Mediastinal masses: Quantitative assessment with diffusion-weighted (DW) - and short inversion time inversion recovery (STIR) - MR imaging. What is the appropriate method for characterization of mediastinal masses on the MR images?

Poster No.: C-0089
Congress: ECR 2014
Type: Scientific Exhibit
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Keywords: Image verification, Imaging sequences, MR-Diffusion/Perfusion, Mediastinum
DOI: 10.1594/ecr2014/C-0089

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Aims and objectives

Primary tumors and cysts of the mediastinum are relatively uncommon: they represent approximately 3% of tumors within the chest (1). However, there are chances to see such patients in daily practices because they include various diseases occurring in various age groups. We can often successfully diagnose mediastinal masses including lymph nodes with and/or without metastasis by carefully considering the clinical data such as patient's age, gender, and laboratory findings and the image findings such as site, size, shape, and internal characteristics of a mass and relation between a mass and neighboring structures. Evaluation the image findings in detail is essential for choosing the appropriate treatment strategy.

The initial workup of a suspected mediastinal mass involves obtaining postanterior and lateral chest radiographs. This can provide information pertaining to the size, anatomic location, density, and composition of the mass. CT and MRI is used to further characterize mediastinal masses and their relationship to surrounding structures as well as to identify cystic, vascular, and soft-tissue structures. Although nuclear scans and biochemical studies such as positron emission tomography (PET) can be used to further characterize a lesion, tissue diagnosis is almost always required. If a mass likely to be benign after initial workup, it can be removed surgically without biopsy. Otherwise, a diagnostic biopsy specimen can be obtained by transthoracic or transbronchial needle aspiration, mediastinoscopy, anterior mediastinotomy, or video-assisted thoracic surgery (VATS), depending on the anatomic location and radiographic appearance of the lesion (2). Therefore, a more accurate noninvasive method for determining mediastinal mass status would be useful for assigning patients to the most appropriate staging procedure.

Diffusion-weighted (DW) MR images and apparent diffusion coefficient (ADC) values add important information to findings obtained with conventional MR imaging and have been widely used in brain imaging, primarily for the evaluation of acute ischemic stroke, intracranial tumors, and demyelinating disease (3-5). With the advent of the echo-planar MR imaging technique, DW MR imaging of the abdomen and thoracic cavity has become possible with fast imaging times, which minimize the effects of gross physiologic motion from respiration and cardiac movement (6). The application of DW echo-planar MR imaging has extended to the breast and prostatic regions and allows for differentiation between tumor and normal tissue (7,8). DW MR imaging has also been used in the hepatic and thoracic lesion to help differentiate between malignant and benign lesions (9,10). ADCs are expected to vary according to the microstructures of tissues or pathophysiologic states that are intrinsic to different tissues, and are assumed to be correlation to cellularities, capillary perfusion, necrosis, mucin, etc.(10-17). In addition, it was reported that quantitative and qualitative analyses of STIR turbo-spin-echo(TSE) MR imaging enable differentiation of lymph nodes with metastasis from those without with sensitivity values that are greater than or equal to those of FDG-PET (18). Therefore, we hypothesized that on DW MR images, signal intensities, ADCs of mediastinal masses...
change by various factors as well as those of tumors in other various areas and correlate well with pathological findings.

Thus, the purpose of our study was to evaluate DW- and STIR- MR Imaging for characterization of mediastinal masses by using quantitative analysis. In addition, the correlations with the pathological findings were examined.
Methods and materials

This study was approved by the institutional review board, and informed consent was waived.

Patients

Thirty-five patients suspected of having mediastinal mass on the basis of findings at postanterior and lateral chest radiographs or CT were examined with contrast material-enhanced CT, DW- and STIR- MR imaging at Hokkaido University Hospital within two weeks before anterior mediastinotomy, or VATS, during the period of (2007 and 2009). These 35 patients (mean age, 61.7 years; age range, 17-81 years) included 22 men and 13 women. The final diagnosis of mediastinal mass was based on pathologic findings in resected specimens.

