ORIGINAL ARTICLE

CT-guided Hook Wire Localization of Subpleural Lung Lesions for Video-assisted Thoracoscopic Surgery (VATS)

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Background/Purpose: Histologic diagnosis of suspicious small subpleural lung lesions is difficult and often impossible using existing image-guided needle biopsy techniques including video-assisted thoracoscopic wedge resection. Preoperative lung lesion localization provides a more obvious target to facilitate intraoperative resection. This study reviewed the indications, results and complications of CT-guided hook wire localization for subpleural lung lesions in video-assisted thoracoscopic surgery (VATS).

Methods: Between February 2001 and January 2007, 41 patients (20 males, 21 females; mean age, 52.5 ± 5.1 years) with 43 subpleural pulmonary lesions underwent preoperative CT-guided double-thorn hook wire localization prior to video-assisted thoracoscopic wedge resection. Nodule diameters ranged from 2 mm to 26 mm (mean, 9.7 ± 1.6 mm). The distance of the lung lesions from the nearest pleural surfaces ranged from 2 mm to 30 mm (mean, 9.6 ± 2.0 mm). Patients then received VATS within 5 hours. The efficacy of preoperative localization was evaluated in terms of procedure time, VATS success rate and associated complications of localization.

Results: Forty-three wedge resections of the lungs containing 43 subpleural lung lesions as guided or assisted by the inserted hook wires were successfully performed in 41 VATS procedures (41 of 43 procedures, 95.3%). The mean procedure time for preoperative CT-guided hook wire localization was 30.4 ± 2.8 minutes. Eight patients had asymptomatic minimal pneumothoraces (18.6%); six patients had minimal needle tract parenchymal hemorrhages (13.9%) and one patient (2.3%) had an estimated 100 mL of hemothorax due to a small intercostal artery bleed that was cauterized during operation. The mean procedure time for VATS was 103 ± 9.7 minutes (range, 44–198 minutes). Pathologic examination revealed seven primary lung cancers, 11 metastases, one hemangioma, 19 definite non-neoplastic pathologies, two nonspecific chronic inflammation, and three metallic foreign bodies. Diagnostic yield was 95%. No major complications related to the preoperative hook wire localization and VATS were noted.

Conclusion: CT-guided hook wire fixation is useful, helps in precise lesion localization in VATS wedge resection, and has a low rate of minor complications. [*J Formos Med Assoc* 2007;106(11):911–918]

Key Words: CT-guidance, hook wire, peripheral pulmonary lesions, video-assisted thoracoscopic surgery

The detection of small pulmonary nodules has been relatively easy in recent years in view of the widespread use of multidetector spiral computed tomography (CT) in the routine follow-up of oncologic patients, and low-dose CT lung cancer screening in a number of countries. In clinical practice, pulmonary nodules often undergo careful imaging evaluation or follow-up because they carry

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a 48% risk of malignancy in a reported series.[1] Popular noninvasive imaging evaluation for solitary lung nodules are dynamic contrast enhancement pattern on multidetector CT and positron emission tomography with radiolabeled [^{18}F]-2-fluoro-deoxy-D-glucose (PET-FDG) imaging/CT.[2] They have reasonable diagnostic accuracies of 85% and 93%, respectively, for malignancy.[2] However, their diagnostic sensitivities vary considerably, in view of the variable diagnostic criteria used and small lesion size.[3,4] Lung nodules > 5 mm carry a significant risk of malignancy, implying that aggressive intervention to obtain tissue proof is needed.[5] CT-guided coaxial cutting needle biopsy and video-assisted thoracoscopic surgery (VATS) are the standard appropriate minimally invasive techniques for acquiring tissue proof of lung nodules.[6–8] CT-guided needle biopsy may be difficult to perform when a lung nodule is less than 1.5 cm and within 2 cm from the pleural surface, and is associated with a lower diagnostic accuracy of 84% compared to a diagnostic accuracy of 95% for lung nodules larger than 1.5 cm.[8] As for VATS, a small subpleural lung nodule less than 10 mm in size and more than 5 mm deep to the pleural surface may be associated with a 63% chance of failure to be identified.[9] Nonetheless, to get tissue proof for a small subpleural lung nodule less than 10 mm, VATS seems to be the only practical way. In this situation, the operative procedure time may be prolonged because much time is wasted in finding the nodule. The originally planned minimally invasive VATS procedures are often converted to open thoracotomies.[9] To solve this dilemma, preoperative localization of small subpleural lung nodules before VATS has been developed over the years.[8] Although preoperative localization is not new, to the best of our knowledge, the experience reported from Taiwan is preliminary and limited.[10] Furthermore, we have expanded the indication of this technique to include localization of three foreign bodies and two cases of ectopic endometriosis. In this paper, we report on our experience with CT-guided localization of subpleural lung lesions before VATS using a double-thorn hook wire.

