

Needlescopy-assisted resection of pulmonary nodule after dual localization

Running head: Use of needlescopy for pulmonary nodule

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ABSTRACT: The aim of this study was to evaluate the feasibility of dual localization with hookwire and lipiodol before needlescopy-assisted resection for pulmonary nodule.

Computed tomography-guided dual marking was performed on 36 pulmonary nodules of 32 patients and needlescopy-assisted resection was performed monitored by C-arm fluoroscopy.

The mean age of the patients was 58 ± 12 years (range, 12-77 years). The mean size of the nodules was 7.5 ± 3.7 mm (range, 3-17 mm). Their mean distance from the pleural surface was 7.3 ± 7.5 mm (range, 0-35 mm). There were 9 pure ground glass opacity lesions, 5 semisolid lesions and 22 solid lesions. The time of the dual localization procedure was 13.1 ± 4.8 (range 7-23) minutes. Complications of the marking were pneumothorax in 9 patients, and intrapulmonary bleeding in 3. One hookwire dislodged during the operation. All nodules were successfully resected under needlescopy without conversion to a conventional thoracoscopy (5 mm or 10 mm thoracoscopy) or a minithoracotomy. There was no complication related to needlescopy-assisted resection.

Dual marking with hookwire and lipiodol is safe and no time consuming procedure, and needlescopy-assisted lung resection for small nodules is a technically feasible and useful for histologic diagnosis and treatment.

INTRODUCTION

Because of the development of computed tomography (CT) and the more widespread use of chest CT in health screens, small peripheral pulmonary nodules which could not be detected by conventional radiography, or ground-glass opacity (GGO) lesions that require an exact diagnosis are detected more frequently. However, because it is not easy to confidently differentiate a benign pulmonary lesion from a malignant one with CT criteria, a histopathologic diagnosis is usually required. Performing a percutaneous or transbronchial biopsy for these lesions is often difficult when the lesion size is ≤ 15 mm, when the lesions are GGO, or when the lesions are located in a site that is difficult for these methods [1]. A surgical open lung biopsy has been considered the gold standard diagnostic modality, generally used as a final option due to its association with substantial morbidity and mortality, even with the advances in surgical technique and postoperative care. However, the frequency of thoracoscopic lung biopsies has increased because it is minimally invasive, results in fewer postoperative complications, and reduces the duration of pleural drainage and the length of the hospital stay. Therefore, thoracoscopic surgical techniques have been used in diagnostic excisional biopsies, as well as in therapeutic resection. Moreover, as thoracoscopic lung biopsy techniques continue to improve, the size of the thoracoscopy has gradually decreased.

Recently, a lung biopsy using a needlescopy (2-mm thoracoscopy) and accompanying instruments has been introduced [2]. The needlescopic lung biopsy which is much less invasive compared with other thoracoscopic procedures may reduce post operative pain, leave minimal scarring, and allow for more rapid recovery [3]. We have previously reported on the possibility of pulmonary nodule resection using a needlescopy [3].

However, successful resection using thoracoscopic biopsy, especially in the case of needlescopy, is difficult with small or deeply situated pulmonary nodules because of the lack of digital palpation. Furthermore, a bronchioloalveolar carcinoma with a GGO finding on CT frequently cannot be palpated or visualized, even in the case of lesions that are located just beneath the visceral pleura [4-8]. Therefore, preoperative localization of these pulmonary lesions is mandatory and various localization techniques have been described, either preoperatively (microcoils, dye, hookwire, lipiodol) [8-12] or intrathoracoscopically (finger palpation, intrathoracoscopic ultrasound, radio-guided surgery) [13, 14]. However, to our knowledge, none of these methods has been widely adopted because of some negative aspects of these techniques during the operation. The hookwire technique allows precise and quick preoperative localization, but has a problem with dislodgement of the hookwire [15-17], air

embolism, and inaccurate resection margins. Lipiodol is safe and inexpensive materials for localization [18], but lesions cannot be quickly detected. So, we have used a combined technique with the mammographic hookwire and lipiodol for needlescopic biopsy to make up for the weak points in the solitary hookwire and lipiodol techniques.

The aim of this study was to evaluate the usefulness of a dual localization technique with hookwire and lipiodol performed under CT-fluoroscopy guidance before needlescopy-assisted lung biopsy.

MATERIALS AND METHODS

Patients

All pulmonary nodules that were potentially difficult to localize during surgery were candidates for the preoperative marking procedure. This procedure was performed when both the radiologists and surgeons thought it might be difficult to find the target lesion by thoracoscopy alone. GGO lesions, small nodules (<10 mm), or lesions situated under the pulmonary parenchymal surface which could not be detected by needlescopy were included in this study.

