Original Article

A convenient method for identifying a small pulmonary nodule using a dyed swab and geometric mapping

Mitsuhiro Kamiyoshihara, Takashi Ibe, Natsuko Kawatani, Fumi Ohsawa, Ryohei Yoshikawa, Kimihiro Shimizu

Department of General Thoracic Surgery, Maebashi Red Cross Hospital, Maebashi, Japan

Contributions: (I) Conception and design: M Kamiyoshihara; (II) Administrative support: None; (III) Provision of study materials or patients: M Kamiyoshihara; (IV) Collection and assembly of data: T Ibe, N Kawatani, F Ohsawa, R Yoshikawa; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Dr. Mitsuhiro Kamiyoshihara. Department of General Thoracic Surgery, Maebashi Red Cross Hospital, 3-21-36 Asahi-Cho, Maebashi, Gunma 371-0014, Japan. Email: micha2005jp@yahoo.co.jp.

Background: Computed tomography (CT)—guided lung needle marking is useful to identify pulmonary nodules. However, certain complications sometimes trigger severe after-effects or death. So, we present a convenient and safe method by which small pulmonary nodules can be identified using a particular dye [2% (w/v) gentian violet].

Methods: A patient is initially placed in the lateral operative position. Under CT guidance, a "magic marker" is used to identify the skin above the pulmonary nodule. During the operation, the chest wall is punctured on that mark using a needle loop retractor (Mini Loop Retractor II). A swab saturated in the dye solution is attached to a silk thread and passed through the loop. The loop and string are subsequently retracted. The dye-stamp is apparent on the lung surface above the nodule after the lung is inflated. If the scapula, any vertebra, or the clavicle compromised access to a nodule, we used our geometric technique to locate that nodule.

Results: We used this technique to treat 51 lesions of 50 patients presenting from 2013 to 2015. Mean tumor diameter was 7 mm. All lesions were identified via thoracoscopy, all nodules were constrained by ring forceps, and wedge resections were performed using a stapler. All lesions lay very close to the staple markings, as judged by finger or instrument palpation. No complications were encountered.

Conclusions: The advantages of our technique are that it is simple and easy, air emboli are not an issue, the skin marking is rapid, safety is assured, and the skin marking does not require hospitalization. Our method is also useful such as following situations; it defines the margins of the cut line upon anatomical segmentectomy, indicates where a skin incision is required, and identifies impalpable nodules, which aids the lung resection but provides frozen sections to the pathologist.

Keywords: Computed tomography; preoperative management; small pulmonary nodule; thoracoscopic surgery

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Introduction

Various marking techniques have been developed because of the difficulty in finding small-sized peripheral lung lesions during video-assisted thoracic surgery. In particular, computed tomography (CT)—guided lung needle marking is useful for identifying pulmonary nodules. However, complications sometimes cause severe after-effects or death, such as pneumothorax, intrapulmonary hematoma, hemothorax, and air embolism (1-5). Therefore, we developed a new CT-guided marking method that only requires a mark to be made with a magic marker on the