Methods

The medical records of 41 patients with 43 subpleural lung lesions who underwent preoperative CT-guided hook-wire localization performed between February 2001 and January 2007 were retrospectively reviewed. There were 20 males and 21 females; their ages ranged from 14 to 83 years, with a mean age of 52.5 ± 5.1 years. Twenty-four patients had known malignancy as follows: lung cancer (6), osteosarcoma (3), colon cancer (3), renal cell carcinoma (3), esophageal cancer (1), gastric cancer (1), hepatocellular carcinoma (1), cervical cancer (1), urinary bladder cancer (1), tongue cancer (1), thyroid cancer (1), choriocarcinoma (1), and uterine leiomyosarcoma (1).

These patients were referred from a team of thoracic surgeons for preoperative CT-guided hook wire localization because the subpleural lung lesions noted at initial diagnostic CT were presumably too small and/or too deep-seated to be detected by thoracoscopic visualization or palpation in 37 patients, failed CT-guided needle lung biopsies in two patients (patients 6 and 9), and foreign bodies that were difficult to identify thoracoscopically in two patients (patients 22 and 37/38). The size of the subpleural lung lesions ranged from 2 mm to 26 mm (mean, 9.7 ± 1.6 mm). The distance of the lung lesions from the nearest pleural surface was 2 mm to 30 mm (mean, 9.6 ± 2.0 mm). Nodules located more than 30 mm distant from the pleural surface were not included because they were not compatible with the definition of subpleural nodules.[11,12] We could not measure the size and subpleural distance of a bead-like tiny lesion that was located within the intersegmental fissures in the right lower lobe of patient 9.

On the day of planned VATS, patients were brought to our CT room. The necessity and possible risks of preoperative hook wire localization were explained to the patients and family members, and informed consents were obtained. The patients were placed on a CT scanner (GE HiSpeed, Milwaukee, WI, USA) in a position that allowed shortest direct access route for hook wire insertion.

A direct, vertical needle path through the lung aiming at a subpleural lung lesion was taken whenever possible. The skin around the planned needle puncture site was cleansed and sterilized using betadine. After local anesthesia, a small skin niche was made using a scalpel. Then, a 10.7-cm long, 20-gauge cannula needle housing the 20-cm long double-thorn hook wire (DuaLok™, Bard Inc., United Kingdom) (Figure 1) was gradually inserted through the chest wall with sequential CT guidance. The subpleural lung lesions or nodules were pierced through by the cannula needle whenever possible. When it was technically difficult or the lung lesions were too small, the hook wire was deployed in the adjacent lung as close to the lesion as possible. When the cannula needle tip was placed in a proper position deep to or adjacent to the lesions, the hook wire was advanced along the cannula until the marker on the wire met the external end of the cannula, which indicated complete deployment of the hook wire. Immediate follow-up CT scans were performed to confirm the relation of the fully deployed hooks with the subpleural lung lesions or nodules (Figure 2). Procedure-related pneumothorax and hemorrhage were scrutinized and recorded after reading the immediate follow-up CT scans. If there was no related symptomatic complication, the outer cannula needle was withdrawn, leaving a portion of the hook wire extended outside the chest wall. The wire was carefully wrapped up by 4 × 4 cm gauzes and laid upon the skin with further coverage by a few gauze dressings. Care was taken to ensure that the exteriorized segment of hook wire was not bent to conform to the chest wall, as bent hook wire might prevent free sliding through the chest wall during patients' normal respiration or during unilateral lung collapse in the subsequent VATS procedures. At the end of the localization procedures, patients were transferred to the operation room or back to the ward until the operation room was available. VATS was scheduled within 3 hours of the CT-guided hook wire insertions.