MR Imaging Examination

All MR examinations were performed with a 1.5-T clinical imager (Avanto; Siemens, Erlangen, Germany) by using a body phased-array coil. Patients were in the supine position throughout the examination. Prior to DW-and STIR-MR imaging, T1-and T2-weighted images were obtained in the transverse plane in each patient. Transverse DW MR images were obtained with b values of 50 and 1000 sec/mm$^2$. The components of the applied gradients for diffusion weighting, which consisted of three orthogonal gradients, were equal in read, phase, and section orientation to obtain maximum total gradient strength. DW half-Fourier single-shot turbo spin-echo imaging was used in this study. Other parameters were as follows: repetition time msec/echo time msec, 3000/69; effective band width, 2056 Hz/pixel; number of signals acquired, two; matrix, 78 × 128; field of view, 45 × 28.1 cm; and section thickness, 6mm. Transverse breath-hold STIR MR images were obtained with the following parameters: 3830/91; inversion time, 170msec; matrix, 320 × 192; field of view, 35 × 26.3 cm; and section thickness, 6mm; a 0.9% saline phantom was placed alongside the chest wall at imaging of each patient. The saline phantom consisted of 100 mL of 0.9% saline within a plastic tube covered by a plastic cap.

Lymph Node Sampling and Mediastinal Tumor Extraction and Histopathologic Examination

All operations were systematically performed by the surgeon.

All resected lymph nodes and tumors were fixed in 10% buffered formalin and were routinely processed before histologic examination. Each histologic specimen contained the largest cut surface of each lymph node and tumor and evaluated by at least two
pathologists. In addition, all lymph nodes and tumors were histologically reviewed for
confirmation independently by a single pathologist.

**Analysis of MR images**

**Quantitative analysis of DW MR images**

On DW MR images obtained with low- and high- b values, all signal intensities were
measured in circular or oval regions of interest drawn over lymph node, tumor, spinal
cord, and the phantom of 100 mL of 0.9% saline by a chest radiologist with 15 years of
experience (J.N.). The regions of interest drawn over the lymph node, tumor, spinal
cord, and saline phantom encompassed the entire cross-sectional area of the lymph
node, tumor, spinal cord, and saline phantom (3-10 mm in diameter). All signal intensities
of mediastinal masses were normalized by comparing them with the signal intensities of
the spinal cord and the 0.9% saline phantom to produce mediastinal mass-spinal cord (low b MmScR1 and high b MmScR2) and mediastinal mass-saline ratio (low b MmSR1 and high b MmSR2).

The low b MmScR1 was the formula low b MmScR1 = \( \frac{SI_{MM}}{SI_{SC}} \),
where \( SI_{MM} \) is the signal intensity of the mediastinal mass, \( SI_{SC} \) is
the signal intensity of the spinal cord on DW MR image obtained with
low b value.

The high b MmScR2 was the formula high b MmScR2 = \( \frac{SI_{MM}}{SI_{SC}} \),
where \( SI_{MM} \) is the signal intensity of the mediastinal mass, \( SI_{SC} \) is
the signal intensity of the spinal cord on DW MR image obtained with
high b value.

The low b MmSR1 was the formula low b MmSR1 = \( \frac{SI_{MM}}{SI_{SP}} \),
where \( SI_{MM} \) is the signal intensity of the mediastinal mass, \( SI_{SP} \) is
the a signal intensity of the saline phantom on DW MR image
obtained with low b value.

The high b MmSR2 was the formula high b MmSR2 = \( \frac{SI_{MM}}{SI_{SP}} \),
where \( SI_{MM} \) is the signal intensity of the mediastinal mass, \( SI_{SP} \) is
the a signal intensity of the saline phantom on DW MR image obtained with high $b$ value.

**ADC** values were calculated with a linear regression analysis of the natural log of signal intensity versus the gradient factor according to the following equation: 

$$ADC = -\left[ \ln \left( \frac{S_h}{S_l} \right) \right] \div (b_h - b_l)$$

$S_h$ and $S_l$ were the signal intensities in the region of interest obtained with two different gradient factors ($b_h$ and $b_l$). In this study, $b_h$ was 1000 sec/mm$^2$ and $b_l$ was 50 sec/mm$^2$. Regions of interest with a diameter of 3-10 mm were positioned for the measurement of **ADC** in each mediastinal mass. The regions of interest were placed on the multiple areas of mediastinal masses.

**Quantitative analysis of STIR MR images**

Similarly, from STIR MR images, all signal intensities of mediastinal masses were normalized by comparing them with the signal intensities of the spinal cord and the 0.9% saline phantom to produce mediastinal mass-spinal cord ($MmScR3$) and mediastinal mass-saline ratio ($MmSR3$).