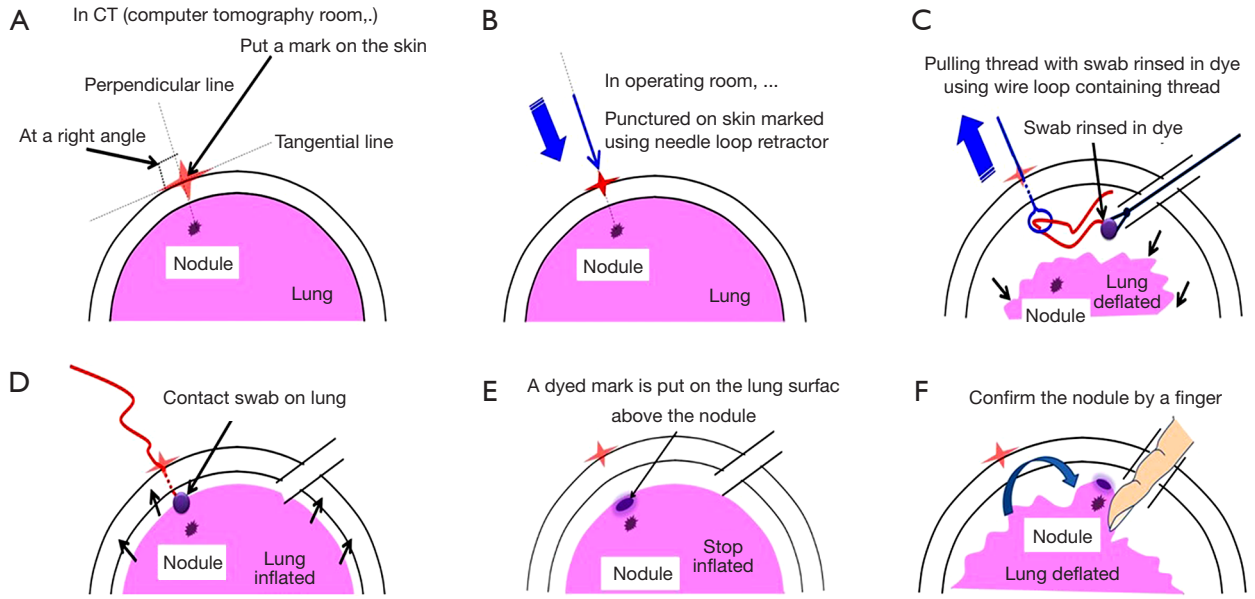

Figure 1 Photographs of the method used to identify a small pulmonary nodule using a dye swab. (A) A mark was placed on the body surface with a magic marker across a perpendicular line to the pulmonary nodule under computed tomography (CT) guidance; (B) in the operating room, a needle with a looped wire on the inner needle was placed on the marked skin; (C) a thread with the dye swab was passed to the looped wire in the pleural space, and the looped wire was removed; (D) the lung was inflated; (E) consequently, the lung was deflated, and the dye marked the lung surface above the nodule; (F) the nodule was confirmed by finger palpation through a port.

body surface—and no thoracocentesis—and we identify small pulmonary nodules using gentian violet solution (triphenylmethane; Pyoctanin®) dye during the surgery. Additionally, we use a geometrically modified technique to identify the difficult location of the pulmonary nodule. Our method is so safe and easy that we have been applying it to locate the skin incision and confirm the margin for segmentectomy and the nodule in the frozen section.

Methods

This technique was performed on 51 lesions in 50 patients (22 males and 28 females) from September 2013 to December 2015. This study was waived by the Institutional Review Board of Maebashi Red Cross Hospital because of non-invasive method.

Technique (*Figures 1,2*)

(I) Angiographic catheters were cut to about 15 cm in length, arranged in 12 rows 1 cm apart, and placed on the body surface as a marking device (*Figure 3A*). These materials did not produce a metal artifact;

(II) The patient was placed on the CT table, in the same manner as they would be positioned on the operating table, to draw a mark on the skin above the pulmonary nodule. A mark was placed with a magic marker on the body surface across a perpendicular line to the pulmonary nodule under CT guidance (*Figure 3B*);

(III) We placed the mark on a bisected or trisected line when the nodule cannot be reached from the body surface (such as the apical portion, near the mediastinal and diaphragmatic surfaces, or behind the scapulae; *Figure 4*). We call this the "the geometrically modified technique";

(IV) The patient was intubated in the operating room with a double lumen endobronchial tube to allow unilateral ventilation. After administering general anesthesia, the patient was placed in the lateral position, so the marking site was exposed;

(V) A needle with a loop wire on the inner needle (Mini Loop Retractor II; Tyco Healthcare Japan, Tokyo, Japan) was placed on the marked skin. A thread with a small swab rinsed in 2% gentian violet solution was passed to the wire loop in the pleural space;

