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Magnetic resonance imaging features of ovarian fibroma, fibrothecoma, and thecoma

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Abstract

Objective: To retrospectively evaluate the conventional and functional (diffusion- or perfusion-weighted) magnetic resonance (MR) imaging features of ovarian fibroma, fibrothecoma, and thecoma.
Materials and Methods: Histologically proven ovarian fibromas ($n = 19$), fibrothecomas ($n = 7$), and thecomas ($n = 2$) were reviewed (26 patients). The morphologic and signal intensity (SI) characteristics on conventional MR imaging ($n = 28$, all cases) were analyzed. The b_{1000} signal intensity on diffusion-weighted image (DWI) ($n = 22$) and the time-to-signal intensity curve on perfusion-weighted image (PWI) ($n = 7$) were also analyzed. The presence and shape of the ipsilateral ovarian tissue surrounding the lesions were evaluated on T2-weighted image.
Results: Twenty-two cases (79%) were predominantly solid tumor. Majority of the detected lesions exhibited the characteristic homogeneous low SI on T1- (24/28, 86%) and T2- (19/28, 68%) weighted image. Conversely, a number of lesions exhibited high SI (9/28, 32%) on T2-weighted image. Most lesions presented with a detectable ipsilateral ovary on T2-weighted image (24/28, 86%). Tumors larger than 6 cm more likely showed atypical morphology (mixed solid and cystic, cystic), atypical SI (high on T1- and T2-weighted image), and large amount ascites. Larger tumor group (>6 cm) was more likely diagnosed as fibrothecoma or thecoma than fibroma by pathology. On DWI, 16 lesions showed low b_{1000} signal intensity (16/22, 73%). On PWI, all lesions showed curve type 1 or 2 (7/7, 100%), which tends to characterize benign lesions. All (16/16, 100%) pre-menopausal women had a detectable ipsilateral ovary, and six (60%) out of 10 post-menopausal women had a detectable ipsilateral ovary ($p < 0.05$).
Conclusions: Combining conventional morphologic and signal intensity characteristics with the findings from DWI or PWI might help differentiate ovarian fibroma, fibrothecoma, and thecoma from ovarian malignancy, although further prospective larger scale study using DWI and PWI is needed.

Key words: Fibrothecoma—Ovarian fibroma—Ovarian neoplasms—Ovary—Magnetic resonance imaging (MRI)

Fibromas, fibrothecomas, and thecomas are the most common solid ovarian tumors and account for 4% of all ovarian neoplasms. Fibroma is the most common sex cord–stromal tumor [1]. These tumors are benign tumors of sex cord–stromal cell origin and are rarely malignant [1]. Fibroma, fibrothecoma, and thecoma are occasionally referred to by the common term ''fibrothecoma'' due to their histologic overlap. On imaging investigations, the tumor commonly appears as a homogeneous solid mass with mild enhancement on computed tomography (CT) [1]. It has been demonstrated that magnetic resonance (MR) imaging is useful for diagnosing ovarian fibromas, fibrothecomas, and thecomas [1–3]. The presentation of tumors in conventional imaging studies is characterized by low to intermediate signal intensity on T1-weighted images and low signal intensity on T2-weighted images, caused by the presence of densely packed connective tissue [2, 3]. The main lesion considered in differential diagnoses of ovarian fibrothecoma is a uterine subserosal leiomyoma, which shows similarities in T2-weighted signal intensities and lesion locations. Accurate diagnosis of the leiomyoma may preclude unnecessary further evaluation in an asymptomatic patient [1–3].