The $MmScR3$ was the formula $MmScR3 = \frac{SI_{MM}}{SI_{SC}}$, where $SI_{MM}$ is the signal intensity of the mediastinal mass and $SI_{SC}$ is the signal intensity of the spinal cord on STIR MR image.

The $MmSR3$ was the formula $MmSR3 = \frac{SI_{MM}}{SI_{SC}}$, where $SI_{MM}$ is the signal intensity of the mediastinal mass and $SI_{SC}$ is the signal intensity of the spinal cord on STIR MR image.

Each $MmScR1s$, $MmScR2s$, $MmSR1s$, $MmSR2s$, **ADCs**, $MmScR3s$, and $MmSR3s$ were compared by using pathologic diagnosis as the standard of reference.

**Data and Statistical Analysis**

The $MmScR1s$, $MmScR2s$, $MmSR1s$, $MmSR2s$, **ADCs**, $MmScR3s$, and $MmSR3s$ of malignant lesions and those of benign lesions were compared by Tukey honestly significantly difference multiple comparison testing.

To evaluate the ability of $MmScR1$, $MmScR2$, $MmSR1$, $MmSR2$, **ADC**, $MmScR3$, and $MmSR3$ to enable the differentiation of malignant lesions from benign lesions, the feasible threshold of $MmScR1$, $MmScR2$, $MmSR1$, $MmSR2$, **ADC**, $MmScR3$, and $MmSR3$ on a per-mass basis was determined by using a receiver operating characteristic-based positive test.
Receiver operating characteristic analysis was used to evaluate the effectiveness of the MmScR1, MmScR2, MmSR1, MmSR2, ADC, MmScR3, and MmSR3 for revealing malignant lesions. Sensitivity, specificity were calculated for each level of MmScR1, MmScR2, MmSR1, MmSR2, ADC, MmScR3, and MmSR3 by varying the MmScR1, MmScR2, MmSR1, MmSR2, ADC, MmScR3, and MmSR3 that signified a positive test (ie, the threshold value).

Feasible threshold values at quantitative analyses of DW- and STIR- MR images were tested for ability to enable a correct diagnosis on a per-patient basis.

Overlapping lesions evaluated with the feasible threshold value were also histologically reviewed.

The abilities of quantitative analyses of DW- and STIR- MR images to enable a correct diagnosis were compared among quantitative analyses of DW- and STIR- MR images on a per-patient basis by using the Mc-Nemar test.

For all statistical analyses, a P value of less than .05 was considered to indicate a statistically significant difference.
Results

All DW- and STIR- MR examinations were completed successfully without adverse effects.

Then, 60 lesions in 35 patients, qualified for MmScR1, MmScR2, MmSR1, MmSR2, ADC, MmScR3, and MmSR3 measurement, and their pathologically diagnosis are listed in Table 1.

**Table 1 on page 21**
Table 1: Diagnosis of 60 lesions in 35 patients

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

The Numbers and mean MmScR1s, MmScR2s, MmSR1s, MmSR2s, ADCs, MmScR3s, and MmSR3s of mediastinal masses are shown in Table 2.

Table 2 on page 21

![Table 2](image)

Table 2: Numbers and mean MmScR1s, MmScR2s, MmSR1s, MmSR2s, ADCs, MmScR3s, and MmSR3s of mediastinal masses

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

The mean MmScR2, MmSR2, ADC, MmScR3, and MmSR3 for malignant lesions were significantly different from those for benign lesions (P < 0.05). However, there were no significant differences in the mean MmScR2, MmSR2, ADC, MmScR3, and MmSR3 for mediastinal masses among histologic types (P > 0.05).

Results with the receiver operating characteristic-based positive test for MmScR2, MmSR2, ADC, MmScR3, and MmSR3 on a per-mass basis are shown in Figure 1-5.

Fig. 1 on page 22
Fig. 1: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmScR2 on a per-mass basis. # = sensitivity, # = specificity. An MmScR2 of 0.520 was adopted as the threshold for a positive test.

**References:** Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

**Figure 1.**

An **MmScR2** of 0.520 was adopted as the threshold for a positive test (ie, an **MmScR2** greater than 0.520 indicated that that a mass is a malignant lesion). The **sensitivity** and **specificity** for differentiating malignant lesions from benign lesions by using this threshold **MmScR2** were **70.8%** and **72.2%**, respectively.

*Overlapped lesions*
The MmScR2s of 7 (29.2%) of 24 malignant lesions were overlapped with those of benign lesions (ie, the MmScR2s were less than or equal to 0.520). For one overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Six overlapped malignant lesions, causes that had become the false negatives were uncertain.