Between October 2007 and September 2009, CT-guided marking was performed on 44 pulmonary nodules in 40 patients (23 males, 17 females). Of these, lipiodol marking

alone was performed in four patients because they were too close to the diaphragm to localize with a hookwire, and another four patients who were not suitable for the needlescopy-assisted procedure because of pleural adhesions, were excluded. Ultimately, 32 patients with 36 nodules were enrolled in the present study.

The patients were divided into two groups according to the objectives of operation (tissue diagnosis or curative surgery). Operations with curative intent were carried out when small lesions were confirmed as hamartoma by preoperative percutaneous needle aspiration biopsy or were strongly suspected to be metastatic lung cancer lesions that could be resected by the thoracoscopic method.

Preoperative localization for pulmonary nodule

Just before surgery, a dual localization was performed under intermittent CT (Brilliance 64, Phillips, Amsterdam, the Netherlands) fluoroscopy guidance by one of three board-certified radiologists experienced in CT guided interventional techniques. After local anesthesia of the thoracic wall, the introducer needle was advanced into the nodule according to the shortest access route, then 0.2 ml of lipiodol contained in a 1 ml syringe was injected at the center of the nodule, and a mammographic hookwire was deployed at the same location (fig. 1). These combined methods were carried out

through one introducer needle after the initial single-puncture. Immediately after the marking procedure, all patients underwent a CT scan to confirm correct positioning of the lipiodol and the hookwire tip, and to determine whether procedure-related complications such as pneumothorax, or hemorrhage had occurred. Then the patients were transported directly to the operation room and underwent an operation.

Operative techniques

As we have previously mentioned [3], needlescopy-assisted surgeries were performed under one-lung anesthesia, using a double-lumen endotracheal tube with three thoracoports (one 11.5-mm port and two 2-mm miniports). Initially, an incision of about 15mm was usually made at the sixth or seventh intercostal space on the anterior axillary line and an 11.5-mm port was inserted through the incision. A 2-mm needlescopy was then introduced into the thoracic cavity through the 11.5-mm port to determine whether any dense adhesions were present and to find the location of the target lesion. If pleural adhesion was observed in the thoracic cavity, the needlescopy-assisted procedure was abandoned. In the remainder, a 2-mm port for 2-mm needlescopy (Hopkins II Forward Oblique-Telescope 0°, Karl-Storz GmbH & Co, Tuttlingen, Germany) was created at the fifth or sixth intercostal space on the

midaxillary line and another 2-mm port was created for a MiniSite Endo Grasp (Covidien, Norwalk, CT, USA) at the fifth or sixth intercostal space on the posterior axillary line. An 11.5-mm port was then used to introduce for an endoscopic linear stapler (Endo-GIA 60, Auto Suture Company Division, United States Surgical Corporation, Norwalk, Conn., or ETH-ECR60D, Ethicon Endo-Surgery, Inc., Cincinnati, Ohio) or for specimen extraction.

For diagnostic procedures or in cases of palmar hyperhidrosis, not requiring specimen retrieval, 2-mm ports were used exclusively. However, for extirpative needlescopic procedures, requiring pulmonary resection using an endoscopic linear stapler and specimen extraction, one 11.5-mm port was permitted; all remaining ports were of 2-mm. No benefit was realized by performing the procedure using only needlescopic instrumentation and making an incision for specimen retrieval at the end of the procedure. Therefore, one 11.5-mm incision was made at the outset of the procedure.

After detecting the hookwire-marked site by needlescopy, the precise site and resection margin of the radiopaque lesion was confirmed under fluoroscopic monitoring in multiple projections and resected with endostaplers (fig. 2). Successful resection of the nodule was finally confirmed by viewing the radiopaque nodule within the resected

specimen under C-arm fluoroscopy (fig. 3). The specimen was histologically diagnosed by a routine intraoperative pathologic examination.

RESULTS

Between October 2007 and September 2009, CT-guided dual marking was performed on 36 pulmonary nodules in 32 patients (18 males, 14 females). The mean age of the patients was 58 ± 12 years (range, 12-77 years). Table 1 shows the characteristics of the nodules.

The mean time for the dual localization procedure was 13.1 ± 4.8 (range 7-23) minutes. Although a small pneumothorax occurred in 9 patients and mild intrapulmonary bleeding was observed in 3 cases, no additional treatment was needed for these complications.

