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Original Article

Thoracoscopic Localization of Small Peripheral Pulmonary Lesions Using Percutaneous Computed Tomography-guided Pleural Dye Marking: A Retrospective Analysis

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Small pulmonary lesions are often difficult to localize during thoracoscopic surgery. We describe a new computed tomography (CT)-guided pleural dye-marking method for small peripheral pulmonary lesions that does not involve a visceral pleural puncture. We used this technique for 23 lesions (22 patients) who underwent thoracoscopic partial lung resection (Nov. 2016-Jan. 2018). With the patient in the lateral decubitus position, preoperative CT-guided marking on the skin over the lesion was performed. During the surgery, we marked the visceral pleura with a skin marker directly or with an infant-size nutrition catheter with crystal violet at the tip through a venous indwelling needle inserted perpendicular to the skin marking. We localized and resected the lesions in all cases, without complications. The median nodule size measured histopathologically was 8 (4-20) mm overall, and 7 (0-20) mm of the solid part; the median distance from the visceral pleura to the nodule was 9 (1-33) mm. The median operation time was 67 (37-180) min. The median postoperative hospital stay was 3 (3-11) days. Our CT-guided pleural dye-marking method is useful and safe for the localization of small peripheral pulmonary lesions in thoracoscopic partial lung resections.

Key words: Small pulmonary lesion, ground glass nodule, marking, localization, thoracocentesis

Technological advances in computed tomography (CT) have made it easier to detect smaller-sized pulmonary lesions and ground-glass nodules (GGNs) [1]. As a diagnostic and curative intervention for these lesions with minimal invasion, sublobar resection by video-assisted thoracoscopic surgery has been recognized as being useful [2,3]. Especially in partial lung resections, the localization of lesions is definitely important; however, it is often extremely difficult to identify the location(s) of small lesion(s) via small incisions. Various preoperative marking techniques for the localization of such pulmonary lesions have been devised, and the usability and safety of these methods have been described [4-10].

Approaches to such marking can be classified into the percutaneous approach and the transbronchial approach. Marking methods by the percutaneous approach include the CT-guided placement of point markers (*e.g.*, hook wires or coils) and the injection of dyes or contrast media. Complications associated with visceral pleural puncture in this approach have been reported, including pneumothorax, hemothorax, intrapulmonary hematoma, pleural dissemination,

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needle-tract implantation, and air embolism [4]. An air embolism in particular must be carefully avoided, as it is associated with the potential for serious sequelae and mortality. This catastrophic complication is very rare, but it has been reported in cases in which hook wires were used for the CT-guided marking of lesions [11, 12].

Although marking methods using the transbronchial approach are considered less invasive than those employing the percutaneous approach, they require more manpower, specialized equipment, and techniques for accuracy such as CT fluoroscopy or three-dimensional (3D) imaging [5-7]. We have developed a new CT-guided marking method that does not involve a visceral pleural puncture, and this advantage mitigates the risk of complications associated with a visceral pleural puncture. The new technique enables the easy marking of multiple points without the need for any special equipment. Herein we describe the procedure, feasibility, and reliability of our percutaneous CT-guided pleural dye marking method, based on our retrospective analysis of 22 patients' cases.

Patients and Methods

Study population. From November 2016 to January 2018, 22 patients with 23 small-sized peripheral pulmonary lesions (including 1 patient with 2 lesions in the same lobe) underwent percutaneous CT-guided marking followed by partial lung resection under complete video-assisted thoracoscopic surgery at our hospital. It had been suspected that the patients' lesions would be difficult to identify intraoperatively during thoracoscopic surgery, as they included small-sized lesions with the solid part measuring < 10 mm in dia., deeply located nodules, and pure GGNs without pleural changes; in addition, all cases were located in the outer one-third of the lung field, and the maximum tumor dias. were ≤ 30 mm. We also included some patients with primary lung cancer in whom a lobectomy/segmentectomy had to be avoided because of the patients' advanced age, comorbidities, or inadequate residual pulmonary function. The patients' data were retrospectively collected. This study was conducted in accordance with the amended Declaration of Helsinki, and written informed consent for their data to be used was obtained from all patients. Our institutional review board approved the study (approval no. 0192).