Figure 1. The hook wire is composed of a 20-gauge, 10.7-cm long, calibrated cannula (top). The double-thorn hook wire (bottom) measures 20 cm long. The distance between the hooks is 2 cm wide upon full deployment.

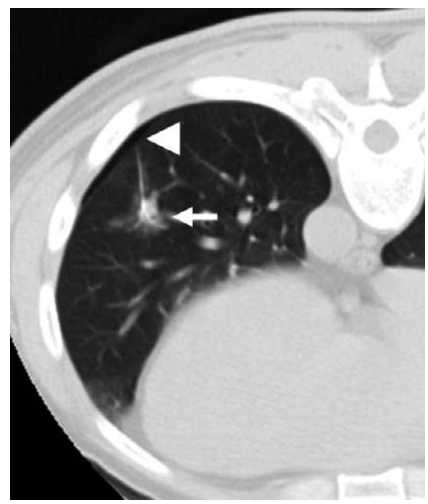

Figure 2. Prone computed tomography shows a left lower lobe, 17 mm deep subpleural lung nodule successfully localized by hook wire (white arrow). The arrowhead denotes minimal pneumothorax. The lesion was proved to be metastatic adenocarcinoma (patient 43).

Thoracoscopic surgeries were performed under general anesthesia using single lung ventilations through double-lumen endobronchial tubes. The gauze dressings of the hook wire were unpacked before lung collapse induced by the anesthesiologists after one lung intubation. A thoracoscope was inserted through a thoracic port at a certain distance from the wire. The hook wire anchored to the lung was identified and gently pulled outward to tent the lung surface. Two other incisions at proper intercostal spaces were made for visualizing and handling the resected lung (Figure 3A). One was used to insert a forceps for grasping the lung around the mostly invisible subpleural lung lesions and the other was used for insertion of a linear endostapler. Wedge resection of the lung tissues containing focal lung lesion was performed using the endostapler, with care taken not to miss

