Assessment of MR Imaging as a Tool to Differentiate between the Major Histological Types of Uterine Sarcomas

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Objectives: We retrospectively compared and quantified magnetic resonance (MR) images to distinguish major histological types of uterine sarcomas and malignant and benign tumors.

Methods: MR images were obtained from patients who underwent preoperative examinations. We compared 25 pathologically confirmed uterine sarcomas (8 leiomyosarcomas, 11 carcinosarcomas, 6 endometrial stromal sarcomas) with 25 uterine leiomyomas. MR findings included tumor size, location, contour, signal intensity (SI), and contrast enhancement. Analysis focused on the contrast ratio (CR) of SI in T2-weighted images for the areas of lowest, highest, and main SI of each tumor as well as the contrast-enhanced ratio (CER) for the main solid part of each tumor in contrast-enhanced T1-weighted images. We evaluated diffusion-weighted (DW) images and apparent diffusion coefficient (ADC) values in 18 tumors (4 sarcomas, 14 leiomyomas).

Results: Uterine sarcomas and leiomyomas differed significantly in tumor location, contour, hemorrhaging, necrotic and cystic components, CR for the area of lowest SI ($P < 0.05$), CR for the area of main SI ($P < 0.01$), and CER ($P < 0.05$). Leiomyosarcomas were larger than carcinosarcomas or endometrial stromal sarcomas, and the CR for the area of lowest SI of leiomyosarcomas ($P < 0.05$) was significantly lower. The CER for endometrial stromal sarcomas ($P < 0.05$) showed the most homogeneous enhancement. Hemorrhagic or necrotic and cystic components were found more often in larger tumors, although there was no significant difference in their occurrence between sarcoma types. All uterine sarcomas showed high intensity on DW images. The ADC values were lower of uterine sarcomas than leiomyomas, although the difference was not statistically significant.

Conclusion: Quantitative assessment using the CR or CER was useful for distinguishing benign and malignant uterine tumors as well as major histological types of uterine sarcomas.

Keywords: contrast ratio, contrast-enhanced ratio, histological differentiation, quantitative assessment, uterine sarcoma

Introduction

Uterine sarcomas are rare tumors, with an annual incidence of 1.7 per 100,000 females, and they constitute about 10% of all malignancies of the uter-
The major histological types are leiomyosarcomas (38 to 46% of uterine sarcomas), carcinosarcomas (27 to 48%), and endometrial stromal sarcomas (10 to 15%). Sarcomas are the most devastating uterine malignancies, characterized by aggressive behavior, rapid growth, and a high rate of dissemination. Five-year survival rates are 19 to 41% for leiomyosarcomas, 21 to 62% for carcinosarcomas, and 45 to 61% for endometrial stromal sarcomas. The prognosis of leiomyosarcomas tends to worsen with age, higher tumor grade and stage, and lack of primary surgical treatment. Carcinosarcomas are highly aggressive tumors with worse prognoses than ordinary endometrial carcinomas. Early stage and low grade endometrial stromal sarcomas have a 97% survival rate but require long-term follow-up because of their characteristic late recurrences. Standardized treatments for uterine sarcomas have not been established, and treatments differ according to the histological subtype. Because of these diagnostic, prognostic, and therapeutic differences, magnetic resonance (MR) imaging becomes an important tool for the initial diagnosis of uterine sarcoma. Several studies have presented MR findings of uterine sarcoma, but diagnosing and distinguishing specific sarcoma groups have been difficult because of the variability of their malignant components, including hemorrhage and necrosis.

We believe no study has assessed and compared the MR features of each uterine sarcoma group. Accordingly, we attempted to distinguish the major histological types of uterine sarcomas and malignant and benign tumors through a retrospective comparison and quantification of MR images.

**Materials and Methods**

**Patients**

An institutional review board approved this retrospective study and waived informed consent. We selected the clinical records and MR images of 25 pathologically confirmed uterine sarcomas (8 leiomyosarcomas, 11 carcinosarcomas, 6 endometrial stromal sarcomas) from patients who underwent preoperative MR examinations between January 1, 2001 and September 30, 2010. The median duration between MR imaging and surgery was 33 days (range, 20 to 52 days). Patients were interviewed to ascertain clinical characteristics that included age, menopausal status, symptoms, pregnancy, childbirth history, medical history, medication history, and presence of infectious diseases. One patient with carcinosarcoma and one with endometrial stromal sarcoma received gonadotropin-releasing hormone analogue treatment before surgery, and a patient with leiomyosarcoma received tamoxifen therapy after breast cancer surgery. Another patient with carcinosarcoma was an atomic-bomb survivor. We also reviewed 25 pathologically confirmed uterine leiomyomas, excluding variants such as red degeneration or lipoleiomyoma, for comparison with uterine sarcomas. We randomly selected patients with uterine leiomyoma from the same period as the patients with uterine sarcoma, eight of whom received gonadotropin-releasing hormone analogue treatment before surgery.

