



Efficiency of thoracoscopic palpation in localizing small pulmonary nodules

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Received: 25 March 2019 / Accepted: 11 May 2019 / Published online: 25 May 2019
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Abstract

Purpose The thoracoscopic localization of small and deep pulmonary nodules can be challenging. We conducted this study to evaluate the efficiency of thoracoscopic palpation in tumor detection.

Methods The subjects of this study were 229 patients with a collective 267 indeterminate pulmonary nodules ≤ 15 mm in diameter, in the outer third of the lung field. The nodules were localized by palpation using the forefinger or a metal suction probe. Based on the distance from the pleura-to-tumor size ratio (D/S), the nodules were classified into group A ($D/S=0$), group B ($0 < D/S \leq 1$), and group C ($D/S > 1$).

Results The median tumor diameter was 10 mm. All 267 nodules were palpable and resected with negative margins via thoracoscopic wedge resection. The majority of the deep nodules had no pleural change (11%, 86%, and 100% in groups A, B, and C, respectively; $P < 0.01$). The median margins were 15, 16, and 14 mm in groups A, B, and C, respectively. In four patients (1.5%) with relatively short margins (2–7 mm), an additional intraoperative wedge resection was performed.

Conclusion Thoracoscopic palpation was effective for tumor detection when the nodules were located in the outer third of the lung.

Keywords Thoracoscopy · VATS · Localization · Palpation · GGN

Introduction

The popularity and efficacy of computed tomography (CT) have increased the identification rate of small pulmonary lesions. These lesions are generally diagnosed and treated via minimally invasive thoracoscopic surgery [1, 2]; however, the thoracoscopic localization of nodules, particularly small and deep ground-glass nodules (GGNs), can be challenging. Consequently, invasive preoperative localization is frequently performed, particularly in East Asia. In addition to the percutaneous insertion of various localizers [3–5], recent technical advances, including virtual bronchoscopy [6] and electromagnetic navigated bronchoscopy [7], facilitate accurate transbronchial insertion. However, the overuse of these procedures is a matter of concern due to their invasiveness and cost. Thoracoscopic palpation is the easiest

and most direct approach to nodule identification. The present study evaluates its efficiency in detecting tumors during thoracoscopic surgery, using the forefinger or a metallic suction tube, and investigates the necessity of an invasive preoperative localization technique.

Materials and methods

A total of 335 patients with an indeterminate pulmonary nodule diameter of ≤ 15 mm underwent surgical resection at the Department of Thoracic Surgical Oncology, Cancer Institute Hospital of JFCR, Tokyo, between October 2015 and September 2017, which accounted for 35% of 949 patients who underwent pulmonary resection at this hospital during the same period. The surgical indication for GGN was a tumor diameter of > 10 mm or lesions showing slow growth on follow-up CT. Thoracoscopic wedge resection was indicated for nodules located in the outer third of the lung field on CT. The exclusion criteria were as follows: nodules not located in the outer third of the lung field on CT ($n = 94$), multiple nodules in the same lobe ($n = 6$),

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lesions that were typical of lung cancer on CT not requiring excisional biopsies ($n=5$), and swollen hilar lymph nodes ($n=1$). The excluded patients underwent anatomical resection, including lobectomy and segmentectomy, without an excisional biopsy. No patients needed to undergo anatomical resection due to difficulty in localizing the nodules because of severe pleural adhesion or a thick thoracic wall. The exclusion criteria eliminated 106 patients, leaving 229 patients for inclusion in the study. The protocols followed for data collection and analysis were approved, and the requirement for obtaining informed consent from each patient was waived by the Institutional Review Board (approval number: 2018–1084).

The tumor size as maximum diameter (S) and distance (D) from the surface of the tumor to the nearest pleura were measured using a 1.25-mm slice CT image. The depths of the nodules were estimated using the distance-to-size ratio (D/S). The nodules were classified into three groups: group A ($D/S=0$), group B ($0 < D/S \leq 1$), and group C ($D/S > 1$) (Fig. 1). The nodules with pleural indentation on CT were classified into group A. The imaging results of the lesions were classified into four types: pure GGNs, part-solid GGNs, cavitory nodules, and solid nodules. GGN was defined as a hazy increase in lung attenuation without

obscuring underlying vascular markings in the lung window on thin-slice CT.

