Diffusion-weighted imaging of solid or predominantly solid gynaecological adnexial masses: is it useful in the differential diagnosis?

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Objectives: This study investigated whether diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values provide specific information that allows the diagnosis of solid or predominantly solid gynaecological adnexial lesions, especially whether they can discriminate benign and malignant lesions.

Methods: DWI was performed in 37 patients with histologically proven solid or predominantly solid adnexial lesions (22 malignant and 15 benign neoplasms). The lesions in our data set were divided into two groups, all adnexial lesions or lesions of ovarian origin, for evaluation. The areas of the highest signal intensity on DWI ($b=800 \text{ s mm}^{-2}$) and the lowest ADC values within the lesions were evaluated.

Results: On DWI, high signal intensity was observed more often in malignant than in benign lesions ($p<0.0001$). There was no significant difference between the ADC values of the malignant and benign lesions in either the adnexial (0.88 ± 0.16 vs 0.84 ± 0.42 ; $p=0.96$) or the ovarian (0.85 ± 0.14 vs 1.05 ± 0.2 ; $p=0.133$) lesions. When signal intensities on DWI were compared, however, malignant lesions had higher values than the benign lesions in both the adnexial (0.69 ± 0.21 vs 0.29 ± 0.13 ; $p<0.0001$) and the ovarian lesions (0.75 ± 0.14 vs 0.37 ± 0.24 ; $p=0.003$).

Conclusion: On DWI, high signal intensity was observed more frequently with the malignant lesions.

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MRI plays an important role in the diagnosis of gynaecological adnexial lesions [1–4]. It provides useful information for the characterisation of various ovarian, uterine and tubal masses. Some morphological and signal intensity features of the lesions on MRI are very important for the differential diagnosis [5], but this information may sometimes be non-specific. Many studies have looked at the utility of diffusion-weighted MRI in the differential diagnosis of benign and malignant gynaecological lesions [6–10]. In particular, the contributions of diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values in differentiating between cystic benign lesions and malignant ovarian and uterine lesions have been evaluated [6–10]. Only one investigation used DWI to assess the solid components of ovarian lesions in a wide study population [11]. To our knowledge, the utility of DWI and ADC values in assessing solid or predominantly solid gynaecological adnexial masses has not been investigated previously.

In this study, our goal was to investigate whether DWI and ADC values provide specific information that can diagnose solid or predominantly solid gynaecological adnexial lesions, in particular, whether these parameters can discriminate benign and malignant lesions.

Methods and materials

Patients

During a 12 month period from August 2007 to September 2008, we performed MRI examinations on 51 patients who were sonographically diagnosed as having solid or predominantly solid adnexial lesions larger than 3 cm in diameter. Patients were included in the study if, on MRI examination, the enhancing adnexial lesion was completely solid or the solid component occupied more than 75% of the lesion (predominantly solid). Three patients were excluded from the study because the solid component of their lesion was less than 75%. A further four patients for whom the MRI suggested a dermoid cyst associated with fatty tissue but no solid component were also excluded. Of the remaining 44 patients, 37 underwent

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Table 1. Apparent diffusion coefficient (ADC) range, mean ADC value, mean signal intensities (quantitative analysis) and relative signal intensities (qualitative analysis) on diffusion-weighted imaging ($b \pm 800 \text{ s mm}^{-2}$)