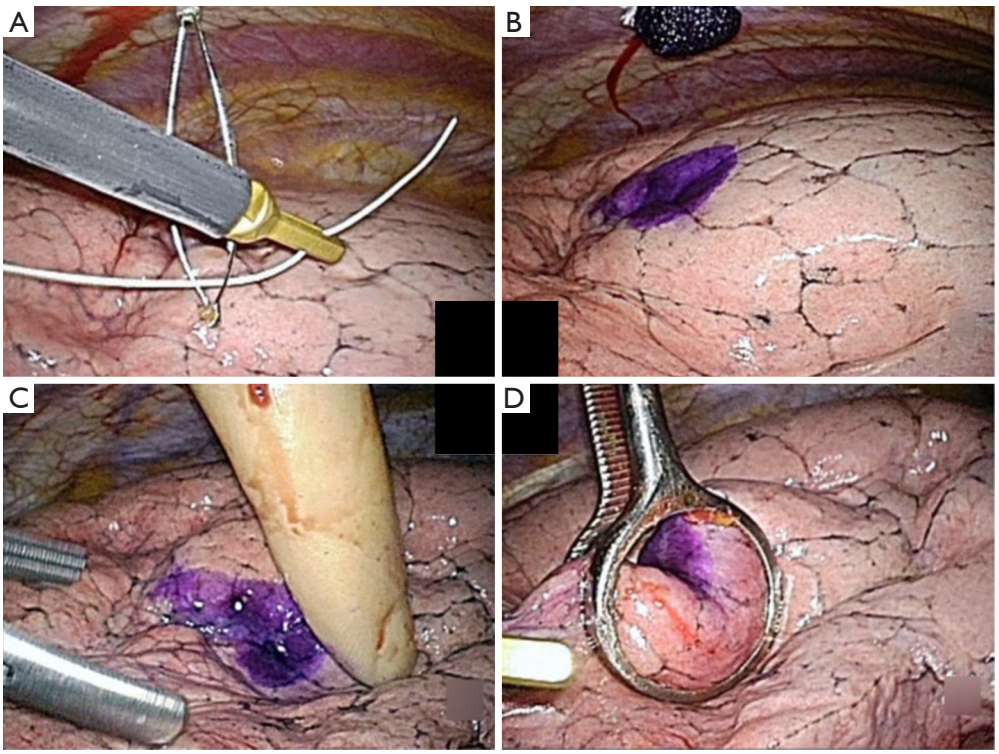

Figure 2 Photographs of the method used to identify a small pulmonary nodule using a dye swab. (A) Corresponding to *Figure 1C*; (B) corresponding to *Figure 1E*; (C) corresponding to *Figure 1F*; (D) The nodule was held using ring forceps.

(VI) The wire loop with the dye swab was taken out of the pleural space;
(VII) The dye swab was put on the surface of the parietal pleura;
(VIII) Then, the lung was inflated and deflated, and dye marked the lung surface above the nodule by contacting with the dye swab;
(IX) The nodule was confirmed by finger palpation through a port;
(X) The nodule was held using ring forceps, and a wedge resection was performed using a stapler.

Results

Mean patient age was 66.3 years (range: 37–97 years). Mean operating time was 145 min (range: 35–300 min), and mean blood loss was 14 g (range: 0–300 g).

The pulmonary nodules were primary lung cancer in 28, metastatic lung cancer in 15, and benign lung disease in 7 patients. The surgical procedure was a wedge resection in 24, lobectomy in 13, segmentectomy in 10, segmentectomy-segmentectomy in 2, and segmentectomy-wedge resection in 1 patient.

No complications were observed during the marking procedure. The nodules were solid in 29, ground-glass opacity in 13, and partially solid nodules in 9 patients. Mean nodule diameter was 10.9±5.5 mm (range: 2.8–22.6 mm), and mean error distance between the center of the nodule and the visceral pleura was 12.0±9.2 mm (range: 0–35.4 mm) as measured by CT.

All lesions were identified by thoracoscopy. We confirmed the lesions by finger palpation through a surgical port. The stamped marking and finger palpation matched for almost all tumor lesions. The stamped marking was within about 1 cm from the lesion in all cases. The distribution of nodules according to depth, diameter, location, and matching is shown in *Figures 5*,*6*. *Figure 5* shows marking-matching according to lobe. The matching rate was 77.8% in the right upper lobe, 75% in the right middle lobe, 84.6% in the right lower lobe, 84.6% in the left upper lobe, and 58.3% in the left lower lobe. *Figure 6* shows that depth was not associated with diameter during marking-matching. Therefore, matching depended on the location of the pulmonary nodule.