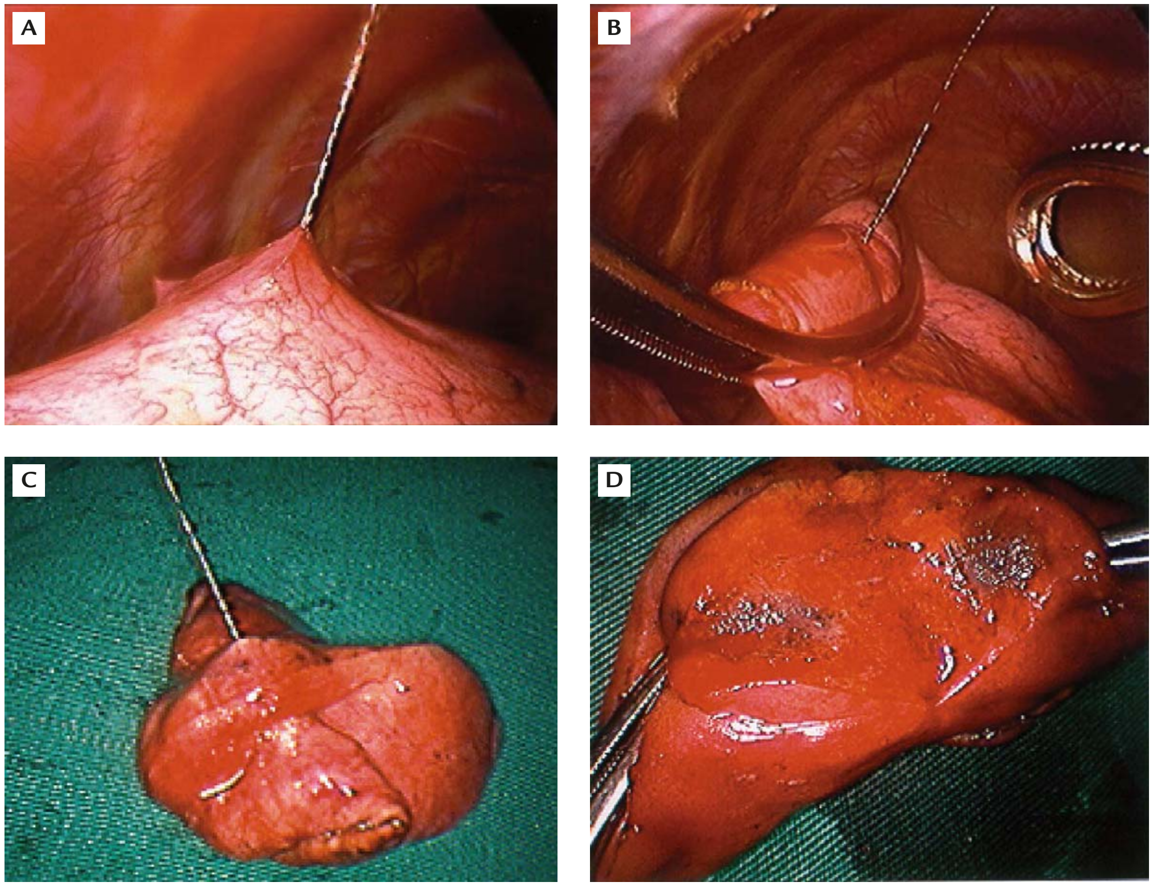

Figure 3. Successful operation for a right lower lobe lung nodule, 6 mm in size and 5 mm below the lung surface (patient 3). The subpleural lung nodule was grossly invisible and undetectable under video-assisted thoracoscopy. (A) Right lateral approach video-assisted thoracoscopic view of the right lower lung, with the patient placed in left decubitus position. Hook wire manipulation causes tenting of the lung surface to facilitate resection. (B) Ongoing wedge resection directly guided by hook wire with no obviously visible subpleural lesion. (C) Resected wedge of lung tissue with the hook wire still in place. (D) Bisected lung specimen which contains a hemorrhagic subpleural metastatic sarcoma. This patient had a history of resected left humeral osteosarcoma.

the lesion or cut the hook wire (Figure 3B). The hook wire anchoring the lung tissue including the lung lesion was packed into sterile gloves and withdrawn out of the chest from one of the intercostal incisions (Figure 3C). All resected lung specimens were incised immediately to locate the lung lesions (Figure 3D), and sent for immediate frozen section. If the diagnosis was primary lung cancer and the patient had no prior history of malignancy, VATS was then converted to thoracotomy for major resection and mediastinal lymphadenectomy. Otherwise, a chest tube was inserted and VATS was completed after excluding bleeding and air leak. VATS procedure time was defined as the time from chest port creation to the time when wounds were closed.

Results

The CT-guided hook wire localization procedures took about 13–60 minutes with a mean of 30.4 ± 2.8 minutes, including one patient with two nodules who underwent successive hook wire localizations in a single session. In 22 of the procedures (22 of 43, 51% of CT-guided hook wire localizations), the hook wire was inserted through the nodules or lung lesions. In the others (21 of 43, 49%), the hook wires were placed in adjacent lung tissue due to small nodule sizes, technical difficulty or patients' failure of proper breath holds. In addition, one bead-like intersegmental fissure lesion was located in an awkward position that did not allow its piercing.