**MR imaging techniques**

MR imaging was performed with one of three 1.5-tesla MR units (Gyrosan ACS-NT PT1000, Philips Medical Systems, The Netherlands; Magnex EPIOS 15, Shimadzu, Kyoto, Japan; Symphony, Siemens Medical Solutions, Erlangen, Germany) or a 3.0T unit (Signa HDx; GE Medical Systems, Milwaukee, WI, USA). Imaging was obtained with body phased-array and cardiac coils. Axial T1-weighted fast-spin-echo (FSE), axial T1-weighted gradient echo (GE), and sagittal T2-weighted FSE images were obtained for all patients.

Parameters for axial T1-weighted FSE images were: repetition time/echo time [TR/TE], 500 to 638/10 to 15 ms; slice thickness, 5 to 10 mm; field of view [FOV], 30 to 36 cm; and matrix, 256 × 120–256; and TR/TE, 500 to 600/7.2 to 7.6 ms; slice thickness, 4 to 7 mm; FOV, 35 cm; and matrix, 320 × 224.

Parameters for axial T1-weighted gradient echo (GE) images were: TR/TE, 165 to 170/4.76 ms; slice thickness, 8 to 10 mm; FOV, 32 cm; and matrix, 256 to 320 × 179 to 192.

Parameters for sagittal T2-weighted FSE images were: TR/TE, 1500 to 3389/80 to 112 ms; slice thickness, 4 to 10 mm; FOV, 25 to 35 cm; and matrix, 256 to 384 × 135 to 229; and TR/TE, 3400 to 5000/102 to 117 ms; slice thickness, 5 to 10 mm; FOV, 18 to 32 cm; matrix, 256 to 384 × 168 to 216; and TR/TE, 3967 to 4967/100 to 105 ms, slice thickness, 2 to 4 mm; FOV, 24 to 26 cm; and matrix, 288 × 288.

Contrast-enhanced T1-weighted FSE images were obtained after intravenous administration of 0.1 mmol/kg of gadopentate dimeglumine (Magnevist®, Bayer HealthCare, Osaka, Japan) in 44 patients, and T1-weighted fat-saturated FSE images (TR/TE, 7.29/4.01 ms; slice thickness, 5.5 to 6 mm; FOV, 25 cm; and matrix, 240 × 240) were obtained in 4 patients with uterine sarcomas and one patient with leiomyoma. Contrast-enhanced T1-weighted images were not available for one patient.
with endometrial stromal sarcoma. Diffusion-weighted (DW) images were obtained of 18 tumors, including one leiomyosarcoma, 2 carcinosarcomas, one endometrial stromal sarcoma, and 14 leiomyomas. DW images (TR/TE, 1500/77 or 6000/83.9 ms; slice thickness, 8 to 10 mm; intersection gap, one to 2 mm; FOV, 35 cm; matrix, 128x128; and gradient factor b values, 0 and 1000 s/mm²) were obtained in the axial plane by combining single-shot echo planar imaging with a chemical shift-selective pulse. Apparent diffusion coefficient (ADC) maps were automatically calculated with workstation software (Centricity™ Workstation, GE Medical Systems) using 2 b-values.

**Image analysis of MR findings**

Two radiologists retrospectively and independently interpreted MR images by consensus. When there were multiple tumors in the uterus, the largest tumor was assessed.

MR findings were assessed by tumor size (greatest diameter), location (myometrium, endometrial cavity, or subserous region), contour (smooth or irregular), presence or absence of hemorrhage, and presence of necrotic and cystic components (areas of high signal intensity [SI] on T2-weighted images without enhancement on contrast-enhanced T1-weighted images).

