Ultrasonographic evaluation of small nodules in the peripheral lung during video-assisted thoracic surgery (VATS)

Seiji Matsumotoa, Toshiki Hiratac, Eiji Ogawaa, Tatsuo Fukusea, Hiroyuki Uedab, Takashi Koyamab, Takayuki Nakamuraa, Hiromi Wadaa,*

aDepartment of Thoracic Surgery, Graduate School of Medicine, Kyoto University, 54 Shogoin Kawara cho, Sakyo ku, Kyoto 606-8397, Japan
bDepartment of Radiology, Graduate School of Medicine, Kyoto University, 54 Shogoin Kawara cho, Sakyo ku, Kyoto 606-8397, Japan
cDepartment of Thoracic Surgery, Kishiwada City Hospital, 1001 Gakuhara cho Kishiwada, 569-8501 Osaka, Japan

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Abstract

Objective: We examined the possibility of intraoperative ultrasonography during video-assisted thoracic surgery (VATS) to localize and make a qualitative diagnosis of small peripheral pulmonary nodules. Methods: Ultrasonography during VATS and conventional thoracotomy was performed on 25 and 18 nodules, respectively, all which were localized in the peripheral lung, were less than 30 mm in diameter and for which there was no definitive diagnosis. Results: All 25 nodules, including 10 invisible but palpable and three both invisible and non-palpable, could be localized by ultrasonography during VATS. If nodules were located less than 15 mm from the pleural surface, ultrasonography during VATS could detect nodules 10 mm or less in diameter. The rate of malignant tumors among 11 of 12 pulmonary nodules (91.6%) showing both heterogeneous and ill-defined patterns was significantly higher than 6 of 16 nodules (37.5%) showing both homogeneous and well-defined patterns on ultrasonography. Conclusions: Our study suggested that ultrasonography during VATS is useful for the detection of peripheral pulmonary nodules, even when they are not identified on video images or palpation, and may enable a differential diagnosis between malignant and non-malignant lesions.

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Keywords: Video-assisted thoracic surgery; Ultrasonography; Pulmonary nodule

1. Introduction

Video-assisted thoracic surgery (VATS) [1,2] is less invasive than conventional thoracotomy and is suitable for the resection of small peripheral lung nodules. However, small peripheral lung nodules often cannot be confirmed using a monitor or palpation with forceps during VATS. To solve this problem, previous investigators have reported that preoperative computed tomography (CT) guide marking [3,4] and pigment infusion [5] were useful to identify the location of peripheral nodules during VATS. Therefore, a procedure that can identify small peripheral nodules during VATS is essential.

Ultrasonography is widely used as a diagnostic tool in various clinical fields, such as percutaneous echoes [6], echoes during surgery [7–11] and transbronchial echoes. However, only a few researchers have reported that ultrasonography can identify peripheral pulmonary nodules [9,10]. Moreover, the ability of ultrasonography to facilitate qualitative diagnosis has not been clarified. Therefore, in this study, we examined whether ultrasonography during VATS can locate a nodule in real time and make a differential diagnosis in the peripheral lungs.

2. Material and methods

We examined 43 nodules from 41 patients. Twenty-five nodules of 23 patients underwent VATS and 18 nodules of 18 patients underwent conventional thoracotomy at Kyoto University Hospital or Kishiwada City Hospital between April 2000 and April 2002. All 41 patients had small
nodules located in the pulmonary peripheral side a one-third and smaller than 30 mm in diameter on chest CT, but preoperative diagnoses of all lesions were not confirmed.

When a small pulmonary nodule is identified on a chest X-ray or CT in an institution, a bronchoscopy is usually performed for diagnosis. If no pathological diagnosis is obtained, VATS is performed, followed by a conventional thoracotomy if the pathological diagnosis reveals primary lung cancer.

However, in cases strongly suspected of lung cancer based on a chest X-ray, CT findings or a tumor marker of serum levels, a conventional thoracotomy is initially performed without VATS.