Lesion	Number of lesions	ADC range	ADC (mean $\pm$ SD)	Quantitatively assessed signal intensity (mean $\pm$ SD)	Qualitatively assessed relative signal intensity
Dysgerminoma	3	0.68–0.71	0.70 ± 0.15	0.99 ± 0.7	All hyperintense
Serous adenocarcinoma	5	0.70–0.88	0.76 ± 0.1	0.69 ± 0.11	1 isointense, 4 hyperintense
Mucinous adenocarcinoma	1	0.70	0.70	0.63	Hyperintense
Granulosa cell tumour	3	0.88–1.11	1 ± 0.12	0.69 ± 0.11	All hyperintense
Endometrioid carcinoma	1	0.78	0.78	0.65	Hyperintense
Serous adenocarcinoma of the fallopian tube	1	1.20	1.20	0.64	Hyperintense
Metastatic ovarian carcinoma	5	0.89–1.11	0.97 ± 0.11	0.74 ± 0.1	All hyperintense
Leiomyosarcoma	3	0.82–1.08	0.96 ± 0.13	0.45 ± 0.21	1 hypo-, 1 iso- and 1 hyperintense
Fibrothecoma	2	0.75–1.35	1.05 ± 0.42	0.37 ± 0.24	1 hypointense, 1 isointense
Degenerated leiomyoma	3	1.12–1.30	1.19 ± 0.11	0.41 ± 0.18	1 hypo-, 1 iso-, 1 hyperintense
Ordinary leiomyoma	10	0.30–1.37	0.69 ± 0.42	0.24 ± 0.11	All hypointense

surgical resection within 2 weeks following the MRI examination. Of these 37 patients (age range 17–82 years, mean 48.8 years), 31 had unilateral and 6 had bilateral lesions. In the bilateral cases (five metastatic ovarian carcinomas and one serous adenocarcinoma), the larger lesion was selected for evaluation. Hence, the study population comprised 37 lesions in 37 patients.

Upon pathology, the final diagnoses for the 37 lesions were dysgerminomas ($n=3$), granulosa cell tumours

($n=3$), serous adenocarcinomas ($n=5$), metastatic ovarian carcinomas ($n=5$, in all 5 patients with gastric carcinoma as the primary lesion), mucinous adenocarcinoma ($n=1$), endometrioid carcinoma ($n=1$), serous adenocarcinoma of the fallopian tube ($n=1$), fibrothecoma ($n=2$), and lesions of myometrial origin (including subserous, pedunculated uterine and broad ligament fibroids) ($n=16$) (comprising ordinary leiomyomas ($n=10$), degenerated leiomyomas ($n=3$) and leiomyosarcoma ($n=3$)).

Table 2. Signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) for all adnexial lesions. High signal intensity was observed more frequently in malignant neoplasms than in benign neoplasms

Signal intensity	Benign lesions ($n=15$)	Malignant lesions ($n=22$)	p -value
Hyperintense	1 (7%)	18 (82%)	0.000
Hypointense	12 (80%)	2 (9%)	
Isointense	2 (13%)	2 (9%)	

Table 3. Signal intensities on T_2 weighted images for all adnexial lesions. High signal intensity was observed more frequently in malignant neoplasms whereas low signal intensity was observed more frequently in benign neoplasms

Signal intensity	Benign lesions ($n=15$)	Malignant lesions ($n=22$)	p -value
Hyperintense	0	15 (68%)	0.000
Hypointense	13 (87%)	1 (5%)	
Isointense	2 (13%)	6 (27%)	

Table 4. Contrast enhancement patterns for all adnexial lesions

Contrast enhancement pattern	Benign lesions ($n=15$)	Malignant lesions ($n=22$)	p -value
Mild	6 (40%)	6 (27%)	0.417
Marked	9 (60%)	16 (73%)	

Table 5. Comparison of apparent diffusion coefficient (ADC) values and signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) in benign and malignant adnexial lesions

	Benign lesions ($n=15$)	Malignant lesions ($n=22$)	p -value
ADC (mean $\pm$ SD)	0.84 ± 0.42	0.88 ± 0.16	0.96
Signal intensity (mean $\pm$ SD)	0.29 ± 0.13	0.69 ± 0.21	0.0001

SD, standard deviation.

Table 6. Apparent diffusion coefficient (ADC) values and signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) in leiomyosarcomas and degenerated myomas

	Degenerated leiomyomas ($n=3$)	Leiomyosarcoma ($n=3$)	<i>p</i> -value
ADC (mean $\pm$ SD)	1.19 ± 0.11	0.96 ± 0.13	0.07
Signal intensity values (mean $\pm$ SD)	0.41 ± 0.19	0.45 ± 0.21	0.83

SD, standard deviation.