Procedure for preoperative CT-guided marking. The CT-guided marking was performed on the day before the surgery (Fig. 1). The patient was placed on the CT examination table in the lateral decubitus position, as the actual operative position. Scaled metal wires were set on the patient around the marking site. Chest CT was performed at the maximal expiratory level, and then we put an "X" mark on the appropriate site of the skin surface with a permanent marker pen and sealed the mark with a piece of waterproof tape. When a patient's tumor(s) were located near the pulmonary ligament or on the bases of the lung, we performed markings in 2 places on the visceral pleura at equal distances from the tumor so that the tumor could be detected on the perpendicular bisector. When tumors were located near the pericardium or the descending aorta, we performed markings at two places at the same axial level as that of the lesion on CT; one at some distance from the visceral pleura just above the tumor, and the other at twice the distance from the first mark. We can detect tumors on the straight-line between the 2 points.

Procedure for intraoperative marking on the lung surface. All surgeries were completed under thoracoscopic guidance alone, with the patient placed in a lateral decubitus position under general anesthesia and one-lung ventilation with a double-lumen endobronchial tube. We used 2 different methods of marking depending on whether or not the incision could be made at the site of the surface marking.

When the incision could be made at the site of the surface marking, we began to make the first port under double-lung ventilation. To avoid injury to the visceral pleura, we incised the parietal pleura using Metzenbaum scissors by lifting the pleura up with a pair of forceps. We then directly marked the surface of the visceral pleura with a surgical skin marker (Method-1, Fig. 2).

When we could not make the incision at the surface marking site indicating the tumor location (*e.g.*, in cases where the tumor location was around the apex, close to the diaphragm, or on the mediastinal side), we used Method-2. In these cases, after creating a camera port under one-lung ventilation, we punctured the chest wall with a venous indwelling needle at the site of the marking and left the outer plastic tube of the needle at the site. Then, with full expansion of the lung under double-lung ventilation, we inserted an infant-size nutri-

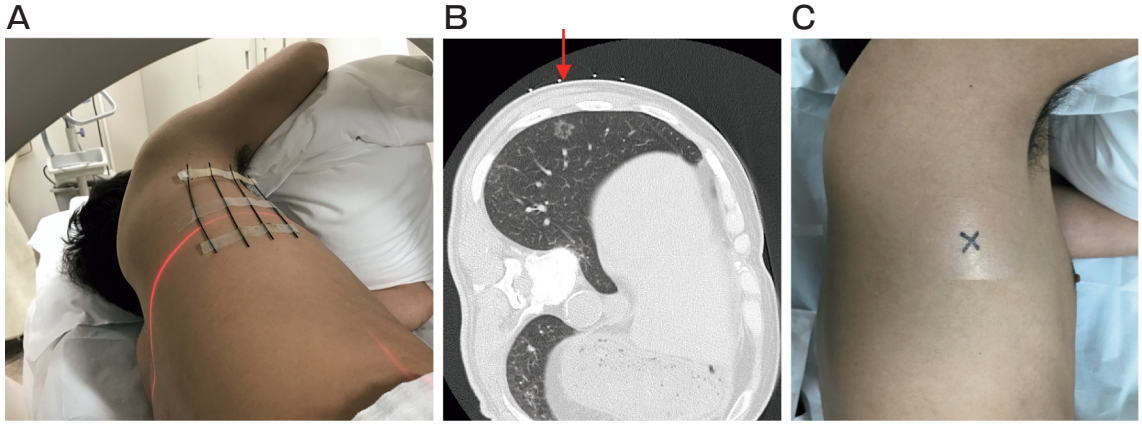

Fig. 1 A, B, A chest CT at the maximal expiratory level is conducted with the patient in the lateral decubitus position on the day before the surgery; C, Putting "X" marks on the body surface with a marker pen.

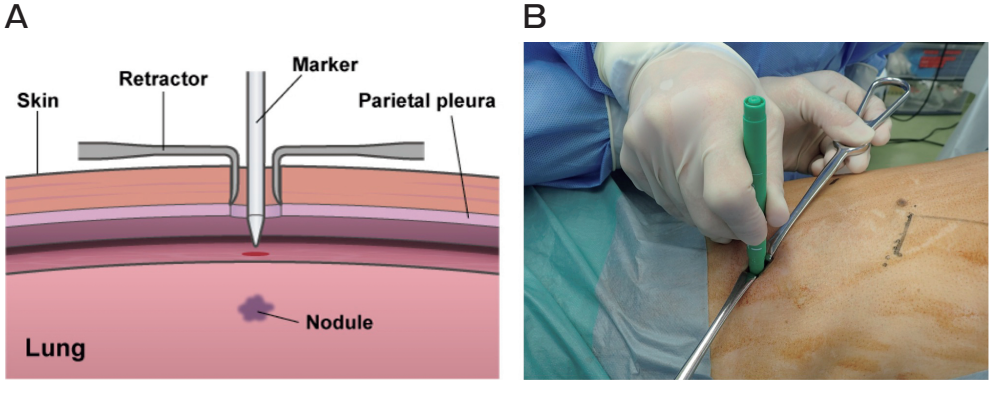

Fig. 2 Method-1. A, B, creating the 1st incision just above the marking site, and Marking directly on the surface of the visceral pleura in both-lung ventilation with a marker pen.

tion catheter with crystal violet at its tip, and marked the surface of the visceral pleura (Method-2, Fig. 3).