And the MmScR2s of 10 (27.8%) of 36 benign lesions were overlapped with those of malignant lesions (ie, the MmScR2s were greater than 0.520). For ten overlapped benign lesions, causes that had become the false positives were uncertain.

Fig. 2 on page 23
Fig. 2: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmSR2 on a per-mass basis. # = sensitivity, # = specificity. An MmSR2 of 0.535 was adopted as the threshold for a positive test.

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

Figure 2.

An MmSR2 of 0.535 was adopted as the threshold for a positive test (ie, an MmSR2 greater than 0.535 indicated that that a mass is a malignant lesion). The sensitivity and specificity for differentiating malignant lesions from benign lesions by using this threshold MmSR2 were 70.8% and 69.4%, respectively.

Overlapped lesions

The MmSR2s of 7 (29.2%) of 24 malignant lesions were overlapped with those of benign lesions (ie, the MmSR2s were less than or equal to 0.535). For One overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Six overlapped malignant lesions, causes that had become the false negatives were uncertain.

And the MmSR2s of 11 (30.6%) of 36 benign lesions were overlapped with those of malignant lesions (ie, the MmSR2s were greater than 0.535). For Eleven overlapped benign lesions, causes that had become the false positives were uncertain.

Fig. 3 on page 24
Fig. 3: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the ADC on a per-mass basis. # = sensitivity, # = specificity. An ADC of \(1.550 \times 10^{-3}\) mm\(^2\)/sec was adopted as the threshold for a positive test.

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

Figure 3.

An ADC of \(1.550 \times 10^{-3}\) mm\(^2\)/sec was adopted as the threshold for a positive test (ie, an ADC less than \(1.550 \times 10^{-3}\) mm\(^2\)/sec indicated that that a mass is a malignant lesion). The sensitivity and specificity for differentiating malignant lesions from benign lesions by using this threshold ADC were 87.5% and 86.1%, respectively.
Overlapped lesions

The ADCs of 3 (12.5%) of 24 malignant lesions were overlapped with those of benign lesions (ie, the ADCs were greater than or equal to $1.550 \times 10^{-3} \text{mm}^2/\text{sec}$). For One overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Two metastatic adenocarcinomas were producing abundant intra- and extra-cellular mucin.

And the ADCs of 5 (13.9%) of 36 benign lesions were overlapped with those of malignant lesions (ie, the ADCs were less than $1.550 \times 10^{-3} \text{mm}^2/\text{sec}$). Two overlapped lymph nodes without metastasis were infiltrated by inflammatory cells including many eosinophils, suggesting a specific inflammatory process of uncertain etiology in these cases. Three overlapped areas were those in Giant cell tumor.

Fig. 4 on page 25
Fig. 4: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmScR3 on a per-mass basis. # = sensitivity, # = specificity. An MmScR3 of 1.045 was adopted as the threshold for a positive test.

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

Figure 4

An MmScR3 of **1.045** was adopted as the threshold for a positive test (ie, an MmScR3 greater than **1.045** indicated that a mass is a malignant lesion). The **sensitivity** and **specificity** for differentiating malignant lesions from benign lesions by using this threshold MmScR3 were **75.0%** and **72.2%**, respectively.

Overlapped lesions
The MmScR3s of 6 (25.0%) of 24 malignant lesions were overlapped with those of benign lesions (ie, the MmScR3s were less than or equal to 1.045). For One overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Five overlapped malignant lesions, causes that had become the false negatives were uncertain.

And the MmScR3s of 10 (27.8%) of 36 benign lesions were overlapped with those of malignant lesions (ie, the MmScR3s were greater than 1.045). For Nine overlapped benign lesions, causes that had become the false positives were uncertain. One overlapped lymph node without metastasis was anthracosillicotic node.

Fig. 5 on page 26
Fig. 5: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmSR3 on a per-mass basis. # = sensitivity, # = specificity. An MmSR3 of 0.353 was adopted as the threshold for a positive test. References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

**Figure 5**

An MmSR3 of 0.353 was adopted as the threshold for a positive test (ie, an MmSR3 greater than 0.353 indicated that that a mass is a malignant lesion). The sensitivity and specificity for differentiating malignant lesions from benign lesions by using this threshold MmSR3 were 87.5% and 80.6%, respectively.