2.1. Preoperative evaluation

Preoperative chest X-ray and CT were performed to evaluate the location, number, longest dimension, shortest dimension, depth, appearance and internal predisposition of the affected nodules in the peripheral lung. The depth of nodules on chest CT was defined as the smallest distance from the nodules to the pulmonary surface. All the distances between the nodules and the lung surface in Section 3 are expressed as measured in the preoperative chest CT.

2.2. Ultrasonography during VATS

The patient was initially ventilated via a double-lumen endotracheal tube under general anesthesia, turned into the lateral decubitus position and three 11.5 mm trocars were set up. After the lung was deflated, we localized the nodules by visualization using a thoracoscope monitor and by palpation with forceps.

Isotonic sodium chloride solution at 37 °C was poured into the thoracic cavity and the ultrasonography probe (a linear array transducer, an Aloka UST-5530, 7.5 MHz probe) was placed on the pulmonary surface suspected of having a pulmonary nodule. The location, longest dimension, shortest dimension, margin and internal predisposition of the nodules were evaluated by ultrasonography. Ultrasonographic signs were recorded as a hard copy and videotape.

After the completion of ultrasonography, partial resection of the lung and a frozen-section histopathological diagnosis were performed immediately. If the nodule was determined to be primary lung cancer, a lobectomy was performed.

The images from both VATS and the thoracotomy were reviewed by a thoracic surgeon and two radiologists during surgery.

2.4. Statistical analysis

Statistical analysis was performed by StatView software (version 5.0, SAS Institute Inc, NC).

The relationships between the detection rate and the depth of the nodules, and the detection rate and the nodule diameter, and the correlation between malignant tumors and benign tumors were evaluated by Fisher’s exact probability test. A P value less than 0.05 was taken to indicate a significant difference.

3. Results

3.1. Patient characteristics

The VATS cases involved 25 nodules: 13 were malignant tumors and 12 were benign tumors. The thoracotomy cases involved 18 nodules: 17 malignant tumors and one benign tumor (Table 1).

Table 1

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>VATS (n = 25)</th>
<th>Thoracotomy (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M/F)</td>
<td>14/9</td>
<td>8/10</td>
</tr>
<tr>
<td>Median age (yr)</td>
<td>61.8 (35–80)</td>
<td>58.8 (46–75)</td>
</tr>
<tr>
<td>Malignant tumors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Metastatic lung tumor</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Benign tumors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

VATS cases involved 25 nodules of 23 patients.
3.2. Analysis of the VATS cases

3.2.1. Detection rate of nodules by video imaging, palpation, and ultrasonography

Of the 25 nodules treated by VATS, 15 (60%) were visible and identified on video images through a thoracoscope. The other 10 nodules were not identified on video images, and three were not palpable. Using ultrasonography, however, all 25 nodules were recognized during VATS. The detection rates of pulmonary nodules by ultrasonography were significantly higher than by video imaging ($P = 0.0006$) (Table 2).

3.2.2. Detection rate, depth and diameter of the nodules

Among nodules located at a depth of more than 5 mm from the pleural surface, detection by ultrasonography was significantly higher than by video imaging ($P = 0.006$) (Fig. 1A).

For nodules with a diameter less than 10 mm on the chest CT, the detection rate by ultrasonography was significantly higher than by video imaging ($P = 0.012$) (Fig. 1B).

3.3. Differential diagnosis of pulmonary nodules (combination analysis of the 25 VATS cases and 18 thoracotomy cases)

3.3.1. Ultrasonographic classification of nodule (Fig. 2A, B)

Ultrasonographic findings were divided into the following two patterns.

Homogeneous pattern. The interior of the lesion was homogeneous with a low echoic pattern, for example, Fig. 2A, pulmonary tuberculosis.

Heterogeneous pattern. The interior of the lesion was heterogeneous, with a punctile hyperechoic pattern, for example, Fig. 2B, lung cancer.

3.3.2. Ultrasonographic classification of nodule margin findings (Fig. 2C, D)

Ultrasonographic margin findings were divided into the following two patterns.