Table 7. Apparent diffusion coefficient (ADC) values and signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) in fibrotechomas and ordinary leiomyomas

	Fibrothecoma ($n=2$)	Ordinary leiomyoma ($n=10$)	<i>p</i> -value
ADC (mean $\pm$ SD)	1.19 ± 0.11	0.96 ± 0.13	0.07
Signal intensity values (mean $\pm$ SD)	0.41 ± 0.19	0.45 ± 0.21	0.83

SD, standard deviation.

Table 8. Signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) of ovarian lesions. High signal intensity was observed more frequently in malignant neoplasms than in benign neoplasms

Signal intensity	Benign lesions ($n=2$)	Malignant lesions ($n=18$)	<i>p</i> -value
Hyperintense	0	17 (85%)	0.001
Hypointense	1 (50%)	0	
Isointense	1 (50%)	1 (15%)	

There were 15 benign and 22 malignant lesions. Lesion size varied between 31 mm and 220 mm.

MR protocol

All scans were performed on the same 1.5 T imaging system (Magnetom Symphony, Siemens Medical Solutions, Erlangen, Germany). This system provides a maximum gradient strength of 30 mT m^{-1} with a peak slew rate of $100 \text{ mT m}^{-1} \text{ ms}^{-1}$. Diffusion-weighted MR images were obtained by a four-element phased-array multicoil for the body, using a multisection single-shot echo planar sequence in the axial plane without breath holding. The following parameters were used for the DWI sequence: parallel imaging reduction factor of two; repetition time (TR)/echo time (TE)=4400/85 ms; section thickness,

6 mm; intersection gap, 1 mm; matrix size, 128×128 ; field of view, $400 \times 400 \text{ mm}$; partial Fourier factor, 6/8; bandwidth, 1370 Hz per pixel; seven excitations, water excitation with b values of 50, 400 and 800 s mm^{-2} . Fat saturation was used to avoid chemical shift artefacts. The whole sequence consisted of 30 sections. The study was performed during normal respiration. In addition, the routine abdominal imaging protocol was used. For the upper abdomen, this protocol included axial and coronal breath-hold T_2 weighted half-Fourier single-shot turbo-spin-echo (HASTE) sequences (TR/TE=1000/84 ms; section thickness, 6 mm; intersection gap, 1.2 mm), axial in-phase and opposed-phase images (TR/TE=174/2.38 and 174/4.76 ms; section thickness, 8 mm; intersection gap, 1.6 mm), and breath-hold T_1 weighted fat-suppressed spoiled gradient-echo shared pre-pulse sequences (TR/TE=5.11/2.51 ms; section thickness, 4 mm;

Table 9. Signal intensities on the T_2 weighted images of ovarian lesions

Signal intensity	Benign lesions ($n=2$)	Malignant lesions ($n=18$)	<i>p</i> -value
Hyperintense	0	14 (78%)	0.000
Hypointense	2 (100%)	0	
Isointense	0	4 (22%)	

Table 10. Enhancement patterns for ovarian lesions

Contrast enhancement pattern	Benign lesions ($n=2$)	Malignant lesions ($n=18$)	<i>p</i> -value
Mild	2 (100%)	6 (33%)	0.068
Marked	0	12 (67%)	

Table 11. Apparent diffusion coefficient (ADC) values and signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) of benign and malignant ovarian lesions

	Benign lesions ($n=2$)	Malignant lesions ($n=18$)	<i>p</i> -value
ADC (mean $\pm$ SD)	1.05 ± 0.42	0.85 ± 0.14	0.133
Signal intensity (mean $\pm$ SD)	0.37 ± 0.24	0.75 ± 0.14	0.003

SD, standard deviation.