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Another considered lesion in differential diagnosis is malignant ovarian tumor. Although one of the key accepted imaging criteria for malignant ovarian tumors is the presence of a solid mass or a large solid component of the lesion, fibrothecomas are overwhelmingly benign solid ovarian masses. The accurate diagnosis of these tumors and their differentiation from malignant masses is important because this step can significantly affect patient management, avoiding unnecessary preoperative metastatic work-up and surgery, decreasing patient anxiety, and avoiding the morbidity associated with invasive surgical procedures [4]. Although these are generally solid tumors, edema and cyst formation can be noted in pathologic examination, which explains varying degree of high signal intensity portions on T2-weighted image [1, 4–7]. Larger fibrothecomas were shown to be more likely to exhibit degenerative and edematous changes [1, 4]. Fibrothecomas can also present with ascites or pleural effusions, known as Meigs syndrome [1, 4]. Such atypical characteristics contribute to imaging profiles that mimics those of malignant ovarian tumors.

Diffusion- and perfusion-weighted MR imaging approaches are useful in the assessment of the microvascular and cellular characteristics of masses in abdominopelvic images, with recent reports showing their effectiveness in the differentiation of benign from malignant adnexal masses [8–10]. To our knowledge, however, there have been only a few studies evaluating the MR imaging features of fibrothecomas, particularly the diffusion- and perfusion-weighted MR imaging features. Therefore, the purpose of the present study was to evaluate MR imaging features of 28 cases of fibromas, fibrothecomas, and thecomas using diffusion- or perfusion-weighted MR imaging as well as conventional MR imaging.

Patients and methods

Our study was approved by the institutional review board. However, as this study was a clinical retrospective investigation, informed consent was not required.

Patient population

A computerized search was conducted to identify surgically confirmed cases of ovarian fibromas, fibrothecomas, and thecomas with MR imaging from January 2009 to February 2012. We identified and evaluated pathologically confirmed 28 cases of fibrothecomas (19 fibromas, 7 fibrothecomas, and 2 thecomas) in 26 patients. Each patient's medical records detailing the clinical symptoms, surgical outcomes, and results of pathological examinations were reviewed retrospectively. Sixteen women were premenopausal and 10 were postmenopausal. The mean patient age was 44.3 years (range, 27–62 years). All MR imaging procedures were performed within 2 weeks prior to the surgery.

MR imaging protocol

The MR imaging studies were performed using a 1.5-T MR scanner (Achieva; Philips Medical System, Best, The Netherlands) and a phased array torso coil. Half an hour before MR imaging, patients received 20 mg intramuscular injections of scopolamine butylbromide as an antiperistaltic agent.

Conventional MR images (n = 28) were obtained. After sagittal localization, axial T1-weighted turbo spin-echo images (TR range/TE range, 620/10; section thickness, 5 mm; intersection gap, 1 mm; field of view, 25 cm; acquired signals, 2; bandwidth, 250 Hz; matrix, 256 × 256) were obtained. Axial, sagittal, and coronal T2-weighted turbo spin-echo images (TR range/TE range, 6000/100; section thickness, 5 mm; intersection gap, 1 mm; field of view, 25 cm; acquired signals, 2; bandwidth, 250 Hz; matrix, 256 × 256) were obtained. After injection of gadoterate meglumine (Dotarem®; Guderbet, France) at a dose of 0.1 mmol/kg body weight, fat-suppressed, T1-weighted axial and sagittal images were obtained using parameters identical to those used in the pre-contrast T1-weighted imaging.

Diffusion-weighted MR images (DWI) (n = 22) (TR range/TE range, 10,000/59; section thickness, 5 mm; intersection gap, 1 mm; field of view, 25 cm; matrix, 128 × 128) were obtained in the axial plane using a single-shot spin-echo echoplanar sequence with the sensitivity encoding technique (sensitivity encoding factor, 2). The b values corresponding to the diffusion-sensitizing gradient were 0 and 1000 s/mm^2. A dynamic contrast-enhanced fat-suppressed T1-weighted three dimensional fast field echo sequence (n = 7) (TR range/TE range, 5–6/2–3; flip angle, 10°; section thickness, 5 mm; intersection gap, 1 mm; field of view,25 cm; acquired signals, 2; bandwidth, 190 Hz; matrix, 356 × 356) was performed through the tumor and the adjacent myometrium in the optimal plane at the level where "solid tissue" was observed on non-enhanced MR images. Contrast-enhanced image acquisition started simultaneously with the administration of gadolinium chelate, with 7–12 continuous sets of image series acquired over 4–6 min. These dynamic contrast-enhanced images acquired before the post contrast images as being a part of conventional MR images.

