Magnetic Resonance Imaging and Diffusion-Weighted Imaging in Categorization of Uterine Sarcoma: Correlation with Pathological Findings

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Aims and objectives

We investigated the utility of magnetic resonance imaging (MRI) and diffusion-weighted imaging (DWI-MRI) in the categorization of uterine sarcoma (US) and compared them with pathological findings.

Methods and materials

Study subjects

From June 2010 to December 2012, 437 consecutive patients with clinically suspected gynaecological disease underwent prospective MRI examinations before pelvic or laparoscopic surgery at our institution. Twenty-two patients (19-73 years of age; average age, 52.7 ± 12.3 years) with pathologically proven US were included in this study. To compare the apparent diffusion coefficient values (ADCs) of benign and malignant uterine lesions, we also selected a limited numbers of leiomyomas and adenomyomas for the comparative group. The criteria were as follows: first, to minimize the selection bias caused by multiple lesions in one patient, we chose only patients with a solitary lesion for either the leiomyoma or adenomyoma group; second, patients with any previous pelvic surgery or radiation history were arbitrarily excluded, because the inherent structure of the uterus may have been altered. Thus, 21 leiomyomas (24-72 years of age; average age, 47.7 ± 13.9 years) and 20 adenomyomas (34-51 years of age; average age, 41.4 ± 5.2 years) were included. Our institutional review board approved the study, and the requirement for informed consent was waived for all participants.

Image acquisition

MR imaging was performed using a 1.5-T MR system (Magnetom Avanto, Siemens, Erlangen, Germany) with a phased-array coil. The routine MRI protocols used for the assessment of pelvic masses included the axial turbo spin-echo (TSE) T₁-weighted imaging (T₁WI), sagittal TSE T₂-weighted imaging (T₂WI) and axial/sagittal TSE fat-suppressed T₂WI (FS T₂WI). Diffusion-weighted imaging (DWI) using an echo-planar imaging two-dimensional (EP2D) sequence performed in the axial plane with parallel acquisition technique (PAT) by using b value = 0, 100 and 800s/mm². Contrast-enhanced pelvic imaging was acquired at multiple phases of contrast medium enhancement in both sagittal and axial planes. The detailed MRI acquisition parameters were listed in Table 1.

Image analysis

The location, size (largest dimension in two orthogonal planes), shape (round, oval, lobulated) and margin (clear or ambiguous); visibility of endometrium and hemorrhage
component (high signal on $T_1$WI) within the lesion; and presence of pelvic free fluid and lymph nodes were noted. Further, the homogeneity of $T_1$WI/$T_2$WI signals, accompanying lesions and extra-uterine extension were separately evaluated and recorded. On $T_1$WI, hypo-, iso-, and hyperintensity were similar for the pelvic fluid, pelvic wall muscle, and fat signal; on $T_2$WI, hypo-, iso-, and hyperintensity were similar for the pelvic bone, pelvic wall muscle, and fat signal; on $b = 800 \text{ mm}^2/\text{s}$ DWI images, the low, intermediate, high signal intensities were similar for the pelvic bone, myometrium, and endometrium. After the intravenous injection of the contrast medium, the degree of lesion enhancement was graded as follows: 1, weak enhancement (less than the myometrium); 2, mild enhancement (equal to the myometrium); 3, avid enhancement (superior to the myometrium). ADCs were measured manually on post-processing workstation (Leonardo,Siemens,Germany) by one reviewer (H.Z.).

Two observers (G. F. Z. and H.Z., with 10 and 6 years of experience in gynaecological imaging,respectively), who were blinded to the histological results independently analysed MRI datasets of each participant. At the end of the study, two observers were also required to give the tumor stage according to new FIGO system for US[18 on page ]. For inter-observer discrepancies in the evaluation of uterine lesions, consensus was achieved.

Statistical analyses

Continuous variables were expressed as the means ± standard deviation (SD) and compared with the unpaired t-test if normally distributed or the Mann-Whitney test if not normally distributed. A nonparametric test (Mann-Whitney) was used to test other nonparametric variables within each group. Kappa statistics were used to calculate the inter-observer reliability as percentage of agreement between the observer evaluations before the consensus reading was made. The area under the receiver operating characteristic (ROC) curve (AUC) was calculated for ADCs to discriminate US from leiomyoma. SPSS (version 13.0, SPSS Inc.,Chicago,USA) was used to perform statistical analyses.

Results

Baseline characteristics

The histopathological specimens revealed 22 primary USs, including seven LSs (39-73 years of age; average age, 53.0 ± 10.6 years), three ESSs (19-66 years of age; average age, 37.7 ± 24.9 years), six ASs (49-65 years of age; average age, 58.0 ± 6.0 years), and six CSs (43-62 years of age; average age, 54.7 ± 6.7 years). Three tumors were in stage I, one in stage II, and three in stage III in the LS group; one tumor was in stage I, one in stage II, and one in stage III in the ESS group; six tumors were in stage I, one in stage II, and one in stage III in the AS
group; and five tumors were in stage I and one in stage III in the CS group. The details of baseline characteristics for each subtype of US are summarized in Table 2.

**MRI characteristics**

Two lesions (one adenosarcoma and one carcinosarcoma) could not be detected on MRI by either observer because the lesions were too small. Eleven USs (11/20, 55%; Fig. 1) were confined to the uterine cavity, four (4/20, 20%) to the cervical canal, and five (5/20, 25%) to the myometrium. Two ESSs were located in the anterior part of the uterine body (Fig. 2, Fig. S1, Table 3). The uterine cavity was more likely to be involved than the other two sites ($p = 0.032$). The maximum diameter of the lesions in the LS group was largest (55.6 ±49.7mm) among the four subtypes.