The operative records of all eligible patients were reviewed. Four staff surgeons performed thoracoscopic palpation during the study period. In all patients, three ports (7, 7, and 20 mm) were used for thoracoscopic wedge resection without mini-thoracotomy and wound retraction. Figure 2 shows the palpation procedure during thoracoscopic surgery. First, the lung section of the area being examined was flattened, and the nodule was identified by sweeping using a metallic suction tube. Subsequently, the lung section was adjusted in order to move the nodule closer to the thoracic wall. The nodule was palpated by inserting the forefinger through the 20-mm incision. A stitch or a clip was used for marking. Repeated palpation was performed to verify the relative position between the marking and the nodule. Wedge resection was performed using endoscopic staplers. The patients underwent additional resection, including lobectomy and lymphadenectomy, as warranted, based on intraoperative, frozen section histopathology findings. Non-invasive CT-guided pulmonary marking (NICTM) was used for guidance during palpation when the operator considered it difficult to approximate the examination area of the tumor. Preoperative skin marking was performed using CT, and

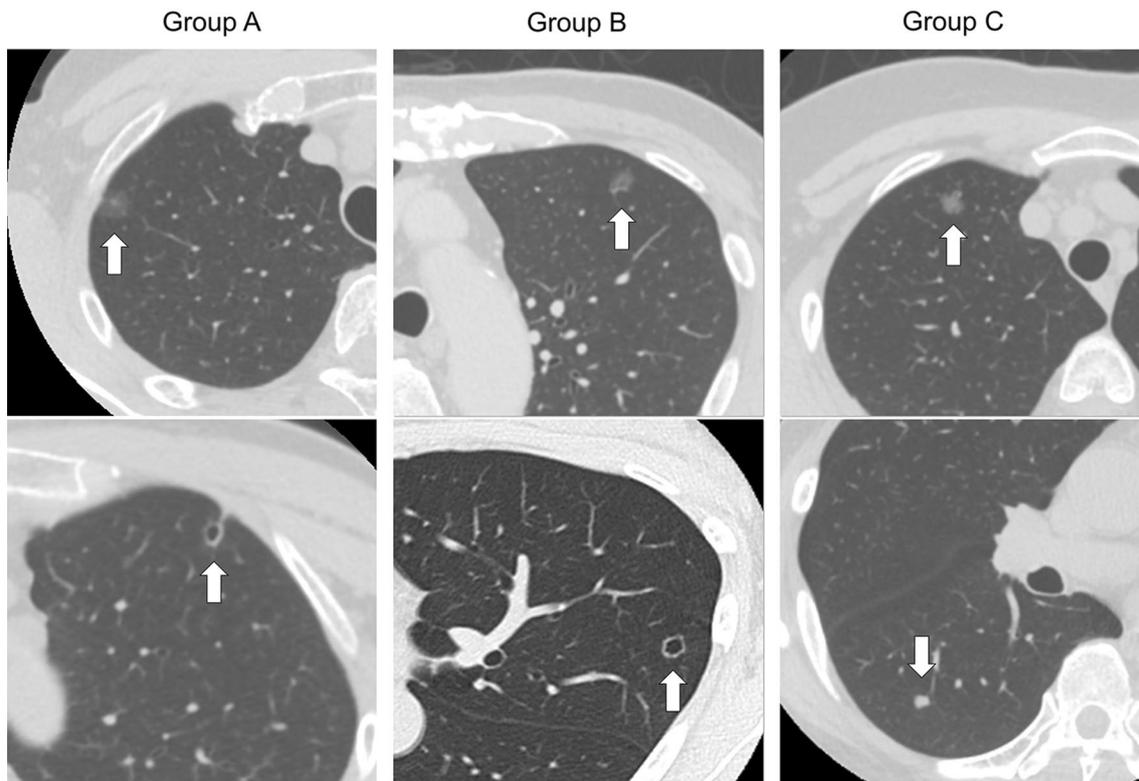


Fig. 1 Representative computed tomography (CT) findings according to the distance from the pleura-to-tumor size ratio (D/S). The nodules (white arrow heads) were classified into three groups: group A

($D/S=0$ or with pleural indentation on CT), group B ($0 < D/S \leq 1$), and group C ($D/S > 1$). CT computed tomography, D/S distance from the pleura-to-tumor size ratio