Analysis of imaging features

The original MR reports were reviewed and the correct diagnosis rate as fibrothecomas versus subserosal leiomyoma or malignant ovarian tumor determined (i.e., if the pathology was fibrothecoma and the report called a lesion a fibroma, it was accepted as "correct diagnosis").

Imaging features were evaluated by consensus of three abdominal radiologists. The conventional MR imaging findings were analyzed for the following

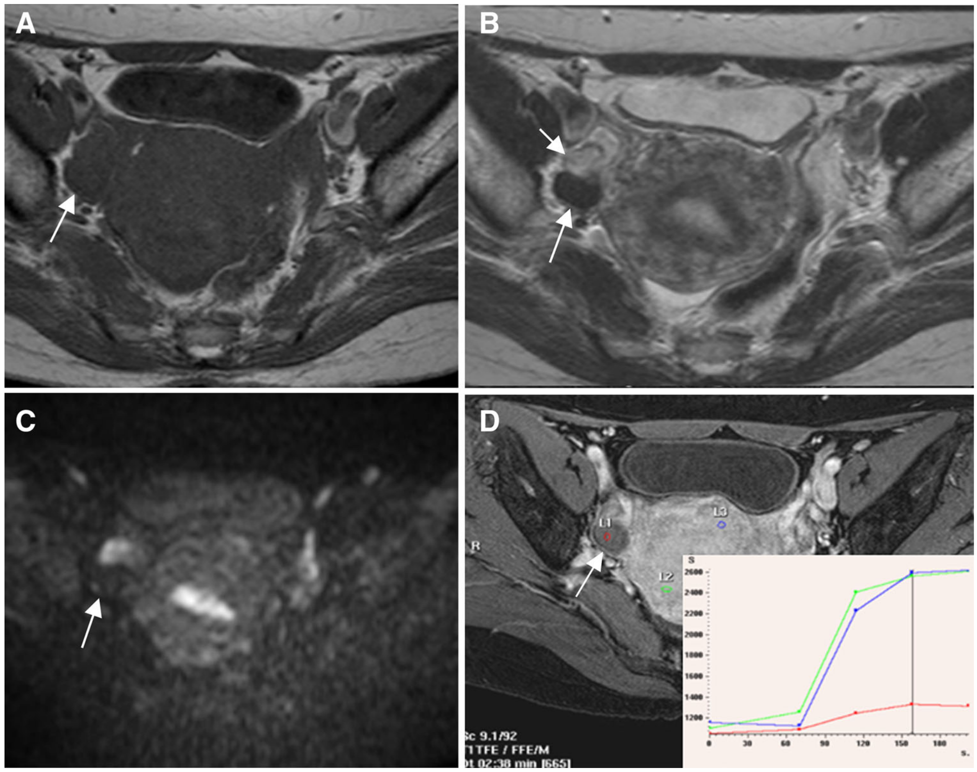


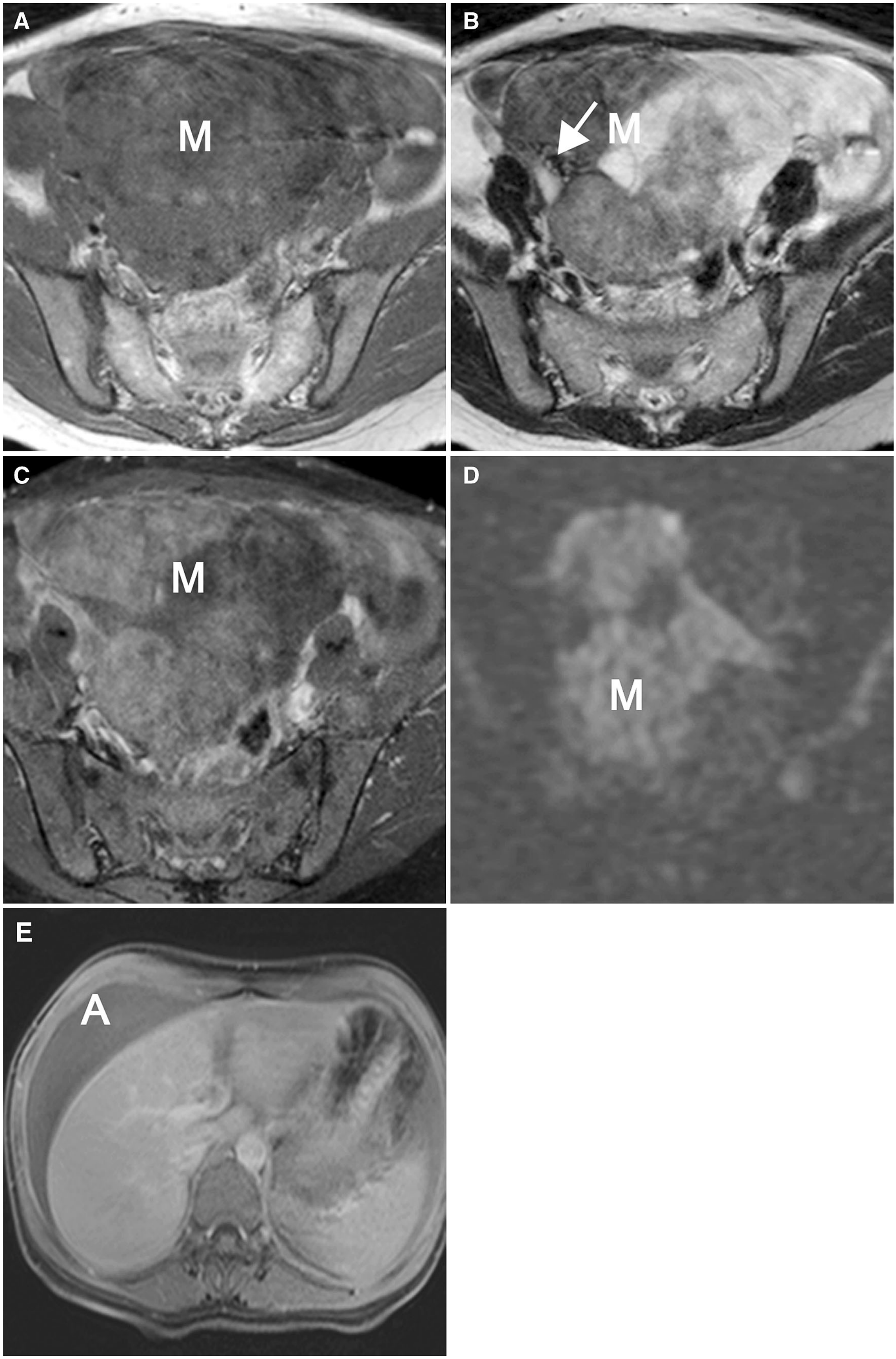
Fig. 1. A 49-year-old female patient with right ovarian fibroma with typical MR imaging features. T1-(**A**) and T2-(**B**) weighted axial MR images show right ovarian fibroma (*arrow*) that is hypointense compared to the outer myometrium. Note the presence of a normal, ovoid-shaped ipsilateral ovary (*short arrow* in **B**). **C** Diffusion-weighted MR imaging in the axial plane shows low signal intensity on the right ovarian mass (*arrow*), compared to the endometrial fluid collection. **D** Contrast-enhanced, fat-suppressed, T1-weighted MR image shows mild homogeneous enhancement (*arrow*). The time-signal intensity curve on perfusion-weighted MR imaging was classified as type 1 curve.

parameters and features: tumor size, morphology, signal intensity on T1- and T2-weighted images, and the presence of ascites.