Well-defined pattern. The margin of the nodule was distinct, for example, Fig. 2C, pulmonary tuberculosis.

Ill-defined pattern. The margin of the nodule was unclear, for example, Fig. 2D, metastatic lung tumor from colorectal cancer.

3.4. Differential diagnosis based on internal patterns and the margin of the nodules

We defined primary lung cancer and metastatic lung tumor as malignant tumors and other tumors, e.g. tuberculosis, as benign tumors. The rate of malignant tumors among nodules showing both a heterogeneous pattern and an ill-defined margin (91.6%) was significantly higher than nodules showing a homogeneous pattern with a well-defined margin (37.5%) ($P = 0.0043$). In homogenous patterns, an ill-defined margin indicated a malignant tumor (90.0%) stronger than a well-defined margin (37.5%) ($P = 0.0097$) (Table 3).

4. Comments

In our study, small nodules less than 10 mm in diameter on preoperative chest CT could be detected by ultrasonography during VATS if they were located at a depth less than 15 mm from the pleural surface. The number of nodules detected by preoperative CT was identical with the number of nodules detected by intraoperative ultrasonography in all patients.

Santambrogio et al. [9] performed ultrasonography during VATS on 18 cases with a pulmonary nodule diameter of 20 mm or less and reported that they could detect pulmonary nodules with a minimum diameter of 5 mm by ultrasonography. Greenfield et al. [10] detected 12
nODULES BY ULTRASONOGRAPHY DURING VATS IN 13 PERIPHERAL LUNG NODULES WITH A MINIMUM DIAMETER OF 4 MM AND AT A MAXIMUM DEPTH OF 20 MM FROM THE PLEURAL SURFACE. OUR RESULTS SUPPORTED THESE RESULTS.

OUR STUDY ALSO REVEALED THAT ULTRASONOGRAPHY DURING VATS COULD DETECT 7 OF 25 INVISIBLE AND PALPABLE PULMONARY NODULES, AND MOREOVER, 3 BOTH INVISIBLE AND NON-PALPABLE PULMONARY NODULES. ULTRASONOGRAPHY FACILITATED THE DISCRIMINATION OF THREE NON-PALPABLE LESIONS; TWO PATIENTS HAD ADENOCARCINOMA, AND ONE PATIENT A TUBERCULOUS NODULE. IN THE PATIENT WITH A TUBERCULOUS NODULE, ULTRASONOGRAPHY MADE IT POSSIBLE TO AVOID UNNECESSARY THORACOTOMY FOR DETECTING NODULES.

THE RESULTS DEMONSTRATED THE USEFULNESS OF ULTRASONOGRAPHY DURING VATS IN DETECTING PERIPHERAL PULMONARY NODULES.

IN THE USE OF ULTRASONOGRAPHY TO DETECT NODULES IN OTHER AREAS, THE DETECTION RATE OF HEPATOCELLULAR CARCINOmas IN HEPATIC CIRRHOSIS PATIENTS BY ULTRASONOGRAPHY WAS 33–96% [12–16]. BENNETT ET AL. [16] REPORTED THAT THE SIZES OF EIGHT HEPATOCELLULAR CARCINOMAS DETECTED BY ULTRASONOGRAPHY RANGED FROM 1.2 TO 7.5 CM, BUT NO HEPATOCELLULAR CARCINOMAS LESS THAN 1 CM WERE DETECTED. ENDOSCOPIC ULTRASONOGRAPHY IS THE MOST SENSITIVE METHOD FOR THE DETECTION OF Pancreatic TUMORS, WITH A SENSITIVITY OF 90% [17]. ULTRASONOGRAPHY DURING VATS WAS NOT ONLY EFFECTIVE FOR LOCATING THE PULMONARY NODULES, BUT ALSO FOR DETERMINING THE INCISION LINE, BECAUSE IT SHOWS THE LONGITUDINAL AXIS OF PULMONARY NODULES.