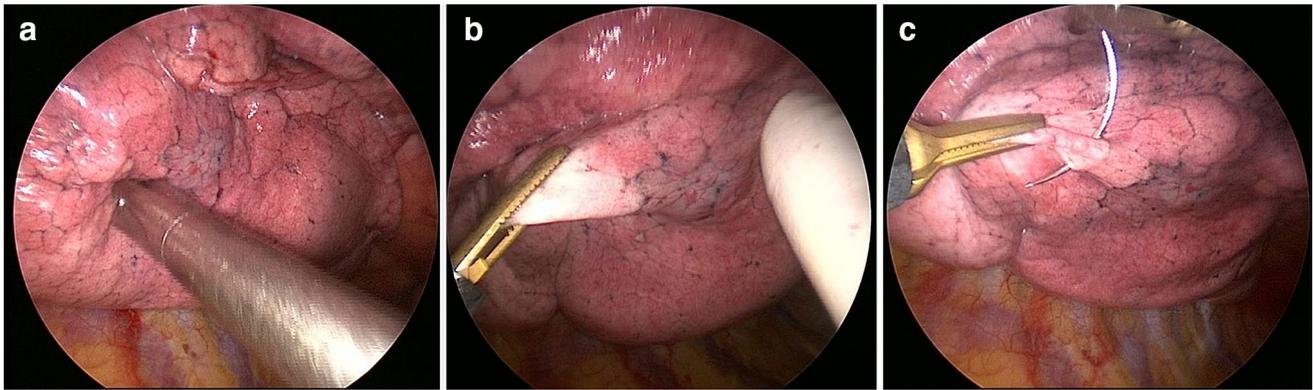


Fig. 2 Palpation procedure during thoracoscopic surgery. **a** First, the lung section of the area being examined was flattened and the nodule was identified by sweeping using a metallic suction tube. **b** The lung is adjusted to bring the nodule closer to the thoracic wall. A forefin-

ger was inserted through a 20-mm incision, and the nodule was palpated. **c** A stitch or a clip was used for marking, and the relative position between the marking and the nodule was confirmed by repeated palpation

intraoperative pigmentation of the visceral pleura was done using pyocyanin blue. This procedure differs from the preoperative percutaneous insertion of localizers as it does not involve puncture of the visceral pleura, which often leads to complications including pneumothorax and air embolism. The technical details of NICTM have been reported in the previous papers [8, 9]. In 20 randomly selected patients with deep nodules (groups B and C), the exact time required for tumor detection was measured using surgical video.

The patients with lung cancer were followed up every 6 months for up to 5 years by full examination and CT scan, with other investigations as deemed clinically necessary. Statistical analyses were performed using JMP 13 software (SAS Institute, Cary, NC, USA). Continuous variables are expressed as the median and range. Variables were compared and analyzed using Student's *t* test, Welch's method, one-way analysis of variance, or Chi-square test. $P < 0.05$ was considered to indicate a significant difference.

Results

The present study included 229 patients, with a collective 267 indeterminate pulmonary nodules measuring ≤ 15 mm in diameter located in the outer third of the lung field on CT. There were 113 men and 116 women (median age 65 years). Table 1 summarizes the clinicopathological features of the 267 resected nodules. The median tumor diameter was 10 mm (range 3–15 mm), and the median distance from the pleura was 1 mm (range 0–22 mm). The majority of nodules (67%) were solid, with 30 (11%) pure GGNs and 51 (19%) part-solid GGNs identified. NICTM was performed for 16 (6%) nodules for guidance during nodule palpation. Pathological examination confirmed that 106 (40%) nodules were lung cancer (42 adenocarcinoma, 22 minimally invasive

Table 1 Characteristics of the resected nodules

Characteristic	<i>N</i> = 267
Tumor size (median, range)	10 mm, 3–15 mm
Distance from the pleura (median, range)	1 mm, 0–22 mm
Tumor type	
Pure GGN	30 (11%)
Part-solid GGN	51 (19%)
Cavitary nodule	8 (3%)
Solid nodule	178 (67%)
Pathological diagnosis	
Lung cancer	106 (40%)
Pulmonary metastasis	133 (50%)
Benign lesion	28 (10%)
Surgical procedure	
Wedge resection	225 (84%)
Wedge resection followed by segmentectomy	4 (1%)
Wedge resection followed by lobectomy	38 (14%)

GGN ground-glass nodules

adenocarcinoma, 36 adenocarcinoma in situ, 5 squamous cell carcinoma, and 1 small cell carcinoma), and 133 (50%) nodules were diagnosed as pulmonary metastases. Additional segmentectomy was performed in four patients and lobectomy was performed in 38 patients, based on intraoperative frozen section histopathology findings.