At needlescopy, the hookwire could be easily seen in all cases and was a great help in locating the target lesion. Fluoroscopy showed the radiopaque nodules clearly in all cases. One hookwire dislodged during the operation. Nevertheless, lipiodol markings seen on fluoroscopy guided a successful wedge resection without difficulty. All nodules were successfully resected under needlescopy without conversion to a conventional thoracoscopy (5 mm or 10 mm thoracoscopy) or a minithoracotomy.

Table 2 shows the postoperative diagnoses of the localized lesions and details further surgical treatments. Twenty four nodules were resected for tissue diagnosis and 12 were resected with curative intent. After examining intraoperative frozen sections of the localized lesions, 9 patients underwent thoracoscopic lobectomy, and one patient underwent thoracoscopic thymectomy. Subtotal gastrectomy was performed in one patient 7 days after needlescopic wedge resection.

The margins of the resected specimen were adequate and negative in 33 cases. The mean distance from the resected margin to the lesion was 4.9 ± 4.5 mm (range, 0-15 mm). Additional wedge resection was needed in three cases and negative resection margins were achieved in all three cases.

There was no complication related to needlescopy-assisted resection. With the exception of 3 patients who required an additional wedge resection and 10 patients who underwent a further procedure (1 thymectomy, 9 lobectomies), the mean operation time was 34.4 ± 14.7 minutes (range, 18-75 minutes), and the mean duration of the indwelling chest tube was 2.2 ± 0.73 days (range, 1-4 days).

DISCUSSION

Needlescopic procedure was defined as surgery using needlescopic instruments that have a diameter of less than 3 mm [19]. In thoracic procedures, this surgical technique had initially been applied mainly to diagnostic thoracoscopy [20], thoracic sympathectomy for palmar hyperhidrosis [21], and laser ablation for spontaneous pneumothorax [22]. Recently, lung biopsies for interstitial lung disease and pulmonary resections for indeterminate pulmonary nodules have been introduced [3, 23].

Needlescopic lung surgery is much less invasive compared with more conventional procedures and is technically feasible and safe [3]. Furthermore, needlescopic lung resection seems to result in less postoperative pain and scarring than conventional thoracoscopy. Accordingly, the appropriate use of 2-mm instrumentation is likely to enhance patient satisfaction by minimizing incision-related morbidities and improving cosmesis.

However, it is very difficult to grasp the lung firmly with the mini-forceps because of its short jaws and poor holding strength, and the lung was easily injured when the lesion had been grasped. For these reasons, a localization method which was different from conventional thoracoscopic methods was needed.

Conventional thoracoscopic resection of small peripheral pulmonary nodules by digital palpation is both straightforward and rapid when a nodule is in contact with the

pleural surface. On the contrary, when a nodule is too small or deep to the pleural surface, digital palpation may not be possible and this may result in conversion to open surgery. And this appears to be more frequent if the distance between the nodule and the nearest pleural surface is more than 5 mm and when nodule is 10 mm or less in size [24]. Furthermore, because ground-glass opacity (GGO) lesions cannot usually be palpated or visualized during surgery regardless of lesion size or depth, localization by digital palpation is not possible, and thus, several marking techniques have been developed for the preoperative and intraoperative localizations of these lesions.

In our institution, the hookwire method was initially used in needlescopy-assisted surgeries in order to detect the lesions quickly and reduce lung injury by using the hookwire, instead of the lung surface, as the grasping portion.

However, excessive traction on the grasped hookwire to ensure the resection margin caused hookwire dislodgement, making it very difficult to detect and resect pulmonary lesions. In addition, even though the resection margin was negative, it is still difficult to maintain a proper resection margin (≥ 10 mm or double lengths of tumor itself) with the single hookwire method in the case of malignant diseases.

For these reasons, a dual localization method with hookwire and lipiodol was thought to be needed in needlescopy-assisted pulmonary resection.

The marking procedure with lipiodol has the following advantages: (1) overresection of the normal lung tissue around the nodules is prevented because lipiodol marks the nodules as clear spots that are less than 1 cm in size during fluoroscopy; (2) the lipiodol remains up to 3 months after the marking, which solves the problem of requiring both a CT and the operating room simultaneously; (3) although the barium marking procedure affects pathologic findings caused by the inflammatory response and barium itself, lipiodol did not affect the pathologic findings; and (4) even in the case of deeply situated nodules, the lipiodol marking could easily localize the nodules as a clear spot because it diffused only to a small extent [18]. Because of these advantages, lipiodol was chosen as the dual marking material.