The average time between the end of hook wire localization procedure and the first incision in the operation room was 1.8 hours (range, 0.7–5.1 hours). The average time for VATS wedge resection was 103 minutes.

In 43 CT-guided hook wire localization procedures, all the pulmonary lesions were successfully localized by hook wires without major complications. One patient underwent resection of two widely separated right middle lobe nodules in one VATS session by the insertion of two hook wires for localization (no. 10 and 11). Another patient underwent two separate hook wire localization procedures on different days for complete lesion resections (no. 37 and 38). There were three hook wire dislodgments (3 of 43, 6.9%) noted on thoracoscopy. VATS wedge resections of intrapulmonary lesions directly guided by hook wires were successful in 41 procedures (41 of 43, 95.3%). Two VATS were converted to mini-thoracotomies due to severe pleural surface adhesion causing difficulty in inserting the thoracoscope in one, and complete dislodgment of hook wire without any visible site of pleural puncture in the other. The subsequent lung nodule resections took considerably longer than usual (189 minutes and 150 minutes, respectively, compared to an average of 103 minutes). In two other incidences of hook wire dislodgment, the hook wire insertion sites were identifiable by blood stained spots on the pleural surfaces, which were showing some air leak phenomenon.

The most common complications were six asymptomatic minimal pneumothoraces (18.6%) and five minimal intrapulmonary hemorrhages (13.9%) detected on follow-up CT scans immediately after successful wire deployment while the patients were still on the CT table. One patient (2.3%) had an intercostal artery bleed noted during VATS, estimated blood loss of about 100 mL. One patient (2.3%) experienced prolonged air leak for 12 days after VATS without related symptoms, and healed after clinical observation in the ward.

The histologic diagnoses were obtained in 43 specimens. Pathologic examination revealed seven primary lung cancers, 11 metastases, one hemangioma, 19 definite non-neoplastic pathologies, two nonspecific chronic inflammation, and three metallic foreign bodies (Table).

Guided by the pathologic diagnoses from intraoperative frozen sections, seven patients who had primary lung cancers underwent open thoracotomies in the same operative sessions, and received lobectomies and systemized lymphadenectomy.

Discussion

Our experience with the double-thorn hook wire system in CT-guided localization of peripheral lung lesions for VATS is promising, as it obtained a 95% overall diagnostic yield (38 definite pathologic diagnoses among a total of 40 specimens, after excluding 3 metallic foreign bodies). Such a number of preoperative localization techniques for small subpleural lung lesions to assist VATS have been developed.[12–16] Each of these localization methods has its own advantages and drawbacks. Like masking of lung lesions or nodules by accidental widespread diffusion of methylene blue stain,[13] inconvenience of intraoperative fluoroscopy[14] or sonography, attenuation of ultrasound by emphysematous lung or difficulty in detecting the more deeply seated lung nodules or lesions with ultrasound are some of the limitations.[15] The disadvantages of radionuclide marking are the requirement of a handheld gamma probe and increased exposure to radiation.[16] On the other hand, the hook wire localization technique has several major advantages over the other methods of localization. First, the CT-guided hook wire deployment procedure time is quite short, 30.4 minutes on average in our series. Second, the deployed hook wires in the lung parenchyma can be used to retract the lung containing the subpleural lung lesion to assist their precise wedge resection. Furthermore, this capability to manipulate the lung by the anchored hook wire may avoid the need of a third thoracoscopic access to suspend the lung parenchyma.[17]

As for preoperative wire localization, there are many types reported in the literature. These include the earliest commercially available mammographic