Table 12. Apparent diffusion coefficient (ADC) values and signal intensities on diffusion-weighted imaging ($b=800 \text{ s mm}^{-2}$) in primary ovarian neoplasms and metastatic ovarian lesions

	Primary ovarian neoplasm ($n=13$)	Metastatic ovarian lesions ($n=5$)	p -value
ADC (mean $\pm$ SD)	0.8 ± 0.14	0.97 ± 0.15	0.021
Signal intensity (mean $\pm$ SD)	0.75 ± 0.16	0.74 ± 0.11	0.909

SD, standard deviation.

Figure 1. Dysgerminoma in a 17-year-old girl. (a) On T_2 weighted axial MRI, a homogeneous mild hyperintense solid lesion is seen in the right adnexa (arrows). (b) A sagittal T_2 weighted image shows the tumour (arrows). (c) T_1 weighted fat-saturated post-contrast axial MRI shows homogeneous enhancement of the lesion. (d) A diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI demonstrates that the lesion has high signal intensity. (e) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass is $0.71 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

intersection gap, 0.8 mm). These upper abdominal sequences were acquired before contrast administration and during the arterial, venous and delayed phases following contrast administration. For the pelvis, the routine protocol involved axial, coronal and sagittal HASTE sequences, axial and sagittal T_1 weighted spin-echo sequences (TR/TE=672/14 ms; section thickness, 5 mm; intersection gap, 1 mm), axial and sagittal breath-hold T_1 weighted fat-suppressed spoiled gradient-echo shared pre-pulse sequences. These sequences were acquired before contrast administration and during the delayed phase following contrast administration.

Image analysis

The MR examinations were reviewed retrospectively using the histopathological diagnosis as a reference. The acquired images were transferred to a workstation

(Leonardo; Siemens Medical Systems) on which all the ADC maps were created automatically using standard software (Leonardo, Siemens Medical Solutions). The mean ADC values were determined on images with b factors of 50 and 800 s mm^{-2} . The signal intensities of the lesions were measured on this workstation for qualitative and quantitative analysis.

For the qualitative analysis, two radiologists (BB and SB) evaluated the lesions' signal intensities on the DWI ($b=800 \text{ s mm}^{-2}$) and T_2 weighted and T_1 weighted post-contrast (delayed-phase) images, recording a consensus reading. On DWI, the signal intensity of each lesion was evaluated as hyperintense, isointense or hypointense relative to that of the myometrium. On T_2 weighted images, the signal intensity of each lesion was determined by comparison with the signal intensity of the outer myometrium, which corresponds to the external third of the myometrium excluding the arcuate veins. For lesions with heterogeneous signal intensity, the dominant signal

(a)

(b)

(c)

(d)

Figure 2. Bilateral serous adenocarcinoma in a 65-year-old woman. (a) On T_2 weighted axial MRI, two solid masses with heterogeneous signal intensity are seen in bilateral lower abdominal quadrants (arrows). (b) A T_1 weighted fat-saturated post-contrast axial MRI shows homogeneous enhancement of the lesions. (c) A diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI demonstrates the high signal intensity of the lesions. (d) On the apparent diffusion coefficient (ADC) map, the ADC value within the large mass is $0.70 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

intensity (hypointense or hyperintense) was taken into consideration. On T_1 weighted post-contrast (delayed-phase) images, the enhancement patterns were divided in two groups: mildly or markedly enhancing. Marked enhancement was recorded for lesions whose signal intensity was equal to or higher than that of the myometrium, whereas lesions with lesser signal intensity were recorded as showing mild enhancement.

For the quantitative analysis, one of the authors (BB) placed circular regions of interest (ROIs) of 1 cm^2 on the solid component of the lesions on the ADC maps and DWI ($b=800 \text{ s mm}^{-2}$), avoiding apparent heterogeneity. The ROI was placed within the lesions in the area with the lowest ADC value on ADC map and highest intensity on DWI ($b=800 \text{ s mm}^{-2}$). At least three measurements were obtained and averaged. The lesions in our data set were divided into two main groups for evaluation. The first group included all adnexial lesions, the second consisted of lesions of ovarian origin, excluding uterine or tubal lesions.