Operative technique for lung resection. The operative technique for lung resection involved the creation of 3 thoracic ports; one for the ring-shaped grasping forceps, the second for the endoscopic stapler device, and the third for the introduction of the thoracoscope. In all cases, we localized the tumor(s) by finger palpation with the aid of the markings on the surface of the visceral pleura. If necessary, we expanded the skin incision for effective finger palpation. Each thoracoscopic partial lung resection was performed with a surgical safety margin using an endoscopic stapler under thoracoscopic guidance. To confirm the inclusion of the culprit lesion in the resected lung and that the surgical margin was adequate, the resected lung was cut and the specimen was immediately sent for histopathology.

Results

During the study period, all 23 of the lesions in the 22 patients could be marked based on the CT images prior to the surgery. The patient characteristics are summarized in Table 1. The patient series was 12 males (54.5%) and 10 females (45.5%); median age, 73 (59-89) years; median size of the nodules as measured on preoperative CT images, 11 (3-23) mm overall, and 9 (0-22) mm of the solid part; median distance from the visceral pleura to the nodule, 9 (1-33) mm.

All 23 of the lesions were successfully localized by palpation using the marking, and each thoracoscopic partial lung resection was performed without any complications. In addition, all of the lesions were included

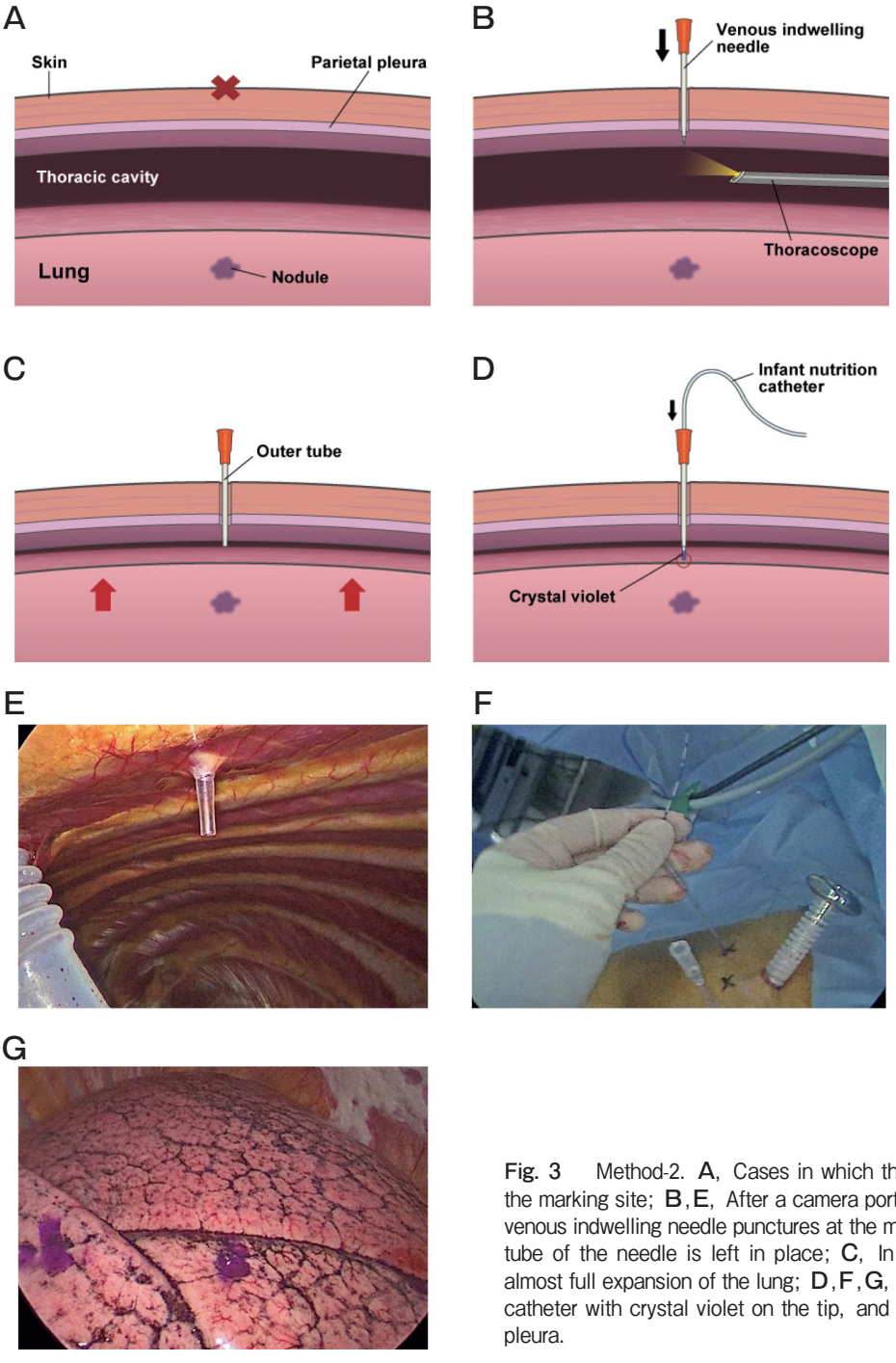

Fig. 3 Method-2. A, Cases in which the incision cannot be made just above the marking site; B, E, After a camera port is created in one-lung ventilation, the venous indwelling needle punctures at the marking point, and only the outer plastic tube of the needle is left in place; C, In both-lung ventilation, waiting for the almost full expansion of the lung; D, F, G, The insertion of an infant-size nutrition catheter with crystal violet on the tip, and marking on the surface of the visceral pleura.