The mass size was assessed as the major tumor diameter, measured along the three dimensions. In terms of morphology, the masses were classified as either predominantly solid, mixed solid/cystic, and predominantly cystic; a tumor was described as predominantly solid when it was composed of more than 70% solid area and predominantly cystic when it was composed of more than 70% cystic area. The signal intensity of the solid components within tumors was compared to that of the outer myometrium or the skeletal muscle on T1- (low to intermediate signal intensity, high signal intensity) and T2-weighted imaging (homogeneous or heterogeneous low signal intensity, high signal intensity). The presence of ascites was also evaluated. The amount of ascites was rated as none, small and large. Because the amount of ascites could not be accurately quantified with MR images, it was defined as small if the ascites was confined to the pelvic cavity or localized within the peritoneal cavity, and as large if the ascites overflowed into the peritoneal cavity from the pelvic cavity.

On DWI, signal intensity of the solid components within the tumors at $b = 1000$ s/mm^2 was compared with that of serous fluid (i.e., cystic bladder or cerebrospinal fluid), and the signal intensity was evaluated as either high or low signal intensity. High signal intensity is considered to be a characteristic of malignant tumors and low signal intensity generally favors a diagnosis of a benign mass [9, 10]. On perfusion-weighted MR imaging (PWI), the dynamic enhancement pattern of the solid components within the tumors was evaluated and compared with that of the normal outer myometrium. The time-signal intensity curves were classified as type 1 (a gradual increase in the signal intensity of the mass without a well-defined peak), type 2 (a moderate initial increase in the signal intensity followed by a plateau), and type 3 (an intense initial increase in signal intensity). Type 1 or 2 curves generally favor a diagnosis of a benign mass, while the type 3 curve is characteristic of malignant tumors [8, 10].

The presence or absence of ipsilateral ovaries was evaluated for each mass. Ovarian tissue considered to be present when demonstrable follicles were detected in the presumed ovarian tissue on T2-weighted images. In cases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◀ **Fig. 2.** A 36-year-old female patient with right ovarian fibroma with an atypical MR imaging profile. The large heterogeneous mass and large amount of ascites mimics a malignant tumor. **A** T1-weighted MR image in axial plane shows a large solid mass (*M*) with low signal intensity. **B** T2-weighted MR image in the axial plane shows heterogeneously high signal intensity mixed solid and cystic mass (*M*). Normal ovoid-shaped right ovary (*arrow*) abutting the mass (*M*) is noted. **C** Contrast-enhanced, fat-suppressed, T1-weighted MR image shows mild enhancement of the mass (*M*). **D** Diffusion-weighted MR image in the axial plane shows low signal intensity on the right ovarian mass (M). **E** Contrast-enhanced, fat-suppressed, T1-weighted MR image shows associated large amount ascites **A**, which resolved after resection of right ovary mass.

in which the ovarian tissue was detected, the shape and positioning of the ovary relative to the mass were described as crescent-shaped or normal ovoid-shaped.

Analysis of clinical and pathologic features

The clinical features of the 26 patients, including clinical symptoms or signs, were retrospectively analyzed. The pathologic analysis performed after surgery was also reviewed. The MR imaging findings were correlated with the pathologic features.

