Ultrasonographic Evaluation of Pleural and Chest Wall Invasion of Lung Cancer*

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The significance of ultrasonography was tested in evaluation of cancerous invasion into the pleura and chest wall in patients with lung cancer. The degree of the invasion was ultrasonographically classified into four grades, that is, uP-0, uP-1, uP-2 and uP-3, corresponding with the classification proposed by the Japan Lung Cancer Society, which is graded by surgical findings. The total accuracy of this method was 77 percent. Especially for uP-3, which is the most critical grade regarding decisions on surgical intervention, this figure was 100 percent. It is suggested that this approach can delineate cancerous invasion into the pleura and chest wall sufficiently well for daily clinical use and staging of patients with lung cancer.

Until recently, the application of ultrasonography has been considered to be somewhat limited in chest diseases because of the presence of air in the lung that impedes ultrasonic transmission. However, many pathologic lung conditions, especially cancer, are very frequently accompanied by airless lesions in the peripheral lung area, such as atelectasis, pleural indention, loculated pleural effusion and primary tumor itself. These airless lesions act as an ultrasonographic window, permitting penetration of ultrasonic waves into lung parenchyma. Ultrasonography has the specific ability to discriminate many soft tissues clearly and is also able to image these lesions in real-time even during their movement due to ventilation. On the basis of these characteristics of the ultrasonography, we tested the usefulness of ultrasonography for evaluation of cancerous invasion into the pleura and chest wall in patients with lung cancer.

METHODS AND MATERIALS

Sixty-five patients with lung cancer judged to have lesions abutting the chest wall were selected as candidates for this study. These 65 cases comprised 31 cases of epidermoid carcinoma, 28 cases of adenocarcinoma, three cases of large cell carcinoma, two cases of alveolar cell carcinoma and one case of small cell carcinoma. The ultrasonic instruments used in this study were model SAL-50A (Toshiba, Japan) and model SSD-256 (Aloka, Japan) with 3.5-MHz and 5.0-MHz linear array scanners. As a coupling medium, water-soluble ultrasound transmission gel (Aquasonic; Parker, United States) was applied to the skin without a water path. We routinely applied the scanner intercostally to the chest wall above the lung lesion. The scale shown in each ultrasonogram hereafter corresponds to a width of 1 cm. The focal zone is from 0 to 8 cm in depth.

Typical ultrasonograms of normal pleura and pleura invaded by lung cancer are shown in Figure 1. These were recorded from a patient with lung cancer in the left lower lobe. As shown on the left (right lung), the image of the normal lung is diffusely hypoechoic and details of its inner structures are not discernible. The lung surface is visible as a hypoechoic curved line, although the parietal and visceral pleurae cannot be distinguished. The right-hand ultrasonogram is an example of the pleura in contact with lung cancer. The lung cancer, about 2 cm in diameter in the left lower lobe, is imaged as a relatively low-echogenic round area along with the pleura, accompanying an echogenic shadow within the lung parenchyma. The hypoechoic curved line representing the surface of the left lung is partially obliterated in the right-hand portion indicated by the arrow because of cancerous invasion into pleura. For the detection of these lesions, we attempted to record multiple pictures with different contact angles between chest wall and scanner and at different inspiratory levels.

The pathologic changes along with the pleura and chest wall of these subjects were macroscopically and histologically examined during the operation and compared with findings on the ultrasonogram.

The Japan Lung Cancer Society classifies pleural and chest wall invasion into four grades, namely P-0, P-1, P-2 and P-3 on the basis of surgical findings:

P-0 means no pleural and chest wall invasion.

P-1 means limited invasion into the visceral pleura.

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Figure 1. Typical ultrasonograms of normal pleura (right lung [RT]) and the pleura which is invaded by lung cancer (left lung [LT], indicated by an arrow).
P-2 means invasion into the visceral and parietal pleurae.
P-3 means invasion into the chest wall through the visceral and parietal pleurae.

Therefore, we also ultrasonographically classified these changes into four grades, namely uP-0, uP-1, uP-2 and uP-3, and equated these to the respective grades according to surgical findings. The ultrasonographic criteria are as follows:
uP-0 means the tumor has not invaded from visceral pleura and cannot be visualized.
uP-1 means the tumor is in contact with the visceral pleura, but visceral and parietal pleurae are intact, and smooth respiratory movement of tumor is visualized.
uP-2 means the tumor is in contact with the chest wall; visceral pleura is irregular or cut off and parietal pleura is irregular, and smooth respiratory movement of tumor is disturbed.
uP-3 means the tumor echoes extend to the chest wall through the visceral and parietal pleurae and the cut-off sign of visceral and parietal pleurae is seen; the respiratory movement of the tumor cannot be visualized.