All 267 nodules were palpable and resected with negative margins, via thoracoscopic wedge resection. No patient underwent an invasive preoperative marking procedure or required conversion to thoracotomy or anatomical resection. Table 2 shows the surgical outcomes based on nodule depths. There were 166 (62%) nodules in group A, 71 (27%) nodules in group B, and 30 (11%) nodules in group C. There was no significant difference in the tumor diameters

Table 2 Surgical outcomes based on nodule depth

Characteristic	Group A N= 166 (62%)	Group B N= 71 (27%)	Group C N= 30 (11%)	P
Tumor size (median, range)	10 mm, 3–15 mm	9 mm, 4–15 mm	9 mm, 6–14 mm	0.07
Distance from the pleura	0 mm, 0–9 mm	5 mm, 1–13 mm	14 mm, 7–22 mm	<0.01
Pleural indentation on CT	39 (23%)	0 (0%)	0 (0%)	<0.01
D/S	0, 0–1.3	0.6, 0.1–1.0	1.4, 1.1–3.7	<0.01
Tumor type				<0.01
Pure GGN	11 (7%)	16 (23%)	3 (10%)	
Part-solid GGN	39 (23%)	10 (14%)	2 (7%)	
Cavitary nodule	2 (1%)	4 (6%)	2 (7%)	
Solid nodule	114 (69%)	41 (58%)	23 (77%)	
Localization				<0.01
Pleural change and palpation	147 (89%)	10 (14%)	0 (0%)	
Palpation only	15 (9%)	50 (70%)	29 (97%)	
Palpation and NICTM	4 (2%)	11 (15%)	1 (3%)	
Margin positive	0	0	0	1
Margin	15 mm, 2–30 mm	16 mm, 2–32 mm	14 mm, 5–30 mm	0.53
Margin/tumor size ratio	1.6, 0.3–5.0	1.8, 0.2–3.3	1.6, 0.6–3.8	0.57
Additional wedge resection	2 (1.2%)	2 (2.8%)	0 (0%)	0.52
Local recurrence	0	0	0	1

The nodules were classified into three groups: group A ($D/S=0$ or with pleural indentation on CT), group B ($0 < D/S \leq 1$), and group C ($D/S > 1$)

CT computed tomography, D/S distance from the pleura-to-tumor size ratio, GGN ground-glass nodules, NICTM noninvasive CT-guided pulmonary marking

among the three groups. Most of the deep nodules did not exhibit pleural changes and were undetected only by sight [11%, 86%, and 100% ($P < 0.01$) in groups A, B, and C, respectively]. The median tumor margins were 15, 16, and 14 mm, which were 1.6, 1.8, and 1.6 times as long as the tumor diameters in groups A, B, and C, respectively, with no significant difference among the groups. Additional intraoperative wedge resection was performed in four patients (1.5%; two from group A and two from group B) with relatively short margins (range 2–7 mm); however, no residual tumor was found in the specimens. No local recurrence was found in the follow-up period (median 21 months). The total procedure time for single wedge resection was 70 min (range 30–128 min), 77 min (range 42–116 min), and 81 min (range 35–105 min) in groups A, B, and C, respectively. There was no significant difference in the time spent for tumor detection between groups B and C [21 s (range 2–492 s) vs. 91 s (range 32–157 s)] or between the pure GGNs and other nodules [91 s (range 4–351 s) vs. 32 s (range 2–492 s)].

Discussion

In the present study, all 267 indeterminate pulmonary nodules ≤ 15 mm in diameter located in the outer third of the lung field on CT were palpable and able to be resected with negative margins, via thoracoscopic wedge resection,

without invasive preoperative localization or conversion to thoracotomy or anatomical resection.