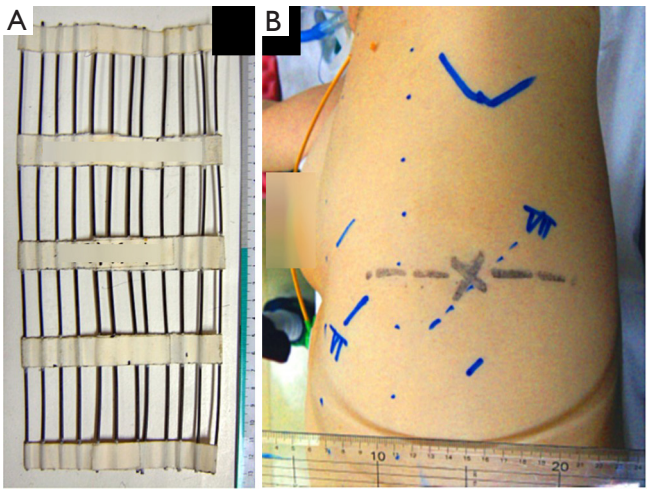

Figure 3 The marker material and the body surface. (A) The marker material was made of angiographic catheters; (B) a black cross mark was drawn on the body surface with a magic marker.

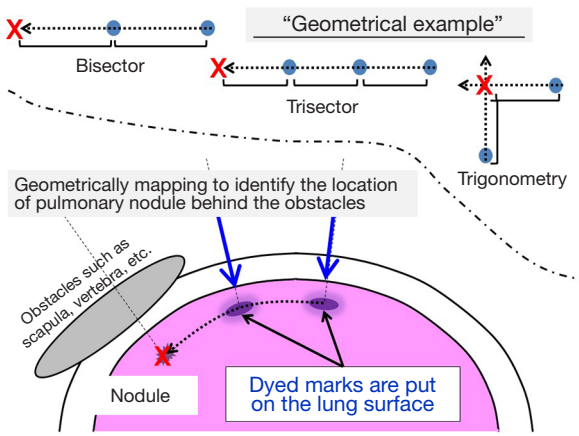

Figure 4 Diagram of the "geometric modified technique".

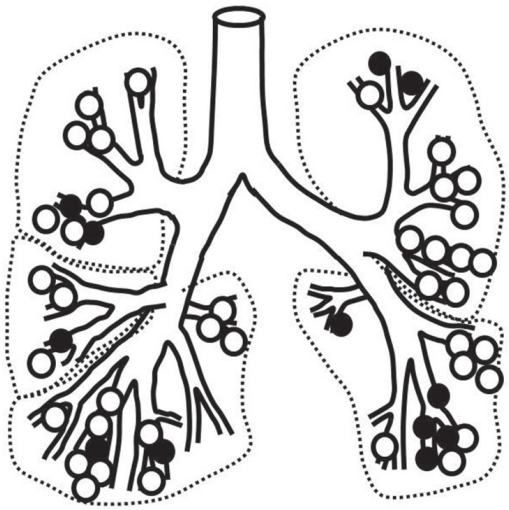

Figure 5 Distribution of nodules according to depth, diameter, location, and matching (white circles: matching; black circles: mismatching).

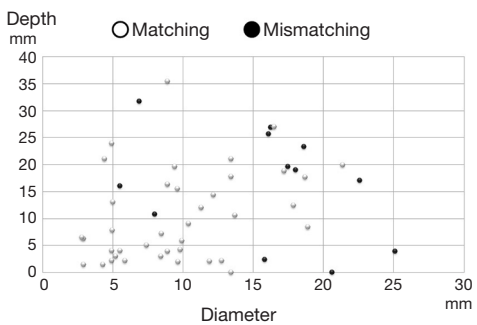

Figure 6 Distribution of nodules according to depth and diameter (white circles, matching; black circles, mismatching).

No intra or postoperative mortality or morbidity was recorded.