On MRI, most of the USs (17/20, 85%) appeared as a solitary, solid tumor. In this study, 12 lesions were clearly demarcated, but in another eight patients, the margin was ambiguous. On $T_1$WI, most patients (13/20, 65%) showed intermediate signals. On $T_2$WI, the tumor signals appeared more diverse and relatively, the LS lesions (6/22, 27.3%) showed more mixed signals than the other groups. In terms of $T_1$WI/$T_2$WI signal heterogeneity, the $T_1$WI signals of the lesions in each group had no specific character. All tumors (7/7, 100%) in the LS group had an inhomogeneous signal on $T_2$WI, which was clearly different from those of the ESS/AS group ($p = 0.021$) and CS group ($p = 0.003$).

On MRI, normal endometrium could be seen in 11 patients. Extrauterine extension was only observed in the LS group (4/20, 20%). Hemorrhage components were usually observed in the LS group (5/7, 71.4%), which appeared as patchy high signals on $T_1$WI images. However, hemorrhage signals were less well detected in the ESS, AS, and CS groups.

On contrast-enhanced MRI images, most tumors (6/7, 85.7%) in the LS group showed rapid and avid enhancement. In the ESS/AS group, most tumors (5/8, 63%) appeared mild enhancement, and in the CS group, all lesions (5/5, 100%) showed moderate and delayed enhancement (Fig. S2). There was little statistically significant difference in the level of enhancement between any groups ($p = 0.05$).

**DWI-MRI characteristics**

On DWI-MRI images, 14 tumors (14/20, 70%) showed a homogeneously high signal. The mean ADC value was $0.93 \pm 0.30$ in the LS group, $1.19 \pm 0.33$ in the ESS/AS group, and $1.05 \pm 0.22$ in the CS group, with a little overlap (Fig. 3). A significant difference in ADCs was only observed between LS and leiomyoma ($p = 0.018$). When the leiomyomas and adenomyomas were compared, the mean ADC value for US (1.05 ± 0.30) was lower than that for leiomyoma (1.34 ± 0.42) and adenomyoma (1.12 ± 0.14) (Fig. S3). There was a significant difference between the mean ADC value for US and fibroids ($p = 0.019$). If the cut-off value for ADC was set at $1.06 \times 10^{-3}$/mm$^2$/s, its sensitivity and specificity were
81% and 62%, respectively. The AUC was 0.72 (95% confidence interval, 0.556-0.883) for ADC in discriminating LS from leiomyoma.

**Interobserver agreement and radiological-pathological correlations**

Tumor extension, necrosis, hemorrhage, and lymphoadenopathy were clearly observed on both pre- and postcontrast MRI images and were confirmed by the histopathological findings. Compared with histopathological staging, tumor staging with MRI by both reviewers achieved an accuracy of 100% (Fig. 1-2, S1-S2). There was excellent agreement between the two observers in both the MRI findings (kappa = 0.90) and the MRI tumor staging (kappa = 0.93).

**Images for this section:**

![Table 3](image)

**Table 3** The details of locations of four pathological types in the histologically proven 22 uterine sarcomas on MRI.

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Cavity*</th>
<th>Cervical canal</th>
<th>Myometrium</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leiomyosarcoma</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Endometrial stromal sarcoma</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Adenosarcoma</td>
<td>4</td>
<td>1</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Carcinosarcoma †</td>
<td>4</td>
<td>1</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>11*</td>
<td>4</td>
<td>5</td>
<td>20</td>
</tr>
</tbody>
</table>

* If the lesion involved both cavity and cervical canal and the main body located in the cavity, then the lesion was regarded in the cavity;
† There was one case in both adenosarcoma and carcinosarcoma group in whom the lesion was too small could not be detected on MRI;
‡ there was significant difference in the location of US occurrence between cavity and myometrium (p = 0.032)

**Fig. 1:** The details of locations of four pathological types in the histologically proven 22 uterine sarcomas on MRI.
Fig. 2: Figure S1: A 19-year-old female patient with histologically proven endometrial stromal sarcoma (stage Ic). (A) Axial T1WI outlined a homogeneous solid mass (arrowheads) with isointensity, in the right uterine body. Note the high signals indicative
of fluid in the cavity (*). (B) On T2WI, the well-defined tumor margin was located in the myometrium with isohyperintensity. On DWI-MRI (b = 800 s/mm²) (C) and the ADC map (D), the lesion was well displayed (arrowheads) and appeared as homogeneous intermediate signal. The tumor showed homogeneously avid enhancement on contrast-enhanced images (E), and on a time-signal intensity curve (F), the degree of enhancement of the lesion (red line) was greater than that of the normal myometrium (yellow line).

Fig. 3: Figure 3: Box-and-whisker plots of the calculated ADC values (10⁻³/mm²/s) for the uterine sarcoma subtypes. There were no significant differences in mean ADC value of the US subtypes. A significant difference in ADCs was only observed between leiomyosarcoma (0.93 ± 0.30) and leiomyoma (1.34 ± 0.42) (p = 0.018).
Conclusion

MRI characteristics showed no specific differences between any subtypes of uterine sarcoma. ADC is helpful in discriminating uterine sarcomas from uterine fibroids. MRI may be used as a reliable imaging modality for staging preoperative uterine sarcomas.

Personal information

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References