Table. Clinical characteristics of patients and pathologic results

No.	Clinical information	Lesion			Pathology
		Nodule location	Size (mm)	Depth (mm)	
1	A subpleural nodule	RML	2	4	Interstitial fibrosis
2	Solitary lung nodule	LLL	12	7	Reactive lymphoid hyperplasia
3	Osteosarcoma	RLL	6	5	Osteosarcoma, metastatic
4	Gastric cancer	RML	7	0	Caseating granuloma
5	Thyroid cancer	LUL	4	5	Follicular cancer, metastatic
6	Bilateral nodules	LUL	10	10	Sarcoma, metastatic
7	Osteosarcoma	LLL	15	10	Osteosarcoma, metastatic
8	Lung cancer	LLL	16	11	Bronchoalveolar cancer
9	Choriocarcinoma	RLL	*	*	Choriocarcinoma, metastatic
10	Lung nodules	RUL	19	5	Bronchoalveolar cancer
11	Lung nodules	RML	14	7	Bronchoalveolar cancer
12	Solitary lung nodule	RML	8	5	Squamous cell cancer, metastatic
13	Solitary lung nodule	LLL	4	2	Interstitial fibrosis
14	Cervical cancer	RUL	4	7	Interstitial fibrosis
15	Esophageal cancer	RLL	15	30	SCC, primary
16	Renal cell cancer	LUL	8	9	Renal cell cancer, metastatic
17	Cyclic hemoptysis	LLL	26	12	Endometriosis
18	Colon cancer	RUL	2	7	Chronic inflammation and fibrosis
19	Colon cancer	RLL	13	20	Adenocarcinoma, metastatic
20	BLL nodules	RLL	4	2	Cryptococcosis
21	Renal cell cancer	RLL	6	9	Cryptococcosis
22	Radio-opaque foreign body	RUL	14	4.4	Metallic foreign body
23	Tongue cancer	RML	4	20	Old granuloma
24	Lung cancer	LLL	12	1.4	Hemangioma
25	Urinary bladder cancer	LUL	8	15	Adenocarcinoma, metastatic
26	Solitary nodule	LUL	19	10	Adenocarcinoma, primary
27	Osteosarcoma	RUL	5	10	Interstitial fibrosis
28	Cyclic hemoptysis	RUL	4	30	Endometriosis
29	Lung cancer	RUL	7	9	Caseating granuloma
30	BLL nodules	LLL	11	5	Noncaseating granuloma
31	Lung cancer	RLL	6	16	Adenocarcinoma, metastatic
32	Lung nodules	RLL	11	7	Caseating granuloma
33	Lung cancer	RLL	9	10	Noncaseating granuloma
34	Hepatocellular carcinoma	RUL	14	7	Hepatocellular cacinoma, metastatic
35	Solitary lung nodule	RML	9.3	8.5	Adenocarcinoma, primary
36	Lung nodules	RLL	10	2	Caseating granuloma
37	A needle	LUL	†	20	A needle
38	A broken needle	LUL	‡	3.8	A broken piece of needle
39	Lung cancer (SCC)	RLL	20	10	Adenocarcinoma, second primary
40	Colon cancer	RLL	7	12	Cryptococcosis
41	Uterine leiomyosarcoma	RML	8	10	Leiomyosarcoma, metastatic
42	Solitary nodule	RLL	7.5	8	Caseating granuloma
43	Rectal cancer	LLL	8.5	17	Adenocarcinoma, metastatic

**This lesion appeared as bead-like nodular thickenings which were difficult to measure individually; †the length of the needle is 30 mm; ‡the length of the broken needle is 9 mm. RUL = right upper lobe; RML = right middle lobe; RLL = right lower lobe; LUL = left upper lobe; LLL = left lower lobe; BLL = bilateral lower lobes; SCC = squamous cell carcinoma.*

Kopans and Hawkins II simple hook wires,[18,19] Mammorep J-hook wire,[20] cork-screw (or circular) wire,[21] spiral wire[17] and custom-made double-coil and cloverleaf wire.[22] The double-thorn hook wire used in our series was initially reported by Yeow et al.[10] The advantage of the double-thorn mammographic hook wire over other hook wires is a wider anchorage of lung adjacent to the focal lung lesion. Its ability to be repositioned if needed is superior to simple hook wire. The double-thorn hook wire applied in our series had promising results.