The intraoperative detection of small pulmonary nodules during thoracoscopic exploration, and the indications for preoperative marking, has long been a concern. Suzuki et al. [10] recommended preoperative marking when the distance to the pleural surface was > 5 mm for nodules < 10 mm in diameter because of the 63% probability of conversion to thoracotomy. Saito et al. [11] suggested using a formula ($\text{depth} = 0.836 \times \text{size} - 2.811$) to differentiate between undetectable and detectable small peripheral pulmonary nodules. Tamura et al. [12] reported that thoracoscopic lesion detection was difficult for lung nodules < 15 mm in size and when the distance to the nearest pleural surface was > 10 mm. The present study included 34 nodules that met Suzuki's criteria, 85 nodules that met Saito's formula, and 29 nodules that met Tamura's conditions. However, all nodules were thoracoscopically palpable. The tumor characteristics reported in studies involving a large series of percutaneous hook-wire insertion [3] and transbronchial dye injection using virtual bronchoscopy [6] were similar to those reported in groups B and C of the present study. In the present study, the indication for tumor detection by thoracoscopic palpation without using an invasive localization technique was nodules in the outer third of the lung field. This criterion included 68% of surgical candidates with an indeterminate pulmonary

nodule diameter ≤ 15 mm. It appears that the percentage corresponds to the ratio of lung volume in the outer third to the inner region $[(3^3 - 2^3)/3^3 \approx 0.70]$. Horeweg et al. [13] reported the characteristics of lung cancers detected by CT screening in the randomized NELSON trial. They observed that 62.2% of lung cancers were localized in the outer one-third of the costal-hilar diameter. Thoracoscopic palpation and wedge resection for the central lesions should not be performed.

Difficulty in palpation is influenced by the type of nodules and their depth. Even in a resected specimen, pure GGNs are soft and difficult to detect. The present study reported 30 pure GGNs, 19 of which were distant from the pleura. Of the 19 patients with deep and pure GGNs, preoperative NICTM was performed in nine (47%) to guide palpation and reduce tumor detection time. The tumor detection time tended to be longer in group C and for pure GGN detection. However, there was no significant difference, possibly due to the extent of lung collapse and the surgeon's experience that influenced the required time.

Localization methods using various localizers [14, 15], including hook wires [3], dyes [5], contrast media, microcoil [4], indocyanine green [16], and radiotracers [17], have been classified into two types: percutaneous and transbronchial. Percutaneous insertion is easy and accurate, but associated with a higher risk of critical complications, particularly air embolism, resulting from puncture of the visceral pleura. Recent technical advances enable accurate transbronchial insertion using virtual bronchoscopy [6] and electromagnetic navigated bronchoscopy [7]; however, this procedure is invasive. Intraoperative DynaCT scan is a less invasive and promising alternative [18], but the expense of equipment and the resolution of the reconstructed images need to be addressed. The increased invasiveness, and time and expense of marking can be avoided if nodules can be identified by palpation. The lack of tactile sensation is considered a weakness of thoracoscopic surgery, and the role of palpation tends to be neglected. Prior to this study, we had performed preoperative CT-guided insertion of hook-wire and thread; however, this led to a case of air embolism and we established that the majority of peripheral nodules were identifiable by thoracoscopic palpation, when performed carefully. Table 3 summarizes the strengths and weaknesses of various localization methods.

Although palpation using a metallic suction tube is enough for the detection of superficial nodules, finger palpation is effective also for sufficient surgical margins. The tumor depth was confirmed through finger palpation more correctly than through metallic suction tube palpation. Most of the invasive localization techniques currently available involve marking of the pleural surface only and offer no information on tumor depth. Wedge resection with insufficient surgical margins for primary lung cancer and

Table 3 Strengths and weaknesses of various localization methods

	Reliability	Simplicity	Invasiveness	Expense
Percutaneous marking	High	High	High	High
Transbronchial marking	High ^a	Low	High	High
Intraoperative CT	High	High	Low	High
Palpation	High	High	Low	Low

^aTransbronchial marking is reliable only when virtual bronchoscopy or electromagnetically navigated bronchoscopy is used