These findings are summarized in Table 1.

### Table 1—Ultrasonographic Classification of Pleural and Chest Wall Invasion of Lung Cancer

<table>
<thead>
<tr>
<th>Tumor Movement</th>
<th>Respiratory Movement</th>
<th>Tumor</th>
<th>Pleural</th>
<th>Parietal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undiscriminated</td>
<td>...</td>
<td>uP-0</td>
<td>Discriminated</td>
<td>Undiscriminated</td>
</tr>
<tr>
<td>Discriminated</td>
<td>+</td>
<td>uP-1</td>
<td>Discriminated</td>
<td>Discriminated</td>
</tr>
<tr>
<td>Discriminated</td>
<td>– or reduced</td>
<td>uP-2</td>
<td>Irregularity, cutoff</td>
<td>Solid pattern</td>
</tr>
<tr>
<td>Discriminated</td>
<td>–</td>
<td>uP-3</td>
<td>Cutoff</td>
<td>Cutoff</td>
</tr>
</tbody>
</table>

**Results**

A typical example of a uP-0 ultrasonogram is shown in Figure 2. As shown by the x-ray-computed tomography (CT) on the left, this patient had adenocarcinoma in a peripheral area of the superior segment of the right lower lobe. The ultrasonogram recorded at the chest wall above the lesion clearly depicts hypoechoic smooth curved lines between the lung and the chest wall indicated by the arrow in the picture at right. The lesion within the lung was not visible because of air within normal alveoli between the lesion and the chest wall.

A typical example of uP-1 ultrasonograms are shown in Figure 3. These two ultrasonograms, A and B, were recorded at identical portions of the chest wall above the lung lesion but at different inspiratory levels. In ultrasonogram A, pleural indentation and loculated pleural effusion between the indented pleural surface and the parietal pleura are visible. Where pleural indentation or pleural irregularity exists, a small amount of loculated effusion is almost always visible in ultrasonograms. In B, a relatively hypoechoic round area of about 1 cm in diameter corresponding to the primary lesion is clearly visible just beneath the hypoechoic curved line of the pleural surface. With these ultrasonograms, we can further confirm the smooth respiratory sliding of the lung along the chest wall. This is also one of the important ultrasonographic findings of uP-1.

Figure 4 shows an ultrasonogram and x-ray-CT picture of uP-2. A tumor echo of about 2 cm in diameter is located just beneath the chest wall. There are
Figures 3. Ultrasonograms A and B show the visceral and parietal pleurae, loculated pleural effusion and indentation and the tumor itself and show the smooth sliding of the tumor.

findings of interruption of the hypoechoic pleural lines and a widening of the pleural space filled with solid echogenic spots. All of these ultrasonographic findings suggest cancerous invasion into the parietal pleura through the visceral pleura.

Figure 5 is another example of uP-3. Figure 5-A shows cut-off sign of the visceral and parietal pleurae, extension of solid echogenic spots from the lung into the chest wall and a tumor shadow in the lung parenchyma which was lacking any respiratory movement. As shown in Figure 5 B-D, it is possible to delineate these pathologic changes selectively and more clearly by adjusting the dynamic range of the ultrasound image. In Figure 5-B, the pleural line is augmented as a white line, and suddenly cut-off by the tumor invading the chest wall. In Figure 5-C, visceral and parietal cut-offs and an invasion into the chest wall are more clearly delineated. Figure 5-D shows rib echo in the invaded tumor accompanied by an acoustic shadow as indicated by the arrows. All of these ultrasonographic findings suggest cancerous invasion of the chest wall.

Figures 4. Interruption of pleural lines and a widening of the pleural space filled with solid echogenic spots.
The accuracy of this approach based on the results obtained in this study is as follows: in a total of 65 patients with lung cancer, the agreement between ultrasonographic and operative findings was satisfactory, the accuracy of diagnosis being 77 percent (50 cases). In 26 patients with uP-0, the accuracy rate was 73 percent (19 cases). In the 11 cases of uP-1, it was 45 percent (five cases), and in the 14 cases of uP-2 and 14 cases of uP-3, they were 86 percent (12 cases) and 100 percent, (14 cases), respectively.