in the initial partial lung resection as confirmed by an intraoperative histopathological examination, and there were no cases that needed additional resection. The postoperative results are summarized in Table 2. Eleven (47.8%) of the 23 lesions were diagnosed as primary lung cancer; the median size of the nodules as measured at the histopathological examination was 8 (4-20) mm overall, and 7 (0-20) mm of the solid part; the median operation time was 67 (37-180) min; the median size of the maximum incision was 30 (20-50) mm; and

Table 1 Patient characteristics

Variables	Values
Number of patients/lesions, n	22/23
Age, median years (range)	73 (59–89)
Gender, n (%)	
Male	12 (54.5)
Female	10 (45.5)
Clinical diagnosis, n (%)	
Lung cancer	15 (65.2)
Metastatic lung tumor	7 (30.4)
Colorectal cancer	2 (8.7)
Renal cell carcinoma	1 (4.3)
Urothelial cell carcinoma	1 (4.3)
Breast cancer	1 (4.3)
Epithelial myoepithelial carcinoma	1 (4.3)
Unknown primary	1 (4.3)
Cryptococcosis	1 (4.3)
Location, n (%)	
Right	12 (52.2)
Upper lobe	8 (34.8)
Middle lobe	0 (0)
Lower lobe	4 (17.4)
Left	11 (47.8)
Upper lobe	5 (21.7)
Lower lobe	6 (26.1)
Nodule type, n (%)	
Solid nodule	15 (65.2)
Part-solid nodule	5 (21.7)
Pure ground glass nodule	3 (13.1)
Pre-operative nodule size, median mm (range)	
Total	11 (3–23)
Solid part	9 (0–22)
Distance from pleura, median mm (range)	9 (1–33)

Table 2 Post-operative results

Variables	Values
Pathological diagnosis, n (%)	
Lung cancer	11 (47.8)
Adenocarcinoma	7 (30.4)
Squamous cell carcinoma	2 (8.7)
Non-mucinous bronchioloalveolar carcinoma	1 (4.3)
Adenocarcinoma in situ	1 (4.3)
Metastatic lung tumor	9 (39.1)
Colorectal cancer	2 (8.7)
Hepatocellular carcinoma	2 (8.7)
Renal cell carcinoma	1 (4.3)
Urothelial cell carcinoma	1 (4.3)
Thyroid cancer	1 (4.3)
Breast cancer	1 (4.3)
Epithelial myoepithelial carcinoma	1 (4.3)
Benign nodule	3 (13.0)
Cryptococcosis	1 (4.3)
Intrapulmonary lymph node	1 (4.3)
Fibrosis	1 (4.3)
Post-operative nodule size, median mm (range)	
Total	8 (4–20)
Solid part	7 (0–20)
Operation time, median min (range)	67 (37–180)
Maximum incision, median mm (range)	30 (20–50)
Used method, number of patients (%)	
Method-1 alone	9 (40.9)
Method-2 alone	11 (50.0)
Both Method-1 and Method-2	2 (9.1)
Hospital stay, median days (range)	5 (5–19)
Post-operative hospital stay, median days (range)	3 (3–11)

the median postoperative hospital stay was 3 (3-11) days.