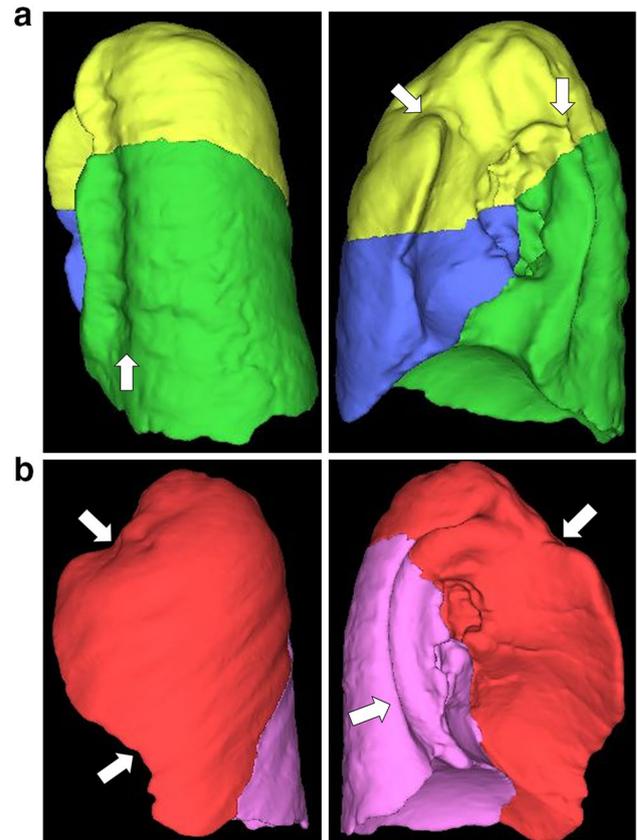


Fig. 3 Examples of useful folds shaped by the mediastinal structure for the anatomical landmarks (white arrow heads), including the vertebra, anterior mediastinum, azygos vein, and the aorta in **a** the right lung and **b** the left lung

pulmonary metastasis has been linked to considerable risk of local recurrence [19, 20].

Preparations are necessary for optimizing quick and accurate tumor detection by palpation during thoracoscopic surgery. It is most important to approximate the examination area by analyzing the CT scan carefully. In addition to fissures and edges, the folds shaped by the mediastinal structures, pulmonary vessels, and intrapulmonary lymph nodes can be useful anatomical landmarks (Fig. 3). NICTM

is an easy and useful method to narrow the examination area and reduce the tumor detection time. Decisions regarding surgical indication and surgical procedure are also important. Surgical resection is not recommended for small, pure GGNs < 5 mm in diameter. Wedge resection is not recommended for nodules other than those located in the outer third of the lung field as they are usually too deep for sufficient margins to be obtained. Thoracoscopic tumor detection is more difficult in certain conditions; for example, if there is insufficient lung collapse, severe adhesion close to the tumor requires extra-pleural dissection, multiple nodules around the target nodule, and a thick thoracic wall that precludes insertion of the forefinger. In such conditions, invasive preoperative marking should be considered, and the patient must be informed preoperatively of the possibility of conversion to thoracotomy or anatomical resection.

This study had some limitations. As it was a retrospective, observational, single-institution study that included only patients with tumors located in the outer third of the lung field on CT, the results apply to peripheral lesions only. The technical method of thoracoscopic palpation is difficult to translate, and the efficiency of tumor palpation may differ among surgeons and institutions.

In conclusion, thoracoscopic palpation using the forefinger or a metallic suction tube was effective for tumor detection when the nodules were located in the outer third of the lung. Therefore, the number of patients requiring an invasive preoperative localization technique may be lower than that generally considered.

Acknowledgements We have no potential conflicts of interest with any companies or organizations whose products or services might be discussed in this article.