Misdiagnosed cases of uP-0 were all P-1, while misdiagnosed cases of uP-1 comprised two cases of P-2 and two of P-3. Two P-3 cases involved pericardial invasion and pleural adhesion, respectively. Misdiagnosed cases of uP-2 were P-1 and P-3, the latter case being pleural adhesion with pleural indentation.

DISCUSSION

It becomes more important to evaluate the extent of lung cancer before therapy, according to the advances in and variability of therapy, such as surgical, irradiation, chemical and immunologic therapy. The invasion into the pleura and chest wall is a very important factor in selecting the therapy and in estimating the prognosis of the patient with lung cancer.

Several approaches to determine pleural and chest wall invasion of lung cancer have been discussed. Among these methods, the ultrasonographic approach is useful because of its clear discrimination of various soft tissues. When we use ultrasonography to visualize the tumor abutted to the chest wall, we can visualize soft tissues of the chest wall, parietal pleura, pleural space, visceral pleura and lung clearly and can evaluate respiratory and cardiac pulsatile movement of them.

We also can distinguish lung cancer from pneumonia and atelectasis by means of the destruction or disappearance of normal bronchial and vascular echoes. We did not have an opportunity to see pulmonary infarct.

In this study, ultrasonographic evaluation of pleural and chest wall invasion of lung cancer was carried out by an electronic linear scanner. These findings were classified into four grades of uP-0, uP-1, uP-2 and uP-3, corresponding to the respective grades based on surgical findings. The surgical classification of pleural and chest wall invasion of lung cancer, which was proposed by the Japan Lung Cancer Society, is widely used in Japan and the classification as detailed previously is useful to select surgical and postsurgical therapies and to evaluate the resectability of the patient.

The total accuracy of this method was 77 percent in 65 cases. The accuracy in cases of uP-3 is 100 percent, which is the most important grade not only for judging the prognosis of the patient but also for selecting treatment. These results show that this method yielded very important and valuable information in helping us to decide whether or not surgery should be...
concluded.

Similar approaches were used with x-ray CT.\textsuperscript{13-15} Pennes et al\textsuperscript{16} evaluated 33 patients with peripheral pulmonary malignancy contiguous with a pleural surface by x-ray CT. These CT criteria included pleural thickening adjacent to the tumor, encroachment on or increased density of the extrapleural fat, asymmetry of the extrapleural soft tissues adjacent to the tumor, apparent mass invading the chest wall, and rib destruction. The CT scans were classified as positive, negative, or equivocal for invasion, and a decision matrix was constructed comparing CT results with pathologic data. The accuracy of CT was 39 percent for evaluation of invasion if equivocal CT results were counted as radiologic errors. They concluded that CT scanning has low accuracy in assessing chest wall invasion in patients with peripheral lung cancer. The low accuracy seems to be due to the fact that CT cannot discriminate chest wall, visceral pleura, parietal pleura, and tumor itself clearly and they evaluated cases mainly by shape.

Compared with these results, ultrasonography is more reliable because we can discriminate the tumor itself from other soft tissues and airless lesions such as atelectasis and pneumonia in the echo pattern of ultrasonograms.\textsuperscript{17} We sometimes used the 7.5-MHz probe with a water path, and more clearly visualized pleura and tumor only within 3 cm in depth, but we did not use a 10-MHz probe in this study because of poor penetration of ultrasound.

Recently, extended en bloc resection in the cases in which the chest wall was already invaded by the peripheral lung malignancies has been performed, and better survival rates have been reported.\textsuperscript{17-20} When operability is recognized in those cases, we can evaluate the appropriate form of operation, for instance, the site of incision and the necessity for chest wall resection based on ultrasonographic findings.

It is important that we record multiple ultrasonographic pictures with different contact angles between the chest wall and the scanner in several postures, such as the sitting, prone, supine and decubital positions, and at various inspiratory levels. Doing so helps to minimize the area of air and acoustic shadow of ribs and scapulas to get good penetration of ultrasonic waves without an artifact. It also helps to show how close the tumor is to the chest wall.\textsuperscript{21,22} In cases of other pleural diseases, such as hyaloserositis, rheumatoid diseases, asbestosis and tuberculosis, we should evaluate the data carefully as to precise clinical course and other information.

It is suggested that this approach can delineate cancerous invasion into the pleura and chest wall sufficiently well for daily clinical use and the staging of patients with lung cancer.

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