Regarding the number of markings and whether Method-1 or Method-2 was used, Method-1 alone was used in 9 patients, Method-2 alone was used in 11 patients, and both methods were used in 2 patients. Including these 2 patients, a total of 6 patients had undergone multiple markings. The maximum number of marks per patient was 3.

Discussion

The intraoperative localization of small-sized peripheral pulmonary lesions or pure GGNs and a sublobar resection with minimal invasion are important clinical issues, and various marking methods have been reported, including a method that is similar to our new technique: a CT-guided marking method that does not involve a visceral pleural puncture [6-8]. Our method has several advantages compared to the CT-guided placement of hook wires or coils, the injection of dye/contrast media, and various transbronchial approaches.

The most important advantage of our new method is the safety obtained by avoiding a visceral pleural puncture, which is the primary concern in relation to lung marking. In the NAVIGATE study (in which the data of 1,000 patients undergoing electromagnetic navigation bronchoscopy were prospectively evaluated), Khandhar *et al.* reported the occurrence of pneumothorax in 4.9% of the cases and of bronchopulmonary hemorrhage in 1.0%, even with the use of a bronchoscopic approach [9]. Sato *et al.* reported 4 cases of pneumothorax among 380 markings in 100 patients in whom marking was performed by virtual-assisted lung mapping (VAL-MAP), a bronchoscopic multispot dye-marking technique [10].

A second advantage of our new method is that

because the lungs do not collapse with the marking, our method makes it possible to mark multiple sites easily and safely even for a single lesion. When the lesion is too deep, small, or pure (in terms of GGO) to be localized with a single marking, or when it is difficult to mark the visceral pleura just above the lesion, the aid of multiple markings increases the surgeons' confidence in palpation and makes it easier to localize the lesions. A third advantage is that marks on the body surface can be very useful indications for determining the port positions at the start of surgery. In other words, because the tumor location can be realized from the outside, it is easy to develop a surgical strategy and decide the best port positions even before the surgery is begun.

Our new method also has advantages in terms of its availability; no special equipment is necessary (such as metallic coils or hook wires, fluoroscopes, gamma probes, radiotracers, or a 3D CT imaging system); only one surgeon and one radiological technologist are required, and the operators are not exposed to radiation at all, unlike several other CT-guided or bronchoscopic methods.

These advantages can also be said of the methods described by Sekimura *et al.* and Miyoshi *et al.* [7, 8]. The benefit of our new technique is that it enables the creation of the markings as dots without the markings getting blurred or being put on unexpected places, because we do not insert a dye marker until the lungs have fully expanded. Our point-like marks may enable geometric applications of multiple marking, *e.g.*, doubling the distance between the two marking points on the line passing through the points.

However, our method also has some disadvantages. First, the risk of an injury to an intercostal artery or a nerve, or a puncture-site infection caused by puncturing the chest wall during the operation should be mentioned. The possibility of these complications can be considerably reduced by performing the puncture under thoracoscopic observation from the inside of the thoracic cavity. Second, the markings are considered merely guides to make it easier to identify the tumor location, and thus localization of the tumors by finger palpation should be conducted before the lung resection, unlike the hook-wire and metal-coil methods. Even if the actual marking locations have moved from their expected places, they are useful for determining the port positions at the start of surgery, and they also serve as highly effective indicators for localizing tumors by finger palpation.

Third, the difficulty of the marking procedure could increase depending on the tumor location compared to marking via the transbronchial approach. In such difficult cases, it is necessary to detect the tumor in an indirect way using multiple markings. Fourth, abnormal findings of the pleural surface, *e.g.*, adhesions, calcification, thickening, or anthracosis make it difficult to find the markings on the visceral pleura.

This study also has several limitations. The study had a retrospective observational design and was conducted at a single institution with a relatively small population and no comparison group. Only one patient had multiple lesions, and we therefore cannot discuss the utility of our method for such multiple lesions. In addition, if the lesions are not palpable and cannot be localized with our method, conversion to an open approach or a change in the surgical procedure to anatomical resection (such as segmentectomy) would have to be considered.

In conclusion, as a new marking method for identifying small peripheral pulmonary lesions, we devised a simple percutaneous CT-guided pleural marking method that does not involve a visceral pleural puncture. This method is useful and safe for the localization of such lesions, especially for patients who will undergo a partial lung resection under thoracoscopic surgery.

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