Although the dual localization method was used in needlescopy-assisted surgery, the margins of the resected specimen were positive in three cases in this study. This result was thought to be caused by an old model of C-arm fluoroscopic equipment which was not good at identifying the lipiodol marking accurately. After the old model of C-arm fluoroscopy was changed for a new one, all margins of the resected specimen were adequate and negative in 13 cases. Furthermore, after first resection, because the stapled site of the lung was used as the grasp site, we could perform an additional

wedge resection safely without lung injury and achieve a negative resection margin in all three cases.

The mean time for the dual localization procedure was 13.1 ± 4.8 (range 7-23) minutes and minimal complications were observed in 12 (33.3%) cases. Before the dual marking procedure, the hookwire method was performed in eight cases in our institution. The mean time for the hookwire localization was 9.1 ± 3.8 min and 2 (25.0%) complications (1 pneumothorax, 1 hemothorax) occurred. Although the mean time for the dual marking procedure was thought to be longer than the hookwire, statistically, there was no significant difference in localization time ($p=0.06$) and complication rate ($p=0.50$) between the two localization methods.

There were further procedures performed in 11 cases (9 lobectomies, 1 gastrectomy, 1 thymectomy) according to the intraoperative frozen section reports after needlescopy-assisted lung resection. The rest of these cases did not need further surgical treatment because the pulmonary lesions were confirmed as benign or properly resected for treatment, and these patients could quickly recover and be discharged. We thought that needlescopy-assisted lung resection for undetermined nodules or GGO lesions under the dual marking procedure was effective in obtaining a histologic diagnosis compared with

conventional thoracoscopy. To the best of our knowledge, no previous reports have described this combined method, especially under needlescopy-assisted lung resection.

In conclusion, the combined method of mammographic hookwire anchoring and lipiodol injection under CT fluoroscopy is safe and not time-consuming, and needlescopy-assisted lung resection for small nodules or GGO lesions is effective for histologic diagnosis and treatment in some cases. Importantly, this technique has now made it possible both to detect small pulmonary lesions quickly without lung injury and to evaluate whether the lines of resection will achieve the required margins for pulmonary lesions under needlescopic lung resection.

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TABLE 1 Characteristics of the pulmonary nodules

Location (No.)	
Right upper lobe	9
Right middle lobe	9
Right lower lobe	6
Left upper lobe	6
Left lower lobe	6
CT findings (No.)	
Pure GGO	9
Semisolid	5
Solid	22
Mean size (mm)	7.5±3.7 (range, 3-17)
Distance from the pleura to superficial depth (mm)	7.3±7.5 (range, 0-35)

CT: computer tomography; GGO: ground glass opacity.

TABLE 2 Surgical objectives, postoperative diagnoses, and further treatments

Objectives (No.)	Postoperative diagnosis (No.)	Further treatment (No.)
Tissue diagnosis (24)	Primary lung cancer (4)	Lobectomy (9)
	Lung cancer metastasis (3)	Thymectomy (1)
	Anthracotic nodule (6)	Gastrectomy (1)
	Intrapulmonary lymph node (4)	
	Pulmonary rheumatoid nodule (2)	
	Organizing pneumonia (2)	
	Papillary adenoma (1)	
	Atypical adenomatous hyperplasia (1)	
Curative intent (12)	Tuberculosis granuloma (1)	
	Metastatic lung cancer (8)	
	Intrapulmonary lymph node (2)	
Total	Chondroid hamartoma (2)	
	36	11

Fig 1

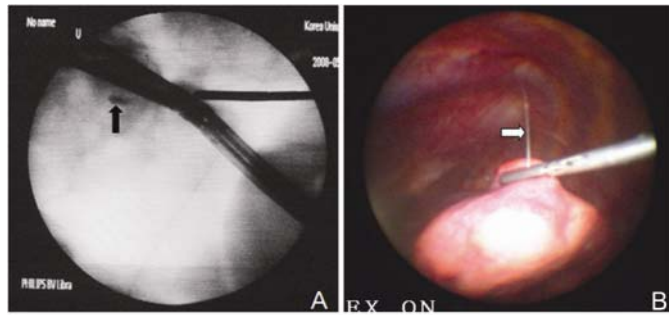


Fig 2

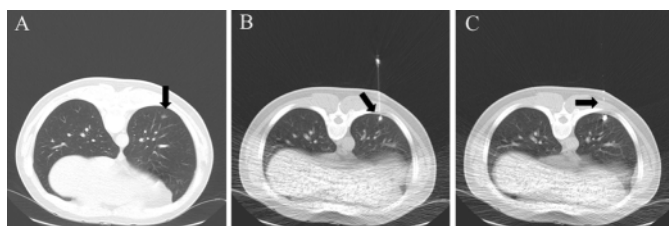


Fig 3