**Overlapped lesions**

The MmSR3s of 3 (12.5%) of 24 malignant lesions were overlapped with those of benign lesions (ie, the MmSR3s were less than or equal to 0.353). For One overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Two overlapped malignant lesions, causes that had become the false negatives were uncertain.

And the MmSR3s of 7 (19.4%) of 36 benign lesions were overlapped with those of malignant lesions (ie, the MmSR3s were greater than 0.353). For Four overlapped benign lesions, causes that had become the false positives were uncertain. Two overlapped areas were those in mature teratoma. One overlapped lymph node without metastasis was anthracosillicotic and hyalinized node.

Quantitative analyses by using ADCs and MmSR3s enable differentiation of malignant mediastinal lesions from benign mediastinal lesions with sensitivity-and specificity- values that are greater than or equal to quantitative analyses by using MmScR2s, MmSR2s, and MmScR3s.

However, there was no significant difference (P > 0.05) among quantitative analyses of MmScR2s, MmSR2s, ADCs, MmScR3s, and MmSR3s for differentiating malignant mediastinal lesions from benign mediastinal lesions.

Representative examples are shown in Figures 6 - 8, respectively.

Fig. 6 on page 27
**Fig. 6:** Images in 44-years-old woman with lymph nodes containing metastasis from thyroid papillary carcinoma. 

- **a.** Transverse contrast-enhanced CT scan shows right anterior mediastinal node.
- **b.** Transverse DW MR image obtained with diffusion gradient 50sec/mm² shows lymph node as high-signal-intensity area.
- **c.** Transverse DW MR image obtained with diffusion gradient 1000sec/mm² also shows lymph node as intermediate-signal-intensity area.
- **d.** Transverse STIR MR image (repetition time msec/echo time msec/inversion time msec, 3830/91/170) shows lymph node as high-signal-intensity area. ADC of the mass was 1.28×10⁻³mm²/sec. On DW MR image with a diffusion gradient of bh = 1000 sec/mm², MmScR² and MmSR² were 0.611 and 0.640, respectively. On STIR MR image, MmScR³ and MmSR³ were 1.043 and 0.367, respectively. Analysis of histologic specimen from right anterior mediastinal node revealed nodular lesions composed of metastasizing papillary carcinoma.

**References:** Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

**Fig. 7** on page 28
Fig. 7: Images in 65-years-old woman with lymph nodes containing metastasis from Lung adenocarcinoma and producing abundant intra- and extra- cellular mucin. 
a.Transverse contrast-enhanced CT scan shows right hilar node. 
b.Transverse DW MR image obtained with diffusion gradient 50sec/mm2 shows lymph node as high-signal-intensity area. 
c.Transverse DW MR image obtained with diffusion gradient 1000sec/mm2 also shows lymph node as intermediate-signal-intensity area. 
d.Transverse STIR MR image (repetition time msec/echo time msec/inversion time msec, 3830/91/170) shows lymph node as high-signal-intensity area. ADC of the mass was 1.630×10-3mm2/sec. On DW MR image with a diffusion gradient of bh = 1000 sec/mm2, MmScR2 and MmSR2 were 0.888 and 1.115, respectively. On STIR MR image, MmScR3 and MmSR3 were 1.369 and 0.479, respectively. Analysis of histologic specimen from right hilar node revealed nodular lesions composed of metastasizing adenocarcinoma producing abundant intra- and extra- cellular mucin. 

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP

Fig. 8 on page 29
Fig. 8: Images in 22-years-old man with Mature teratoma. a. Transverse contrast-enhanced CT scan shows left anterior mediastinal mass. b. Transverse DW MR image obtained with diffusion gradient 50sec/mm² shows mass as high-signal-intensity area. c. Transverse DW MR image obtained with diffusion gradient 1000sec/mm² also shows mass as intermediate-signal-intensity area. d. Transverse STIR MR image (repetition time msec/effective echo time msec/inversion time msec, 3830/91/170) shows mass as high-signal-intensity area. ADCs of the central- and peripheral- zone of the mass were 3.39×10⁻³mm²/sec (central), 1.56×10⁻³mm²/sec (peripheral), respectively. On DW MR images with a diffusion gradient of bh = 1000 sec/mm², MmScR² were 2.209 (central) and 1.791 (peripheral), respectively. MmSR² were 0.594 (central) and 2.222 (peripheral), respectively. On STIR MR image, MmScR³ were 3.342 (central) and 1.845 (peripheral), respectively. MmSR³ were 0.722 (central) and 0.488 (peripheral), respectively. Analysis of histologic specimen from left anterior mediastinal mass revealed mass lesion composed of Mature teratoma. Fat that accompanied fibrosis was seen in the mass, and sebaceous gland, bone, and cartilage were adjacent to it.