For the adnexial lesions, we compared benign with malignant lesions, lesions of myometrial origin (ordinary leiomyomas, degenerated leiomyomas and leiomyosarcomas) with those of non-myometrial origin and

ordinary leiomyomas with fibrotechomas. For the ovarian lesions, we compared benign with malignant lesions and malignant lesions of ovarian origin with those of metastatic origin.

Statistical analysis

For the qualitative analysis, variables were compared between tumour types using the χ^2 test.

For the quantitative analysis of normally distributed data ($p>0.05$ on Levene analysis), we used Student's t -test to compare the ADC values and signal intensities of the adnexial and ovarian lesions. When the data were not normally distributed ($p\leq 0.05$ on Levene analysis), we used the Mann-Whitney U -test. Differences were deemed statistically significant when the p -value was less than 0.05.

Results

Details of the qualitative and quantitative analyses are shown in Table 1.

Figure 3. Granulosa cell tumour in a 20-year-old woman. (a) A T_2 weighted axial MRI shows a mass with a predominantly solid appearance in the right adnex (thick arrows), which extends behind the uterus (thin arrows). The tumour has a cystic component (arrowhead). There is also a cystic lesion in the left adnex (open arrow). (b) A T_1 weighted fat-saturated post-contrast axial MRI shows prominent enhancement of the solid components of the lesion. (c) A diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI demonstrates the high signal intensity of the lesion. (d) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass is $0.88 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

Adnexial lesions

Qualitative analysis

A total of 19 of the 37 lesions (18 of 22 malignant lesions (81.8%), 1 of 15 benign lesions (6.6%)) had higher signal intensity on DWI than the myometrium. High signal intensity was observed more frequently in malignant lesions than in benign lesions ($p < 0.0001$) (Table 2). All of the ordinary leiomyomas had low signal intensity on DWI. In degenerated leiomyomas and

leiomyosarcomas, all of the three types of signal intensity (hypointense, isointense and hyperintense) could be detected.

On T_2 weighted images, 15 of 37 lesions (15 of 22 malignant (68%), no benign lesions) had hyperintense signal intensity. High signal intensity was observed more frequently in malignant lesions than in benign lesions ($p < 0.0001$), and conversely low signal intensity was observed more frequently in benign lesions than in malignant lesions ($p = 0.000$) (Table 3).

(a)

(b)

(c)

(d)

Figure 4. Serous adenocarcinoma of the fallopian tube in a 58-year-old woman. (a) The T_2 weighted axial MRI shows a hypointense solid mass in the right adnex (thick arrows), which extends behind the uterus (thin arrows). (b) A sagittal T_2 weighted image shows the tumour (thick arrows). Thin arrows show the uterus. (c) A diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI demonstrates the predominantly high signal intensity of the lesion (thick arrows). Thin arrows show the uterus. (d) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass (thick arrows) is $1.20 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$. Thin arrows show the uterus.

None of the benign lesions had a dominantly hyperintense signal. Three benign lesions (all degenerated myomas) had heterogeneous signal intensity, but as these lesions were predominantly isointense or hypointense, only these areas were taken into consideration. Three of the malignant lesions (all leiomyosarcomas) had heterogeneous signal intensity. The dominant components were hyperintense for one lesion, isointense for a second and hyperintense for a third.

On post-contrast T_1 weighted images, 25 of 37 lesions (16 of the 22 malignant lesions (73%), 9 of 15 benign (60%)) had marked contrast enhancement (Table 4). There were no statistically significant differences in enhancement patterns between benign and malignant lesions ($p=0.417$).

