile range; PACS =picture archiving and communication system; GGO =ground glass opacity; WHO=World Health Organization; IASLC=The International Association for the Study of Lung Cancer; ATS=American Thoracic Society; ERS=European respiratory society; RUL =right upper lobe; RML =right middle lobe; RLL =right lower lobe; LUL =left upper lobe; LLL =left lower lobe; CI =confidence interval; Ref.=reference value

Declarations

Ethics approval and consent to participate

This study was approved by China-Japan Friendship Hospital Institutional Review

Board (IRB), conformed to the principles outlined in the Declaration of Helsinki and Informed consent was waived due to the retrospective nature of the study.

Consent for publication

Publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions:

Conception and design: HS, YX

Acquisition of data, or analysis and interpretation of data: YX, LM, HS, ZH, ZZ, FX, QM, JL, SX

Drafting the article or revising it critically for important intellectual content: YX, LM, HS, ZH, ZZ, FX, QM, JL, SX

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Figures

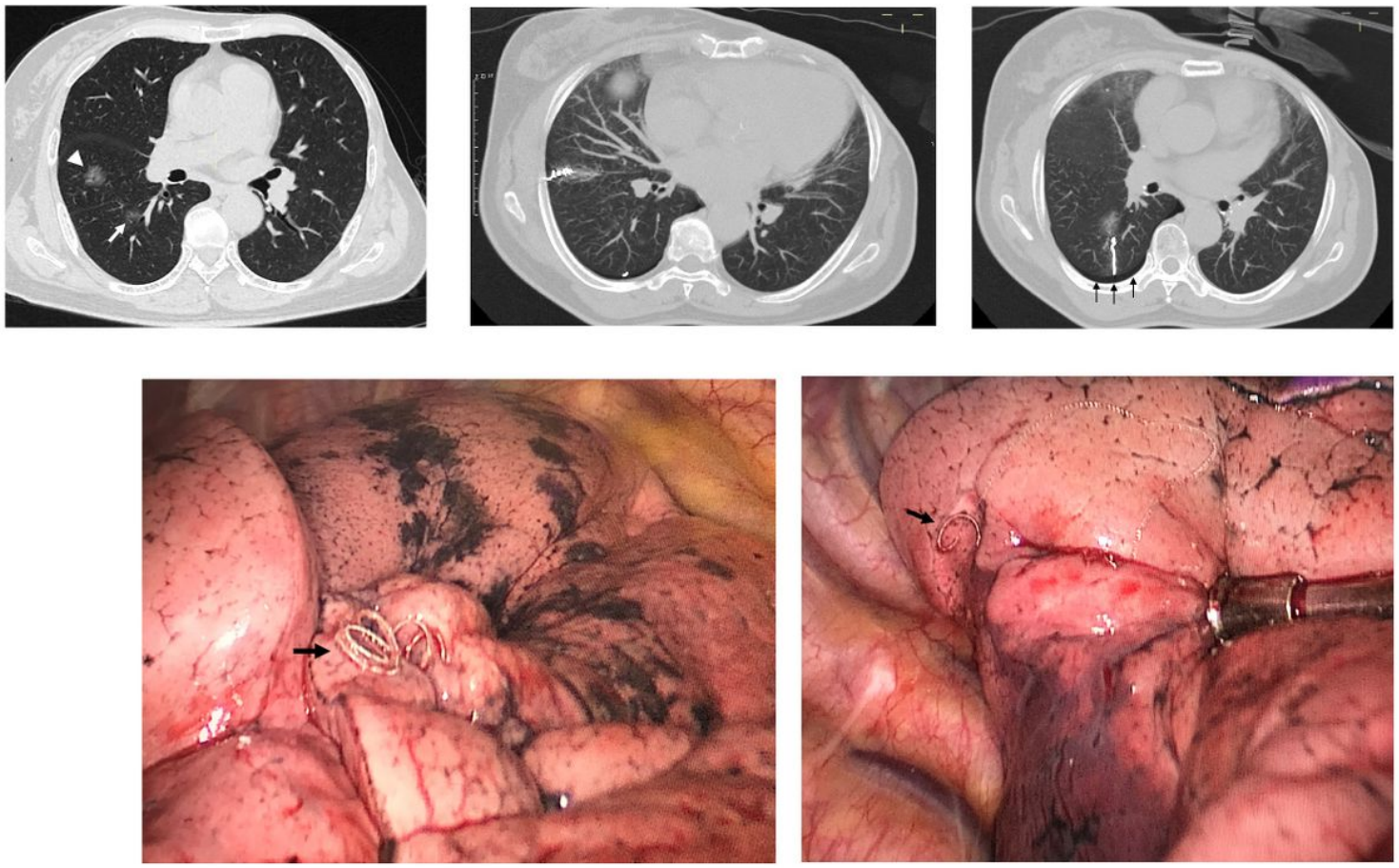

Figure 1

In a 61-year-old female with radical breast cancer surgery three years before, two ground-glass opacity nodules were located in the lateral segment of the right middle lobe (a, white arrowhead) and the dorsal segment of the right lower lobe (a, white arrow), respectively. Histopathologically, the lesion in the right middle lobe was diagnosed as minimally invasive adenocarcinoma and the one in the lower lobe was invasive adenocarcinoma. Neither of them is metastatic disease. The patient maintained a prone position during the interventional procedure (b, middle lobe implantation; c, lower lobe implantation) and the entire implantation was successfully performed with minor pneumothorax (c, indicated with black arrows). The tails of the mircrocoils were visualized during VATS (indicated with black arrows; d, corresponded to Figure b; e, corresponded to Figure c).