The present study focused on the contrast ratio (CR) of SI on T2-weighted images, defined as:

\[ CR = \frac{SI_{tumor} - SI_{iliopsoas muscle}}{SI_{iliopsoas muscle}} \]

We placed regions of interest (ROI) for the SI of the tumor (SI_{tumor}) on the areas of lowest, highest, and main SI (Fig. 1) and calculated the CR of each region 3 times to obtain an average. The main SI was defined as the SI occupying the majority of the tumor. Hemorrhagic parts, necrotic and cystic parts, and calcifications were excluded from measurement. The SI of the iliopsoas muscle (SI_{iliopsoas muscle}) was also measured, but the SI of the uterine myometrium was not used in this formula because SIs in the uterine myometrium on T2-weighted images varied depending on the patient’s menstrual cycle. The CR was calculated for each of the 3 areas of SI.

To quantify the heterogeneity of gadolinium-enhanced tumors, we also calculated the contrast-enhanced ratio (CER) of the main solid part to the whole solid part of the tumor following gadolinium enhancement on T1-weighted images using the formula:

\[ CER = \frac{|SI_{main solid part} - SI_{whole solid part}|}{SI_{whole solid part}} \]

When the SI of the main solid part (SI_{main solid part}) and the SI of the whole solid part (SI_{whole solid part}) represented similar values, the CER absolute value...
was approximated to 0, which was considered to re-
represent tumors with more homogeneous gadolinium 
enhancement. In contrast, when the $SI_{\text{main solid part}}$ and the $SI_{\text{whole solid part}}$ represented markedly differ-
ent values, the CER absolute value was approxi-
mated to one, which was considered to represent 
tumors with more heterogeneous enhancement. To 
eliminate the effects of intratumoral hemorrhagic, 
necrotic, and cystic changes so far as possible, the 
ROI of the $SI_{\text{whole solid part}}$ was strictly measured as 
the enhanced area of the tumor. The $SI_{\text{main solid part}}$ 
was measured as the area of main SI on T2-weighted 
images in the largest cut slice of the tumor (Fig. 2).

We assessed DW images and ADC values in 4 sarcomas and 14 leiomyomas, grading signal intensity on DW images as high, slightly high, or iso to low compared to that of the iliopsoas muscle\(^{12}\) and measuring ADC values for each tumor in ROIs placed on ADC maps at a workstation to exclude hemorrhagic and cystic components.

**Histopathologic analysis**

All specimens were obtained from surgical re-
section of lesions, stained with hematoxylin–eosin, 
and examined by 2 experienced pathologists blind-
ed to the MR results. The histopathologic speci-
mens were evaluated to confirm diagnoses of uter-
ine sarcoma and classified as 8 leiomyosarcomas, 
11 carcinosarcomas, 6 endometrial stromal sarco-
mas, and 25 leiomyomas. Leiomyosarcomas in-
cluded one diagnosis of myxoid leiomyosarcoma. 
Endometrial stromal sarcomas were subdivided in-
to 5 low and one high grade type defined as endo-
metrial sarcoma\(^{9}\) but were evaluated as one catego-
ry (i.e., endometrial stromal tumor) because of the 
study’s small sample size. Carcinosarcomas were 
subdivided into 8 homogeneous and 3 heterogene-
ous types. Four of 25 leiomyomas had hyaline de-
generations.

**Statistical analysis**

Normally distributed data are described as mean ± standard deviation, with skewed data summa-
rized using the median (interquartile range). Com-
parisons of MR findings and clinical parameters 
between uterine sarcomas and leiomyomas were 
performed using Mann-Whitney’s $U$ test for con-
tinuous variables and $\chi^2$ test for categorical vari-
bles. Comparisons among leiomyosarcomas, car-
cinosarcomas, and endometrial stromal sarcomas 
were performed with the Kruskal-Wallis test and $\chi^2$ 
test. For multiple comparisons, analyses were per-
formed with Mann-Whitney’s $U$ test modified with 
Bonferroni criterion. The relationship between tu-
mor characteristics and size was evaluated with 
Mann-Whitney’s $U$ test. We analyzed statistics us-
ing Dr. SPSS II software for Windows (Release 
11.0.1J, SPSS, Inc., Chicago, IL, USA). A $P$ value 
less than 0.05 was considered to be statistically sig-
Results

Table 1 summarizes the clinical features of the various histological types of uterine sarcoma and leiomyoma. Menopausal status and symptoms did not differ significantly between sarcoma groups.