Quantitative analysis

Table 1 shows the ADC values and signal intensities on the DWI ($b=800 \text{ s mm}^{-2}$) for every type of lesion. The mean ADC value of the benign lesions ($n=15$) was 0.84 ± 0.42 (mean $\pm$ standard deviation (SD)), and the

mean ADC value of the malignant lesions ($n=22$) was 0.88 ± 0.16 . There was no significant difference in the ADC values of the benign and malignant lesions ($p=0.96$). When the signal intensities on DWI were compared, however, malignant lesions had higher values (0.69 ± 0.21) than benign neoplasms (0.29 ± 0.13 ; $p<0.0001$) (Table 5).

There were no significant differences in the ADC or signal intensity values of leiomyosarcomas ($n=3$) and degenerated leiomyomas ($n=3$) (Table 6), or of fibrotechomas ($n=2$) and ordinary leiomyomas ($n=10$) (Table 7).

Ovarian lesions

Qualitative analysis

On DWI, 17 of 20 lesions (including 17 of 18 malignant lesions (94.4%)) had higher signal intensity than the myometrium. Only one malignant ovarian lesion (1 of 18 malignant lesions (5.5%)) was isointense with the

(a)

(b)

(c)

(d)

Figure 5. Leiomyosarcoma in a 47-year-old woman. (a) T_2 weighted axial MRI shows a hypointense solid mass in the middle of the lower abdomen (arrows). (b) A T_1 weighted fat-saturated post-contrast axial MRI shows prominent enhancement of the lesion. (c) A diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI demonstrates the high signal intensity of the lesion. (d) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass is $0.82 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

myometrium. None of the benign ovarian lesions ($n=2$) had higher signal intensity than the myometrium. High signal intensity was observed more frequently in malignant lesions than in benign lesions ($p=0.001$) (Table 8).

On T_2 weighted images, 14 of 20 lesions (14 of 18 malignant lesions (78%), no benign lesions) had hyperintense signal. Only low signal intensity was observed in benign neoplasms (Table 9).

On post-contrast T_1 -weighted images, 12 of 20 lesions (12 of 18 malignant lesions (67%), no benign lesions) had marked contrast enhancement (Table 10). Marked enhancement pattern was observed more frequently in malignant lesions than in benign lesions

but this difference was not statistically significant ($p=0.068$).

Quantitative analysis

Table 1 shows the mean ADC values and signal intensities (on the DWI, $b=800 \text{ s mm}^{-2}$) for every type of lesion. The mean ADC value of the benign lesions ($n=2$) was 1.05 ± 0.42 , and the mean ADC value of the malignant lesions ($n=18$) was 0.85 ± 0.14 . There was no significant difference in the ADC values of benign and malignant lesions ($p=0.133$). When signal intensities on DWI were compared, however, malignant lesions had higher values (0.75 ± 0.14) than benign ones (0.37 ± 0.24 ; $p=0.003$) (Table 11).

Figure 6. Fibrothecoma in a 56-year-old woman. (a) On T_2 weighted axial MRI, a heterogeneous hypointense solid lesion is seen in the right adnex (thick arrows). Thin arrows show the uterus. (b) A T_1 weighted fat-saturated post-contrast axial MRI shows no enhancement of the lesion (arrows). (c) On a diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI, the lesion is hypointense (thick arrows). Thin arrows show the uterus. (d) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass (thick arrows) is $0.75 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$. Thin arrows show the uterus.

In the malignant lesion group ($n=18$), when primary ovarian neoplasms ($n=13$) were compared with metastatic ovarian lesions ($n=5$), the ADC values overlapped and there was no significant difference in signal intensity values ($p=0.909$) (Table 12).

Example cases are shown in Figures 1–8.

Discussion

DWI has gradually become accepted in body imaging for the detection and characterisation of focal lesions [12]. It provides information about the biophysical properties of tissues, such as cell organisation and density, microstructure and microcirculation. ADC values are related to the proportion of extracellular and intracellular components within the tissue; increased tissue cellularity or cell density decreases this value. Thus, large ADCs suggest benign processes with poor cellularity, whereas small ADCs might indicate a malignancy with large cell diameter and denser cellularity, which restricts water diffusion [13]. Therefore, ADC measurements can be valuable in differentiating benign and malignant lesions.