Our mean procedure time for VATS after preoperative hook wire localization was 103 minutes (range, 44–198 minutes) because of an extreme case of severe pleural adhesion that prolonged VATS operation time to 198 minutes. One series reported that the VATS procedure time was significantly shortened from 180 minutes without preoperative localization to around 90 minutes with preoperative localization.[23]

It has been recommended that preoperative localization should be performed for small (≤ 10 mm) indeterminate subpleural (≥ 5 mm) pulmonary nodules.[3] The rate of unsuccessful localization by VATS requiring conversion to open thoracotomy dropped from 17% without to 7.5% with preoperative localization.[13] Furthermore, our experience suggests that the indications for preoperative localization of lung nodules may be expanded to include foreign body removal (needles, penetrating metallic foreign body) or non-solid parenchymal lesions such as endometriosis. This low-risk procedure may be used when the thoracic surgeon feels insecure in resecting the targeted lung lesions. Reports have also included peripheral or subpleural lung lesions as deep as 2.5–3.0 cm for preoperative localization for VATS;[11,12,24] we suggest deeper lesions requiring a wider resection should be discouraged.

Complications of CT-guided hook wire insertion in our series included 18.6% (8/43) pneumothorax, 16.3% (7/43) bleeding and 7% (3/43) hook wire dislodgment. All of the pneumothoraces were minimal and asymptomatic (pleural surfaces were < 10 mm from chest wall), and were only visible on CT performed at the end of the procedure. None of these patients required immediate treatment. Our pneumothorax rate is within the range of 18.2–35.3% reported by others.[17,21,25–27] Localized hemorrhage occurred in seven of our CT-guided hook wire localization procedures (7 of 43, 16.3%). Six of these were minimal hemorrhages that were noticeable only on immediate CT, and no hemoptysis was actually noted. However, one accidental puncture of the intercostal artery resulted in 100 mL of hemothorax. This small hemothorax was detected on hook wire removal after complete wedge resection. The bleeder was successful cauterized and there was no drop in blood pressure. The intercostal artery located at the inferior margin of the rib may be avoided by proper needle path insertion. Other than the above mispuncture of the intercostal artery, our hemorrhage rate is within the range of 0–35.3% reported in the literature.[24–26] However, all of our cases of so-called "bleeding" were detected only by CT as increased opacities around the hooks or along the needle paths. Three hook wire dislodgments occurred in 7% of our cases, while two of the three non-visible small subpleural lung lesions were fortunately localized by the blood stain or air leak from the pleural punctures. This incidence is within the 8–20% range reported in the literature.[19,23,28] One hook wire dislodgment occurred because the gauze dressings covering the externalized segment of hook wire was not released during tested one-lung ventilation by the anesthesiologist.[23] Other factors related to hook wire dislodgment are poor anchorage of hook wire deployed within aerated lung without piercing the lung nodule, direct fixation of the externalized portion of hook wire by adhesive tape hindering wire from free sliding during patient's normal respiration, and migration of the hook wire during patient transportation to the operating room.[12] It is recommended that the lung nodule be penetrated during hook wire insertion, otherwise the hook wire should be deployed more than 2 cm deep, as a shallow subpleural position may predispose to dislodgment.[24]

In conclusion, preoperative hook wire localization of a peripheral focal lung lesion may help precise lesion identification, and serve as a traction device to lift up the lung for wedge resection. In addition, a third thoracoscopic trocar access may be avoided during VATS. The possible complications related to preoperative hook wire localization is low.

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