Table 2 summarizes comparisons between uterine sarcomas and leiomyomas. Significant differences were found in tumor location, contour, and presence of hemorrhagic, necrotic, and cystic components. Most leiomyomas had smooth contours, whereas hemorrhages or necrotic and cystic components were frequently found in uterine sarcomas. Quantitative assessment revealed significantly higher CR for the area of lowest SI (1.36 ± 1.58, \( P < 0.05 \)) and the area of main SI (2.54 ± 2.12, \( P < 0.01 \)) in sarcomas than leiomyomas. Further, the CER showed significantly more heterogeneous enhancement in sarcomas than leiomyomas (0.12 ± 0.14, \( P < 0.05 \)).

All 4 cases of uterine sarcoma showed high SI on DW images. Among leiomyomas, 6 cases showed slightly high intensity, and the other 8 cases showed iso to low SI on DW images. The mean ADC value (10^{-3} \text{mm}^2/\text{s}) of sarcomas (1.14 ± 0.34) was lower than that of leiomyomas (1.43 ± 0.20), though the difference was not significant. In 4 sarcoma cases, the mean ADC value was 1.65 in a myxoid leiomyosarcoma, 0.96 in a serous adenocarcinoma with endometrial sarcoma component, 0.94 in an endometrioid adenocarcinoma with leiomyosarcoma component, and 1.01 in an endometrial stromal sarcoma of low grade type.

Table 3 summarizes characteristics from the MR findings of uterine sarcomas. Patients with endometrial stromal sarcomas were significantly younger than patients from the other groups, and leiomyosarcoma tumors were larger than other sarcoma types. Leiomyosarcomas were located mainly in the myometrium, whereas carcinosarcomas were located in the endometrial cavity.

The CR for the area of lowest SI on \( T_2 \)-weighted images was significantly lower in leiomyosarcomas than other sarcomas (0.31 ± 0.39, \( P < 0.05 \), Figs. 1, 3a). Although the CRs for the areas of main and highest SI tended to increase in the order of leiomyosarcoma to carcinosarcoma to endometrial stromal sarcoma, the differences were not significant (Figs. 1, 3b, 3c). The CER for endometrial stromal sarcomas showed the most significant homogeneous enhancement compared to the other 2 sarcoma groups (0.02 ± 0.02, \( P < 0.05 \), Figs. 2, 3d). Figure 4 shows relationships between the CR for the area of lowest SI and the CER for each uterine sarcoma. Scatter plots using a combination of these 2 parameters avoided overlap between leiomyosarcomas and endometrial stromal sarcomas, but the plots of carcinosarcomas showed considerable overlap with the other groups.

Table 4 summarizes the relationship between tumor characteristics and the size of uterine sarcomas. Hemorrhagic or necrotic and cystic components were found more often in larger tumors, although there was no significant difference in their occurrence among the 3 sarcoma groups (Table 3). These components were found in all leiomyosarco-
mas and endometrial stromal sarcomas and nearly half of all carcinosarcoma cases; in particular, 6 of 8 leiomyosarcomas and 3 of 6 endometrial stromal sarcomas had a mass greater than 10 cm in diameter.

**Discussion**

Several studies have reported the MR features for each type of uterine sarcoma, but comparisons between the histological types have not been performed. Our study found that quantitative assessment of the CR on T2-weighted images and the CER on contrast-enhanced T1-weighted images revealed characteristic findings in leiomyosarcomas and endometrial stromal sarcomas. The CR and CER were also useful in differentiating uterine sarcomas from benign leiomyomas. Namimoto and associates\(^1^3\) reported the significantly higher tumor-myometrium contrast ratio on T2-weighted images of uterine sarcomas than leiomyoma, and Tanaka’s group\(^1^4\) reported the high SI on T2-weighted images of more than 70% of smooth muscle tumors of uncertain malignant potential and leiomyosarcomas compared with leiomyomas. Leiomyosarcomas are the most malignant smooth muscle tumors of the uterus, show the microscopic constellation of hypercellularity, severe nuclear atypia, and high mitotic rate, and rarely originate as a malignant counterpart of leiomyomas.\(^9\) We observed the considerable overlap of the CR for the areas of highest SI on T2-weighted images, whereas the CR for the areas of lowest SI showed characteristic findings in leiomyosarcomas, which were thought to reflect their histological features.