References: Diagnosis Center, Medical image Lab, Inc. - Sapporo/JP
### Diagnosis of 60 lesions in 35 patients

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<th>Diagnosis of lesions</th>
<th>No. of Lesions</th>
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<td>Lymph nodes without metastasis (n=23)</td>
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<tr>
<td>Normal</td>
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<tr>
<td>Anthracosilicotic nodes</td>
<td>8</td>
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<tr>
<td>Hyalinized nodes</td>
<td>3</td>
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<tr>
<td>Sarcoid reaction</td>
<td>3</td>
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<tr>
<td>Nodes infiltrated by inflammatory cells including many eosinophils</td>
<td>2</td>
</tr>
<tr>
<td>Anthracosilicotic &amp; Hyalinized nodes</td>
<td>1</td>
</tr>
<tr>
<td>Lymph nodes with metastasis (n=19)</td>
<td></td>
</tr>
<tr>
<td>From lung adenocarcinoma</td>
<td>10</td>
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<tr>
<td>From lung squamous cell carcinoma</td>
<td>2</td>
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<tr>
<td>From lung small cell carcinoma</td>
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<td>Malignant lymphoma (n=6)</td>
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<tr>
<td>Mature teratoma</td>
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<td>Giant cell tumor</td>
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<tr>
<td>Sarcoidosis</td>
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<td><strong>Total</strong></td>
<td><strong>60</strong></td>
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</table>

**Table 1:** Diagnosis of 60 lesions in 35 patients

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Table 2: Numbers and mean MmScR1s, MmScR2s, MmSR1s, MmSR2s, ADCs, MmScR3s, and MmSR3s of mediastinal masses

<table>
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<tr>
<th></th>
<th>MmScR1*</th>
<th>MmSR1*</th>
<th>MmScR2*</th>
<th>MmSR2*</th>
<th>ADC**</th>
<th>MmScR3*</th>
<th>MmSR3*</th>
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<td>Malignant lesions (n=94)</td>
<td>0.862 ± 0.361</td>
<td>0.412 ± 0.377</td>
<td>0.739 ± 0.399</td>
<td>0.889 ± 0.474</td>
<td>1.374 ± 0.161</td>
<td>1.292 ± 0.306</td>
<td>0.392 ± 0.072</td>
</tr>
<tr>
<td>Benign lesions (n=36)</td>
<td>0.806 ± 0.764</td>
<td>0.276 ± 0.286</td>
<td>0.506 ± 0.393</td>
<td>0.573 ± 0.535</td>
<td>1.777 ± 0.385</td>
<td>0.925 ± 0.534</td>
<td>0.271 ± 0.129</td>
</tr>
</tbody>
</table>

Note.
* Data are means ± SDs
** Data are means ± SDs (×10^3 mm²/sec)
† Mean MmScR2 of Malignant mediastinal masses was significantly higher (P < 0.05) than that of Benign mediastinal masses.
‡‡ Mean MmScR3 of Malignant mediastinal masses was significantly higher (P < 0.001) than that of Benign mediastinal masses.
†† Mean MmSR2 of Malignant mediastinal masses was significantly lower (P < 0.0001) than that of Benign mediastinal masses.
‡‡‡ Mean MmSR3 of Malignant mediastinal masses was significantly higher (P < 0.0001) than that of Benign mediastinal masses.
**Fig. 1:** Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmScR2 on a per-mass basis. # = sensitivity, # = specificity. An MmScR2 of 0.520 was adopted as the threshold for a positive test.

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Fig. 2: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmSR2 on a per-mass basis. # = sensitivity, # = specificity. An MmSR2 of 0.535 was adopted as the threshold for a positive test.

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**Fig. 3:** Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the ADC on a per-mass basis. $\# =$ sensitivity, $\# =$ specificity. An ADC of $1.550 \times 10^{-3}$ mm$^2$/sec was adopted as the threshold for a positive test.

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Fig. 4: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmScR3 on a per-mass basis. # = sensitivity, # = specificity. An MmScR3 of 1.045 was adopted as the threshold for a positive test.