Statistical analysis

The differences in the MR imaging features (morphology, signal intensity on T1- and T2-weighted images, ascites, and detectable ipsilateral ovary) and pathologic tumor type between tumors larger than 6 cm or less were assessed. The cut off value (6 cm) was determined according to previous studies [1, 4]. The differences in the MR imaging features (morphology, signal intensity on T1- and T2-weighted images, ascites, and detectable ipsilateral ovary) between different pathologic types (fibroma and fibrothecoma/thecoma) were also evaluated. Both analyses were done using the Fisher exact probability test. Mann–Whitney test was performed to evaluate the difference in the presence of detectable ipsilateral ovary between the pre- and post-menopausal patients. A p value less than 0.05 was considered statistically significant. All analyses were performed with IBM SPSS 20 (IBM Software Inc.).

Results

Imaging features

Twenty-one (75%) cases of the 28 examined cases were diagnosed correctly in the original reports. Among the remaining 7 cases, 5 were initially diagnosed as malignant ovarian tumors, 1 case was diagnosed as cystade-

Table 1. MR imaging characteristics of fibromas, fibrothecomas, and thecomas

Imaging finding	Fibroma (n = 19)	Fibrothecoma/thecoma (n = 9)	Total (No./total)
Conventional MR (n = 28)			
Morphology			
Predominantly solid	84.2% (16/19)	66.7% (6/9)	78.6% (22/28)
Mixed solid/cystic	10.5% (2/19)	33.3% (3/9)	17.8% (5/28)
Predominantly cystic	5.3% (1/19)	0% (0/9)	3.6% (1/28)
Signal intensity			
T1 signal intensity			
Low to intermediate	94.7% (18/19)	66.7% (6/9)	85.7% (24/28)
High	5.3% (1/19)	33.3% (3/9)	14.3% (4/28)
T2 signal intensity			
Homogeneously/heterogeneously low	73.7% (14/19)	55.6% (5/9)	67.9% (19/28)
High	26.3% (5/19)	44.4% (4/9)	32.1% (9/28)
Ascites			
None	36.8% (7/19)	11.1% (1/9)	28.6% (8/28)
Present	63.2% (12/19)	88.9% (8/9)	71.4% (20/28)
Small	47.4% (9/19)	66.7% (6/9)	53.6% (15/28)
Large	15.8% (3/19)	22.2% (2/9)	17.8% (5/28)
Ipsilateral ovary detection			
Not detected	5.3% (1/19)	33.3% (3/9)	14.3% (4/28)
Detected	94.7% (18/19)	66.7% (6/9)	85.7% (24/28)
Crescent-shaped	57.9% (11/19)	22.2% (2/9)	54.2% (13/24)
Ovoid-shaped	36.8% (7/19)	44.4% (4/9)	45.8% (11/24)
DWI (n = 22)			
Signal intensity (b_{1000})			
Low	93.3% (14/15)	28.6% (2/7)	72.7% (16/22)
High	6.7% (1/15)	71.4% (5/7)	27.3% (6/22)
PWI (n = 7)			
Time-signal intensity curve			
Type 1 or 2	100% (7/7)	0% (0/7)	100% (7/7)
Type 3		–	0% (0/7)