Sahdev and colleagues\(^1^5\) reported that most uterine sarcomas, including those of various subtypes, showed strong contrast enhancement. Tanaka’s

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**Table 2. Comparison of magnetic resonance findings of uterine sarcoma and leiomyoma**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Sarcoma</th>
<th>Leiomyoma</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Age (years)(^1)</td>
<td>55 (49–70)</td>
<td>45 (38–49)</td>
<td>&lt; 0.001(^/)</td>
</tr>
<tr>
<td>Size (cm)(^1)</td>
<td>8.0 (6.8–13.1)</td>
<td>9.9 (7.8–13.9)</td>
<td>n. s.(^/)</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td>0.029(^/)</td>
</tr>
<tr>
<td>Myometrium</td>
<td>11</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Endometrial cavity</td>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Subserous region</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Contour</td>
<td></td>
<td></td>
<td>&lt; 0.001(^/)</td>
</tr>
<tr>
<td>Smooth</td>
<td>18</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Irregular</td>
<td>7</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hemorrhages</td>
<td></td>
<td></td>
<td>&lt; 0.001(^/)</td>
</tr>
<tr>
<td>Present</td>
<td>18</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>7</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Necrotic/Cystic components(^*)</td>
<td></td>
<td></td>
<td>0.041(^/)</td>
</tr>
<tr>
<td>Present</td>
<td>20</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>4</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Contrast ratio for area of lowest SI(^1)</td>
<td>1.36 ± 1.58</td>
<td>0.40 ± 0.51</td>
<td>0.049(^/)</td>
</tr>
<tr>
<td>Contrast ratio for area of main SI(^1)</td>
<td>2.54 ± 2.12</td>
<td>0.99 ± 0.76</td>
<td>0.006(^/)</td>
</tr>
<tr>
<td>Contrast ratio for area of highest SI(^1)</td>
<td>3.77 ± 2.99</td>
<td>2.14 ± 1.26</td>
<td>n. s.(^/)</td>
</tr>
<tr>
<td>CER(**)</td>
<td>0.12 ± 0.14</td>
<td>0.04 ± 0.06</td>
<td>0.033(^/)</td>
</tr>
<tr>
<td>ADC value ((\times 10^{-3}) mm(^2)/s)(^1)<strong>(^</strong>)</td>
<td>1.14 ± 0.34</td>
<td>1.43 ± 0.20</td>
<td>n. s.(^/)</td>
</tr>
</tbody>
</table>

\(^1\)Mann-Whitney U test  
\(^1\)Mean and standard deviation  
\(^1\)Median (interquartile ranges)  
\(^1\)\(\chi^2\) test  
\(^*\)One case was excluded from evaluation because no contrast-enhanced T\(_1\)-weighted image had been taken.  
\(**\)Contrast-enhanced T\(_1\)-weighted image was not obtained for one case.  
\(**\)Diffusion-weighted images and apparent diffusion coefficient (ADC) values were evaluated in 4 sarcomas and 14 leiomyomas.  
CER, contrast-enhanced ratio of main solid part; n. s., not significant; SI, signal intensity
group\textsuperscript{14} reported that leiomyosarcomas had well demarcated and unenhanced areas and that carcinosarcomas had both unenhanced and strongly enhanced areas in the same tumor.\textsuperscript{16} Ueda’s group\textsuperscript{17} described the greater enhancement of endometrial stromal sarcomas than the normal myometrium as a result of their hypervascularity. Classic histological characteristics of endometrial stromal sarcomas include a uniform band of small cells, which resembles proliferative phase endometrial stroma, and numerous thin-walled small arteriolar-type vessels.\textsuperscript{3} The assessment of tumor heterogeneity in a contrast-enhanced study is important along with the assessment of tumor vascularity; nevertheless, no study has objectively assessed whether tumor enhancement is homogeneous or heterogeneous. The CER defined in this study enabled a quantitative assessment of the heterogeneity of gadolinium-enhanced tumors and objectively demonstrated the greater homogeneous enhancement of endometrial stromal sarcomas than other uterine sarcomas.