AN ANALYSIS OF ALL 43 CASES OF ULTRASONOGRAPHY DURING VATS AND CONVENTIONAL THORACOTOMY SHOWED THAT IN A PATIENT WITH HOMOGENOUS PATTERNS, AN ILL-DEFINED MARGIN INDICATED A MALIGNANT TUMOR (90.0%) MORE THAN A WELL-DEFINED MARGIN (37.5%) ($P = 0.0097$). MOREOVER, THE RATE OF MALIGNANT TUMORS AMONG NODULES SHOWING BOTH A HETEROGENEOUS AND ILL-DEFINED MARGIN PATTERN (91.6%) WAS SIGNIFICANTLY HIGHER THAN NODULES SHOWING BOTH A HOMOGENEOUS AND WELL-DEFINED MARGIN PATTERN (37.5%) ($P = 0.0043$) (Table 3). THIS RESULT SUGGESTED THAT ULTRASONOGRAPHY MIGHT BE USEFUL FOR DIFFERENTIAL DIAGNOSIS OF LUNG NODULES.

IN OUR STUDY, PALPATION WITH FORCEPS DURING VATS WAS ALSO A RELIABLE TECHNIQUE FOR LOCATING AND CONFIRMING PULMONARY NODULES WITH A DIAMETER LESS THAN 10 MM. HOWEVER, HAYASHI ET AL. [18] COMPARED CONVENTIONAL RESECTION TECHNIQUES AND A NON-TOUCH ISOLATION TECHNIQUE, AND CONCLUDED THAT THE NON-TOUCH ISOLATION TECHNIQUE PREVENTED THE DISSEMINATION OF CANCER CELLS INTO THE PORTAL BLOOD SYSTEM DURING SURGERY. IF MALIGNANCY IS STRONGLY SUSPECTED BY ULTRASONOGRAPHY DURING VATS, IT MAY BE POSSIBLE TO AVOID UNNECESSARY PALPATION AND PREVENT THE DISSEMINATION OF CANCER CELLS.

**Table 3**

<table>
<thead>
<tr>
<th>Differential diagnosis by internal findings and findings from the nodule margins</th>
<th>Ill-defined</th>
<th>Well-defined</th>
<th>Malignancy/total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heterogeneous</td>
<td>11/12 (91.6%)</td>
<td>4/5 (80.0%)</td>
<td>15/17 (88.2%)</td>
</tr>
<tr>
<td>Homogeneous</td>
<td>9/10 (90.0%)</td>
<td>6/16 (37.5%)</td>
<td>15/26 (57.6%)</td>
</tr>
<tr>
<td>Malignancy/total</td>
<td>20/22 (90.9%)</td>
<td>10/21 (47.6%)</td>
<td></td>
</tr>
</tbody>
</table>

The rate of malignant tumors among heterogeneous nodules with an ill-defined pattern was significantly higher than homogeneous nodules showing a well-defined pattern.

**Fig. 2. Ultrasonographic classification of the findings.** (A) Homogeneous pattern: the inside of the lesion showed a homogeneous and low echoic pattern. The pathological diagnosis was pulmonary tuberculosis. (B) Heterogeneous pattern: the inside of the lesion was heterogeneous, with a punctate-like hyperechoic spot. The pathological diagnosis was adenocarcinoma of the lung. (C) Well-defined pattern: the margin of the nodule was clear. Pulmonary tuberculosis. (D) Ill-defined pattern: the margin of the nodule was unclear. Metastastatic lung cancer from colorectal cancer.
Mean operative time of VATS is 2 h 33 min and ultrasonography during VATS can be performed with an average of 7 min, and the technique is relatively simple. The clinical application of this procedure is not likely to be difficult. If ultrasonography can be performed during VATS, preoperative marking with chest CT guidance would become unnecessary, resulting in the elimination of complications and extra expenses.

In conclusion, our study suggested that ultrasonography during VATS may be useful for detecting small peripheral pulmonary nodules that cannot be identified on video images or by palpation, and may enable differential diagnosis between malignant and benign tumors.

References