DWI diffusion-weighted image, *PWI* perfusion-weighted image

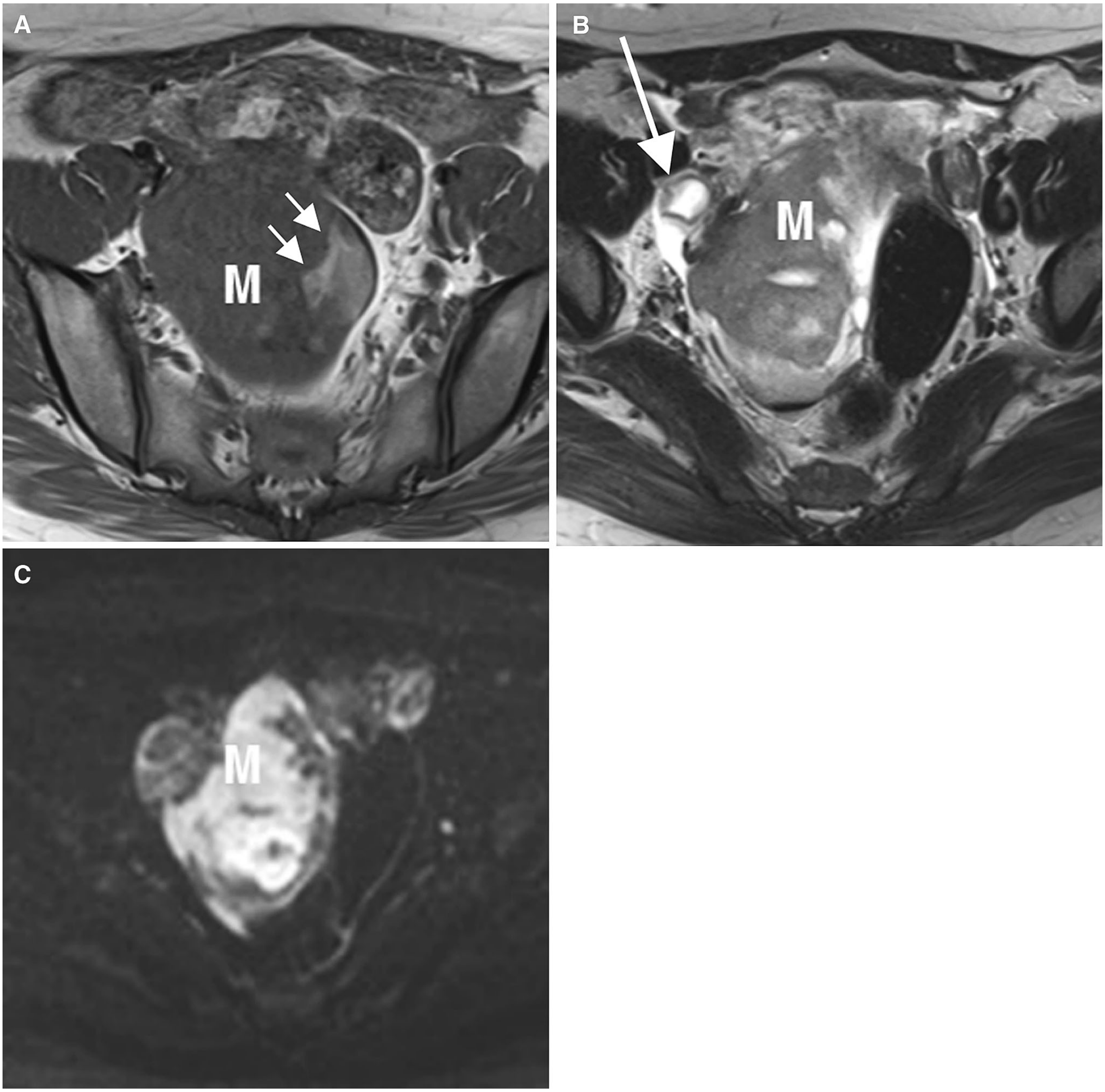

Fig. 3. A 46-year-old female patient with right ovarian thecoma with atypical MR imaging features. The large heterogeneous mass with high signal intensity on diffusion-weighted image mimics malignancy. **A** T1-weighted MR image in axial plane shows large solid mass (*M*) in right pelvic cavity with high signal intensity portion, which suggests hemorrhagic change (*short arrows*). **B** T2-weighted MR image in axial plane shows heterogeneously high signal intensity mass (*M*). Normal ovoid–shaped right ovary (*arrow*) abutting the mass is also noted. **C** Diffusion-weighted MR image in axial plane shows high signal intensity on the mass.

nofibroma, and 1 case was diagnosed as uterine subserosal leiomyoma. Among 5 lesions misdiagnosed as malignant ovarian tumors, 3 cases were performed DWI. Two of the three cases showed low signal intensity and one case showed high signal intensity on DWI (Figs. 2 and 3).