Discussion

The nodules (lateral decubitus position) moved gravitationally during the operation because the patient's position changed from supine. Additionally, the original location (lung inflated) of the nodule on the preoperative CT scan differed from that after the lung was deflated intraoperatively (*Figure* 7), which made it more difficult to identify small nodules. In addition, the small, impalpable ground-glass nodules were located deeply under the lung surface. Therefore, it was very important to mark the lesions preoperatively.

Various marking procedures have been used to localize nodules, such as intrathoracoscopic ultrasound (6-10), CT-guided coil injection (3), CT-guided localization of pulmonary nodules with a methylene blue injection (11), radioisotope marking under CT guidance and localization (12), colored collagen (13), vital dye (14-16), fluoroscopy (17,18) and percutaneous needle localization under CT guidance (4,5). These methods have several advantages and disadvantages (1). Although percutaneous CT-guided wire placement is a common technique (5) performed in many facilities, complications resulting from a visceral pleural puncture, such as pneumothorax, hemothorax, intrapulmonary hemorrhage,

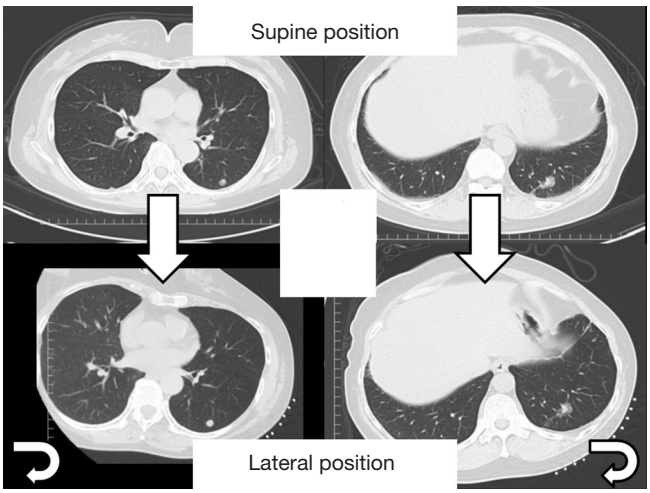

Figure 7 The location of the nodule during the operation seemed different from the location marked during preoperative CT because of the patient's position (supine position or lateral decubitus) and the intraoperatively deflated lung.

and an air embolism, have been reported (19). Marking techniques in which a contrast medium, such as barium sulfate, is injected via bronchoscopy have relatively fewer complications (17), but a thin bronchoscope and skilled practitioners are required. Therefore, these techniques are not available in all facilities. Additionally, a previously reported dye-stamp-marking method (14) cannot be applied to apical nodules or those on the mediastinal and diaphragmatic surfaces, or to the scapula; this is because they cannot be reached from the body surface. However, we modified the method using geometric coordinates of the pulmonary nodule. This method can be applied to all pulmonary nodules located near the pulmonary surface (*Figure 4*).

The advantages of our method are: (I) no risk for air embolism (2); (II) easy; (III) quick; (IV) non-invasive; (V) no need for hospitalization; and (VI) no need for last-minute marking before surgery. On the other hand, it is very difficult to localize deep impalpable pulmonary nodules that lie in the lung parenchyma. Nevertheless, conventional marking methods are difficult and risky to apply for deeper impalpable nodules.

Gentian violet solution is a blue dye and a potent antibacterial agent that is also commonly used for: (I) marking the skin for surgery and allergy testing; (II) treating Tinea infections (e.g., Athlete's foot, jock itch, and ringworm); (III) treating Candida albicans and related infections (e.g., thrush and yeast infections); (IV) treating mouth ulcers; and (V) treating impetigo, primarily before antibiotics (but still useful for patients allergic to penicillin) (20). Gentian violet solution is highly viscous even at low concentrations.

We marked within 1 cm of the lesion in all cases to minimize the gap between the tumor and the mark because of the surgical position, marks on the body surface, and respiratory movements in the same position on the CT table as the patient is positioned in the operating room. Additionally, the matching rate was lower in the left lower lobe than that in the other lobes. No previous study has examined matching rate according to lesion location, probably because the left lower lobe is surrounded by dynamic organs, such as the diaphragm and heart, and moves with them.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was waived by the Institutional Review Board of Maebashi Red Cross Hospital because of non-invasive method and written informed consent was obtained from all patients.

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