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Fig. 5: Graph shows results with receiver operating characteristic-based positive test at quantitative analysis with the MmSR3 on a per-mass basis. # = sensitivity, # = specificity. An MmSR3 of 0.353 was adopted as the threshold for a positive test.

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**Fig. 6:** Images in 44-years-old woman with lymph nodes containing metastasis from thyroid papillary carcinoma. 

a. Transverse contrast-enhanced CT scan shows right anterior mediastinal node.  
b. Transverse DW MR image obtained with diffusion gradient 50sec/mm² shows lymph node as high-signal-intensity area.  
c. Transverse DW MR image obtained with diffusion gradient 1000sec/mm² also shows lymph node as intermediate-signal-intensity area.  
d. Transverse STIR MR image (repetition time msec/effective echo time msec/inversion time msec, 3830/91/170) shows lymph node as high-signal-intensity area. ADC of the mass was 1.28×10⁻³mm²/sec. On DW MR image with a diffusion gradient of bh = 1000 sec/mm², MmScR² and MmSR² were 0.611 and 0.640, respectively. On STIR MR image, MmScR³ and MmSR³ were 1.043 and 0.367, respectively. Analysis of histologic specimen from right anterior mediastinal node revealed nodular lesions composed of metastasizing papillary carcinoma.

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Fig. 7: Images in 65-years-old woman with lymph nodes containing metastasis from Lung adenocarcinoma and producing abundant intra- and extra-cellular mucin. a.Transverse contrast-enhanced CT scan shows right hilar node. b.Transverse DW MR image obtained with diffusion gradient 50sec/mm² shows lymph node as high-signal-intensity area. c.Transverse DW MR image obtained with diffusion gradient 1000sec/mm² also shows lymph node as intermediate-signal-intensity area. d.Transverse STIR MR image (repetition time msec/effective echo time msec/inversion time msec, 3830/91/170) shows lymph node as high-signal-intensity area. ADC of the mass was 1.630×10⁻³mm²/sec. On DW MR image with a diffusion gradient of bh = 1000 sec/mm², MmScR² and MmSR² were 0.888 and 1.115, respectively. On STIR MR image, MmScR³ and MmSR³ were 1.369 and 0.479, respectively. Analysis of histologic specimen from right hilar node revealed nodular lesions composed of metastasizing adenocarcinoma producing abundant intra- and extra-cellular mucin.
Fig. 8: Images in 22-years-old man with Mature teratoma. a. Transverse contrast-enhanced CT scan shows left anterior mediastinal mass. b. Transverse DW MR image obtained with diffusion gradient 50 sec/mm² shows mass as high-signal-intensity area. c. Transverse DW MR image obtained with diffusion gradient 1000 sec/mm² also shows mass as intermediate-signal-intensity area. d. Transverse STIR MR image (repetition time msec/effective echo time msec/inversion time msec, 3830/91/170) shows mass as high-signal-intensity area. ADCs of the central- and peripheral-zone of the mass were 3.39 $\times$ 10⁻³ mm²/sec (central), 1.56 $\times$ 10⁻³ mm²/sec (peripheral), respectively. On DW MR images with a diffusion gradient of $b_h = 1000$ sec/mm², MmScR2 were 2.209 (central) and 1.791 (peripheral), respectively. MmSR2 were 0.594 (central) and 2.222 (peripheral), respectively. On STIR MR image, MmScR3 were 3.342 (central) and 1.845 (peripheral), respectively. MmSR3 were 0.722 (central) and 0.488 (peripheral), respectively. Analysis of histologic specimen from left anterior mediastinal mass revealed mass lesion composed of Mature teratoma. Fat that accompanied fibrosis was seen in the mass, and sebaceous gland, bone, and cartilage were adjacent to it.

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Conclusion

The mediastinum is demarcated by the pleural cavities laterally, the thoracic inlet superiorly, and the diaphragm inferiorly. Although mediastinal tumors are relatively uncommon, they include various diseases and compositions. They occasionally show the specific findings. Although we can often successfully diagnose mediastinal masses including lymph nodes with and/or without metastasis by carefully considering the image findings such as site, size, shape, and internal characteristics of a mass and relation between a mass and neighboring structures, mediastinal malignancies are uncommon, it is occasionally difficult for distinguishing whether they are benign- or malignant-lesions. Accurate evaluation of the benign- or malignant- lesion is a critical factor which may determine the appropriate treatment strategy for patients with mediastinal mass. Although PET has been used to differentiate benign- from malignant- lesions, the diagnostic capability of PET is limited. Therefore, A more accurate noninvasive method for determining mediastinal mass status would be useful for assigning patients to the most appropriate procedure (1,2,19-25). Recently, DW MR imaging has also been used in the hepatic and thoracic lesion to help differentiate between malignant and benign lesions (9,10). Although the total number of patients in this study was small, we found that MmScR2, MmSR2, ADC, MmScR3, and MmSR3 had a significant correlation with the differential diagnosis of benign- and malignant-lesions in the mediastinum.