The results of our study demonstrate that the ADC values are not useful in differentiating benign from

malignant solid gynaecological adnexial lesions. There was no significant difference in the ADC values of benign and malignant lesions; neither was there any significant difference between the ADC values of leiomyomas and degenerated leiomyomas or between the ADC values of fibrotechomas and ordinary leiomyomas. Further, the ADC values of primary and metastatic ovarian lesions overlapped. The ADC values measured in our study are similar to those of the solid components of the ovarian lesions described by Fujii et al [11]. Fujii et al [11] also reported that ADC values did not differ significantly between malignant and benign lesions. In both our study and Fujii et al's, there were many overlaps between the ADC values of the malignant and benign ovarian lesions. As Fujii et al reported in their study, these poor results may largely reflect the increased mean ADC values in malignant lesions and the decreased lowest ADC values in benign lesions. Desmoplastic reaction in the stroma may cause increased mean ADC values in malignant tumours [11]. Because ordinary leiomyomas, which comprised the majority of the benign lesions in our patient group, tend to contain hyalinised collagen, their signal is hypointense on T_2 weighted images. The DWI appearance of leiomyomas can be explained by a " T_2 blackout effect", i.e. hypointensity on DWI owing to hypointensity on T_2

(a)

(b)

(c)

Figure 7. Ordinary leiomyoma in a 37-year-old woman. (a) On T_2 weighted axial MRI, a homogeneous hypointense solid lesion (thick arrows) is seen in the left adnex near the uterus (thin arrows). There is also a small leiomyoma in the fundus of the uterus (arrowhead). (b) On the diffusion weighted ($b=800 \text{ s mm}^{-2}$) axial MRI, the lesion is hypointense (thick arrows). Thin arrows show the uterus. (c) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass is $0.42 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

Figure 8. Degenerated leiomyoma in a 42-year-old woman. (a) On T_2 weighted axial MRI, a heterogeneous hypointense solid lesion (thick arrows) is seen in the left adnex near the uterus (thin arrows). (b) On the diffusion-weighted ($b=800 \text{ s mm}^{-2}$) axial MRI, the lesion is hypointense. (c) On the apparent diffusion coefficient (ADC) map, the ADC value within the mass is $1.30 \times 10^{-3} \text{ mm}^2 \text{ s}^{-1}$.

weighted images, which causes a decrease in the ADC of ordinary leiomyomas [14, 15]. Furthermore, the low ADC value observed for one of the fibrotecomas, a benign lesion, can be explained by the bundles and storiform patterning of spindle cells in fibromas and thecomas [11].

We observed no statistically significant difference between the ADC values of benign and malignant lesions. In lesions of both adnexial and ovarian origin, however, there was a significant difference in the signal intensities of benign and malignant lesions when evaluated on DWI either qualitatively or quantitatively ($b=800 \text{ s mm}^{-2}$). High signal intensity was observed more frequently in malignant lesions than in benign lesions. Fujii et al [11] also reported that the majority of the solid components of malignant ovarian tumours demonstrated high signal intensity on DWI. In our study, one of the three malignant lesions without high signal intensity on DWI was a serous adenocarcinoma (isointense), the other two were uterine leiomyosarcomas (one isointense, one hypointense). Among the malignant lesions studied by Fujii et al [11], a serous adenocarcinoma, two clear cell adenocarcinomas, a metastatic tumour of appendiceal cancer and an endometrioid borderline tumour did not present with high signal intensity. We observed that benign lesions demonstrated hypointense signal characteristics on DWI

($b=800 \text{ s mm}^{-2}$) more frequently than malignant lesions. Only one benign lesion (a degenerated leiomyoma) had a hyperintense signal. Two benign lesions (one degenerated leiomyoma and one fibrothecoma) were isointense. In the group with ovarian lesions, our observations were in concordance with those of Fujii et al [11], who reported that high signal intensity occurred less frequently in benign ovarian tumours than in malignant ones [11]. We note, however, that the number of benign ovarian lesions in our patient group was small.