A scatter plot of the CR for the area of lowest SI and the CER in carcinosarcomas overlapped considerably with the other 2 groups, findings probably attributable to the histological variety of these tumors that generally comprise 2 or more different components. The classification of the World Health Organization designates these tumors as “carcinosarcomas,” but the more commonly used term to describe them is “malignant mixed müllerian tumor (MMMT).”\textsuperscript{3} Carcinosarcomas are composed of an admixture of malignant epithelial elements and sarcomatous elements.\textsuperscript{3,9} The sarcomatous elements can be homologous or heterologous. Homologous mesenchymal components usually consist of undifferentiated sarcomas, leiomyosarcomas, or endometrial stromal sarcomas, whereas heterologous mesenchymal elements typically consist of malignant cartilage or skeletal muscle in the form of rhabdomyoblasts. Carcinosarcomas commonly present as endometrial masses with heterogeneous hyper-

Table 3. Comparison of magnetic resonance findings in uterine sarcomas

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Leiomyosarcoma</th>
<th>Carcinosarcoma</th>
<th>Endometrial stromal sarcoma</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>8</td>
<td>11</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Age (years)\textsuperscript{\dag}</td>
<td>62 (50–72)</td>
<td>56 (54–70)</td>
<td>48 (42–50)</td>
<td>0.021\textsuperscript{$}</td>
</tr>
<tr>
<td>Size (cm)\textsuperscript{\dag}</td>
<td>13.3 (9.7–15.2)</td>
<td>7.0 (5.8–7.8)</td>
<td>9.8 (6.7–12.9)</td>
<td>0.034\textsuperscript{$}</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
<td>0.008\textsuperscript{\textsuperscript{\dag}}</td>
</tr>
<tr>
<td>Myometrium</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Endometrial cavity</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Subserous region</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Contour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Irregular</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hemorrhages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Necrotic/Cystic components\textsuperscript{*}</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast ratio for area of lowest SI\textsuperscript{\dag}</td>
<td>0.31 ± 0.39</td>
<td>1.37 ± 1.08</td>
<td>2.73 ± 2.31</td>
<td>0.012\textsuperscript{$}</td>
</tr>
<tr>
<td>Contrast ratio for area of main SI\textsuperscript{\dag}</td>
<td>1.36 ± 1.00</td>
<td>2.76 ± 1.94</td>
<td>3.73 ± 2.94</td>
<td>n. s.\textsuperscript{$}</td>
</tr>
<tr>
<td>Contrast ratio for area of highest SI\textsuperscript{\dag}</td>
<td>2.39 ± 1.47</td>
<td>3.74 ± 2.75</td>
<td>5.66 ± 4.16</td>
<td>n. s.\textsuperscript{$}</td>
</tr>
<tr>
<td>CER\textsuperscript{\textsuperscript{\dag}**}</td>
<td>0.23 ± 0.18</td>
<td>0.08 ± 0.06</td>
<td>0.02 ± 0.02</td>
<td>0.016\textsuperscript{$}</td>
</tr>
</tbody>
</table>

\textsuperscript{\dag}Kruskal-Wallis test
\textsuperscript{\dag}Mean and standard deviation
\textsuperscript{\dag}Median (interquartile ranges)
\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}\textsuperscript{\dag}χ\textsuperscript{\dag}² test
\textsuperscript{*}One case was excluded from evaluation because no contrast-enhanced T\textsubscript{1}-weighted image had been taken.
\textsuperscript{**}Contrast-enhanced T\textsubscript{1}-weighted image was not obtained for one case.
CER, contrast-enhanced ratio of main solid part; n. s., not significant; SI, signal intensity
Intensity on T2-weighted images, but they have been reported to have no specific MR findings because of various coexisting malignant components that include necroses and hemorrhages. In particular, small-sized carcinosarcomas are difficult to distinguish from endometrial carcinomas. \cite{15,18,20}

The presence of necrotic and hemorrhagic changes in this study were useful in differentiating uterine sarcomas from benign leiomyomas, but these changes were related to tumor size rather than histology. Although tumor size differed significantly among the 3 uterine sarcoma groups, neither necroses nor hemorrhagic changes were related to histological differentiation. On the other hand, there were statistical differences in tumor location among the uterine sarcoma groups. Uterine sarcomas commonly present as large heterogeneous masses, and necrotic and hemorrhagic changes are frequently found in the major subtypes. \cite{15} Leiomyosarcomas commonly present as intramural to subserosal masses that replace the normal uterine architecture. \cite{14,15} Carcinosarcomas are typically endometrial polypoid masses that fill the uterine cavity and prolapse through the cervical os, frequently demonstrate myometrial invasion, and are often indistinguishable from endometrial carcinomas. \cite{9,15} Endometrial stromal sarcomas have variable forms, such as polypoid endometrial masses, intramyometrial masses, and diffuse myometrial