Funding None declared.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Ichinose J, Kohno T, Fujimori S, Mun M. Locoregional control of thoracoscopic lobectomy with selective lymphadenectomy for lung cancer. *Ann Thorac Surg.* 2010;90:235–9.
2. Mun M, Nakao M, Matsuura Y, Ichinose J, Nakagawa K, Okumura S. Video-assisted thoracoscopic surgery lobectomy for non-small cell lung cancer. *Gen Thorac Cardiovasc Surg.* 2018;66:626–31.
3. Ichinose J, Kohno T, Fujimori S, Harano T, Suzuki S. Efficacy and complications of computed tomography-guided hook wire localization. *Ann Thorac Surg.* 2013;96:1203–8.
4. Finley RJ, Mayo JR, Grant K, Clifton JC, English J, Leo J, et al. Preoperative computed tomography-guided microcoil localization of small peripheral pulmonary nodules: a prospective randomized controlled trial. *J Thorac Cardiovasc Surg.* 2015;149:26–31.
5. Lin MW, Tseng YH, Lee YF, Hsieh MS, Ko WC, Chen JY, et al. Computed tomography-guided patent blue vital dye localization of pulmonary nodules in uniportal thoracoscopy. *J Thorac Cardiovasc Surg.* 2016;152(535–544):e532.
6. Sato M, Kuwata T, Yamanashi K, Kitamura A, Misawa K, Imashimizu K, et al. Safety and reproducibility of virtual-assisted lung mapping: a multicentre study in Japan. *Eur J Cardiothorac Surg.* 2017;51:861–8.
7. Anayama T, Qiu J, Chan H, Nakajima T, Weersink R, Daly M, et al. Localization of pulmonary nodules using navigation bronchoscope and a near-infrared fluorescence thoracoscope. *Ann Thorac Surg.* 2015;99:224–30.
8. Matsuura Y, Mun M, Nakagawa K, Okumura S. Efficacy and feasibility of a novel and noninvasive computed tomography-guided marking technique for peripheral pulmonary nodules. *J Thorac Cardiovasc Surg.* 2015;149:1208–9.
9. Mun M, Matsuura Y, Nakao M, Ichinose J, Nakagawa K, Okumura S. Noninvasive computed tomography-guided marking technique for peripheral pulmonary nodules. *J Thorac Dis.* 2016;8:S672–S676676.
10. Suzuki K, Nagai K, Yoshida J, Ohmatsu H, Takahashi K, Nishimura M, et al. Video-assisted thoracoscopic surgery for small indeterminate pulmonary nodules: indications for preoperative marking. *Chest.* 1999;115:563–8.
11. Saito H, Minamiya Y, Matsuzaki I, Tozawa K, Taguchi K, Nakagawa T, et al. Indication for preoperative localization of small peripheral pulmonary nodules in thoracoscopic surgery. *J Thorac Cardiovasc Surg.* 2002;124:1198–202.
12. Tamura M, Oda M, Fujimori H, Shimizu Y, Matsumoto I, Watanabe G. New indication for preoperative marking of small peripheral pulmonary nodules in thoracoscopic surgery. *Interact Cardiovasc Thorac Surg.* 2010;11:590–3.
13. Horeweg N, van der Aalst CM, Thunnissen E, Nackaerts K, Weenink C, Groen HJ, et al. Characteristics of lung cancers detected by computer tomography screening in the randomized NELSON trial. *Am J Respir Crit Care Med.* 2013;187:848–54.
14. Park CH, Han K, Hur J, Lee SM, Lee JW, Hwang SH, et al. Comparative effectiveness and safety of preoperative lung localization for pulmonary nodules: a systematic review and meta-analysis. *Chest.* 2017;151:316–28.
15. Zaman M, Bilal H, Woo CY, Tang A. In patients undergoing video-assisted thoracoscopic surgery excision, what is the best way to locate a subcentimetre solitary pulmonary nodule in order to achieve successful excision? *Interact Cardiovasc Thorac Surg.* 2012;15:266–72.
16. Ujiie H, Kato T, Hu HP, Patel P, Wada H, Fujino K, et al. A novel minimally invasive near-infrared thoracoscopic localization technique of small pulmonary nodules: A phase I feasibility trial. *J Thorac Cardiovasc Surg.* 2017;154:702–11.
17. Starnes SL, Wolujewicz M, Guitron J, Williams V, Scheler J, Ristagno R. Radiotracer localization of nonpalpable pulmonary nodules: a single-center experience. *J Thorac Cardiovasc Surg.* 2018;156:1986–92.
18. Ng CSH, Man Chu C, Kwok MWT, Yim APC, Wong RHL. Hybrid DynaCT scan-guided localization single-port lobectomy [corrected]. *Chest.* 2015;147:e76–e7878.
19. Masai K, Sakurai H, Sukeda A, Suzuki S, Asakura K, Nakagawa K, et al. Prognostic impact of margin distance and tumor spread through air spaces in limited resection for primary lung cancer. *J Thorac Oncol.* 2017;12:1788–97.
20. Shiono S, Ishii G, Nagai K, Yoshida J, Nishimura M, Murata Y, et al. Predictive factors for local recurrence of resected colorectal lung metastases. *Ann Thorac Surg.* 2005;80:1040–5.

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