When looking at malignant lesions, we observed no significant difference between the signal intensities on DWI ($b=800 \text{ s mm}^{-2}$) of primary and metastatic ovarian lesions. When comparing the ADC values of primary and metastatic ovarian lesions, the difference was significant ($p=0.021$) but there was overlap between the two groups. Hence, DWI does not contribute in the differential diagnosis of primary and metastatic ovarian lesions.

Our study also suggests that DWI is not useful in the differential diagnosis of benign and malignant myometrial lesions. All of the ordinary leiomyomas had low signal intensity on DWI. In degenerated leiomyomas and leiomyosarcomas, however, hypointense, isointense and hyperintense signal intensities could all be detected. The ADC values of leiomyosarcomas were lower than those of degenerated leiomyomas

with no overlap, but this difference was not statistically significant ($p=0.07$). The ADC values of ordinary leiomyomas overlapped with those of both degenerated leiomyomas and leiomyosarcomas (Table 1). These findings are similar to those of Tamai et al [8], who compared uterine sarcomas with leiomyomas. This study also reported that the ADC values of leiomyosarcomas were lower than those of degenerated leiomyomas without an overlap, and the difference was statistically significant. Consistent with our study, Tamai et al [8] also reported an overlap in the ADC values of ordinary leiomyomas with those of both degenerated leiomyomas and leiomyosarcomas.

Our study demonstrated that DWI was not useful in the differential diagnosis of subserosal ordinary leiomyomas and fibrotechomas, which have similar signal intensities on routine MR sequences [5]. The ADC values of these lesions overlapped. On DWI, all of the ordinary leiomyomas were hypointense and the fibrotechomas had similar signal characteristics (one hypointense, one isointense). In our patient group, neither of the two fibrotechomas had high signal intensity to differentiate them from ordinary leiomyomas.

In addition to the lesions' characteristics in diffusion-weighted sequences, we also evaluated their enhancement pattern and signal properties in T_2 weighted sequences. In the group with ovarian lesions, we observed that benign lesions had mild enhancement patterns, whereas malignant lesions had marked enhancement (Table 10). When evaluating adnexial lesions, both benign and malignant lesions frequently demonstrated a marked enhancement pattern (Table 4). The high prevalence of marked enhancement pattern in adnexial lesions might be related to the high frequency of lesions with myometrial origin. When evaluating the T_2 weighted sequences of both adnexial and ovarian lesions, malignant lesions had high signal intensity, whereas benign lesions had low signal intensity, and the difference was statistically significant (Table 3 and 9). In our study, high signal intensity in T_2 weighted sequences and marked enhancement in post-contrast sequences generally indicated a malignant lesion, whereas low signal intensity in T_2 weighted sequences and mild enhancement pattern generally indicated a benign lesion.

Our study had some limitations. First, the study population was small and not very diverse. In particular, two-thirds of the benign adnexial lesions were subserosal ordinary leiomyomas. Also, the frequency of benign ovarian lesions was low. Further studies are required to validate the results of our study in a larger population. Second, the abnormal signal intensity observed on DWI may be due to the " T_2 shine-through effect" and may not represent true restricted diffusion. In clinical practice, however, it is useful to evaluate the abnormal signal intensity on DWI, and a relatively high b factor was used for the acquisition of DWI to reduce the " T_2 shine-through effect".

Conclusion

The signal intensities on DWI of benign and malignant lesions differed significantly. High signal intensity was

observed more frequently in malignant than in benign lesions. There was, however, overlap between the ADC values of benign and malignant lesions, in both the adnexial and ovarian groups, which prevents their contribution to the differential diagnosis. Our results suggest that the signal intensity characteristics and ADC values seen on DWI cannot contribute to the differential diagnosis of lesion types.

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