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**Fig. 3.** Box plots indicate the contrast ratio (CR) for the area of lowest signal intensity (SI) (a), the CR for the area of main SI (b), the CR for the area of highest SI (c), and the contrast-enhanced ratio of the main solid part (CER) (d) among leiomyosarcomas (LMS), carcinosarcomas (CS), and endometrial stromal sarcomas (ESS). The line in each box represents the median, and the vertical error bars indicate minimum and maximum values. Analyses were performed using Mann-Whitney’s U test with modified Bonferroni criterion for multiple comparisons. Significant differences in the CR for the area of lowest SI were observed between LMS and ESS ($P < 0.05$) and between LMS and CS ($P < 0.05$). No significant differences were observed in the CR for the areas of main and highest SI. A significant difference in the CER was observed between LMS and ESS ($P < 0.05$).
thickening, and show extraperitoneal pelvic extension that commonly involves the ovary.9,21 Our study suggested that tumor location might help in predicting the histological type of uterine sarcoma, but because histological type cannot be distinguished on the basis of tumor size, necrosis, or hemorrhagic change alone, a detailed assessment of MR imaging is needed.

On DW images, all 4 uterine sarcomas in this study showed high intensity, and 3 of the 4 tumors also showed low mean ADC values. The results in these 3 cases were similar to those of previous reports,12,13,22 but the remaining case, a myxoid leiomyosarcoma, showed a high ADC value due to the myxoid component. Maeda and associates23 reported significantly higher ADC values of myxoid-containing soft-tissue tumors than nonmyxoid soft-tissue tumors; furthermore, the myxoid matrix influenced the ADC values of both benign and malignant tumors. Tamai’s team22 reported the high SI of uterine sarcomas and cellular leiomyomas on DW images. They reported that the ADC value of uterine sarcomas was significantly lower than those of degenerated leiomyomas, whereas the ADC values of ordinary leiomyoma, cellular leiomyoma, and uterine sarcomas were overlapped. In the case of hyperintense uterine myometrial lesions on T2-weighted images, Takeuchi and colleagues12 reported that it was difficult to differentiate uterine leiomyomas from malignant lesions using DW images alone. They reported that the ADC values of the solid part with lower SI on T2-weighted images were significantly lower in malignant tumors than those of benign leiomyomas including cellular leiomyomas and degenerated leiomyomas. Namimoto and associates13 reported that uterine sarcomas and leiomyomas could be sufficiently distinguished by a combination of ADC values and the tumor-myometrium contrast ratio on T2-weighted images, and Kato’s group20 reported that the DW image and ADC mapping image clearly distinguished adenocarcinoma components from sarcoma components in one of 4 cases of carcinosarcoma. DW imaging with ADC values yields quantitative information that reflects tissue cellularity,12,22 so further assessment of uterine sarcomas with various histological components is required that includes DW imaging, ADC values, and histology.

This study has some limitations. Because it was retrospective and included only a small number of patients, further validation of our findings requires a prospective study with a substantially larger sample, and more comparisons are needed using MR images of leiomyomas with more variable degenerations to overcome the selection bias with the leiomyomas in this study.

In conclusion, the quantitative assessment of the CRs or CERs of tumors was useful in distinguishing the major histological types of uterine sarcomas and benign and malignant uterine tumors. When the solid part of a tumor shows homogeneous gadolinium enhancement in younger patients, endometrial stromal sarcoma should be considered. If areas of lower SI on T2-weighted images are observed in a large myometrial tumor with hemorrhage and irregular contours, leiomyosarcoma should be suspected. Leiomyomas of typical histological type

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Size (cm)†</th>
<th>P value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contour</td>
<td>n. s.</td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>9.7 (6.8–14)</td>
<td></td>
</tr>
<tr>
<td>Irregular</td>
<td>7.2 (6.8–10.5)</td>
<td></td>
</tr>
<tr>
<td>Hemorrhages</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>11.0 (7.1–14.0)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>6.8 (3.9–8.2)</td>
<td></td>
</tr>
<tr>
<td>Necrotic/Cystic components</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>11.0 (7.0–14.0)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>5.1 (2.7–6.9)</td>
<td></td>
</tr>
</tbody>
</table>

†Mann-Whitney U test
†Median (interquartile ranges)

n. s., not significant
showed lower SI on T₂-weighted images and more homogeneous gadolinium enhancement compared to sarcomas. Moreover, the presence of hemorrhage, necrotic and cystic components, and irregular contours or unclear margins were useful for distinguishing malignant and benign tumors, but sarcoma groups do not always possess characteristic MR findings.

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References