In this study, our results show that mean ADC of malignant lesions was significantly lower than those of benign lesions and mean MmScR2, MmSR2, MmScR3, and MmSR3 of malignant lesions were significantly higher than those of benign lesions. And the sensitivity, specificity of ADC and MmSR3 were greater than those of MmScR2, MmSR2, and MmScR3.

ADC refers to the specific diffusion capacity of a biologic tissue. ADC depends largely on the presence of barriers to diffusion within the water microenvironment, namely, cell membranes, tight junctions, fibers, macromolecules, and cell organelles (26). Consequently, compartments within different cellular structures may exhibit dissimilar ADCs, and the ADC can therefore aid in determining different tissue types and tissue characteristics (27,28). Therefore, significant differences between benign- and malignant- lesions in the mediastinum were observed in this study.

When $1.550 \times 10^{-3} \text{mm}^2/\text{sec}$ was adopted as the feasible ADC threshold value, ADCs of 3 (12.5%) of 24 areas in malignant lesions were overlapped with those in benign lesions. In two of them, metastatic lymph nodes from lung adenocarcinoma was producing abundant intra- and extra- cellular mucin. One overlapped lymph node had metastasis from well-differentiated adenocarcinoma. And the ADCs of 5 (12.9%) of 36 benign lesions were overlapped with those of malignant lesions( ie, the ADCs were less than $1.550 \times 10^{-3} \text{mm}^2/\text{sec}$). Two overlapped lymph nodes without metastasis were infiltrated by inflammatory cells including many eosinophils, suggesting a specific inflammatory process of uncertain
etiology in these cases. Three overlapped areas were those in Giant cell tumor. Previous studies have revealed a significant correlation between ADC and tumor cellularity (10-17). Tumor cellularity may be an important factor influencing ADCs in viable tumor tissue. In this study, it was thought that the degree of such pathologic changes as amount of mucin production, and infiltrating eosinophils within a lymph node affected the changes in ADC and result in some overlap between areas in malignant lesions and those in benign lesions. Oppositely, it was thought that the degree of such pathologic changes as hyalinization and anthracosis, as well as epithelioid cell granulomas did not affect the changes in ADC.

When 0.353 was adopted as the feasible MmSR3 threshold value, MmSR3s of 3 ( 12.5% ) of 24 areas in malignant lesions were overlapped with those in benign lesions. For One overlapped malignant lesion had metastasis from well-differentiated adenocarcinoma. Two overlapped malignant lesions, causes that had become the false negatives were uncertain. And the MmSR3s of7 ( 19.4% ) of 36 benign lesions were overlapped with those of malignant lesions. For Four overlapped benign lesions, causes that had become the false positives were uncertain. Two overlapped areas were those in mature teratoma. One overlapped lymph node without metastasis was anthracosillicotic and hyalinized node. It was thought that the degree of such pathologic changes as amount of sebaceous gland, bone, cartilage, hyalinization and anthracosis affected the changes in MmSR3.

At comparison of the results of quantitative analyses by using ADCs and MmSR3s, we found that for distinguishing malignant lesions from benign lesions in the mediastinum, quantitative analysis by using ADCs had comparatively high sensitivity, specificity equal to that by using MmSR3s.

There were several limitation to our study. We performed radiologic-pathologic correlation with DW- and STIR- MRI imaging but not with FDG-PET. Therefore, a larger prospective directly comparative study involving FDG-PET would be required to determine the true value of DW- and STIR- MR imaging for the diagnosis of the mediastinal mass.

In conclusion, MmScR2, MmSR2, ADC, MmScR3, and MmSR3 of mediastinal masses correlated well with pathological findings. Quantitative analyses of DW- and STIR- MR images by using MmScR2, MmSR2, ADC, MmScR3, and MmSR3 enable characterization of mediastinal masses. ADCs and MmSR3 measurement may be especially useful.
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