The imaging features are summarized in Table 1. On conventional MR imaging, the mean major tumor diameter was 6.11 cm (range 1.3–15 cm). Twenty-two of the 28 cases (79%) presented as predominantly solid tumors, with only one tumor appearing predominantly cystic. Majority of lesions showed homogeneous low to

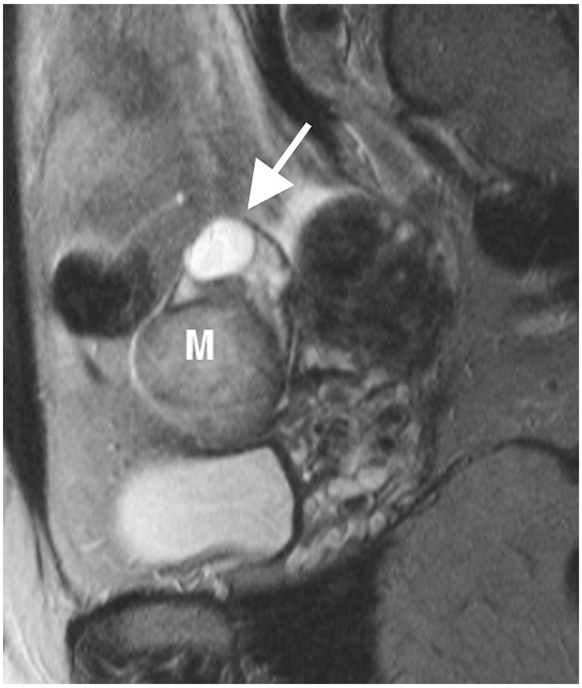

Fig. 4. A 42-year-old female patient with left ovarian fibroma. T2-weighted MR image in sagittal plane shows high signal intensity solid mass (*M*), which is atypical feature of fibroma. Abutting crescent-shaped ipsilateral ovary (*arrow*) is helpful finding to predict benignity.

Fig. 5. A 57-year-old female patient with left ovarian thecoma. T2-weighted MR image in sagittal plane shows large mixed solid and cystic mass with heterogeneously high signal intensity and fluid–fluid levels-hemorrhage, which mimics malignant tumor. Abutting and normal-appearing ipsilateral left ovary is noted (not shown). Pathologic exam after surgery revealed thecoma with hemorrhage and necrotic portions.

intermediate signal intensity on T1-weighted images (24/28, 86%) and homogeneously or heterogeneously low signal intensity on T2-weighted (19/28, 68%) images, in agreement with the established MR imaging presentation profile (Fig. 1). Conversely, a number of lesions showed high signal intensity (9/28, 32%) (Figs. 2, 3, 4 and 5) on T2-weighted images. Ascites were detected in 20 cases (20/28, 71%). Among them, large amount ascites were noted in 5 cases (Fig. 2).

On DWI, 16 lesions showed low b_{1000} signal intensity (16/22, 73%) (Figs. 1 and 2). Seven lesions showed type 1 or 2 time-signal intensity curves (7/7, 100%) on PWI (Fig. 1), which supported a diagnosis of benign lesions (Table 1).

The ipsilateral ovary was observed in most lesions on T2-weighted images (24/28, 86%) (Figs. 1, 2, 3, 4 and 5). The ovary was crescent-shaped and positioned along the periphery of the lesion in 13 cases (13/24, 54%) (Fig. 4) and exhibited a normal, oval shape in 11 cases (11/24, 46%) (Figs. 1, 2, 3 and 5). Sixteen (100%) out of 16 premenopausal women had a detectable ipsilateral ovary, and six (60%) out of 10 post-menopausal women had a detectable ipsilateral ovary ($p < 0.05$).

The imaging features were found to vary significantly with size (larger than 6 and 6 cm or less). Statistically significant differences ($p < 0.05$) between two groups were observed with regard to several parameters such as morphology (mixed solid and cystic, cystic), T1 signal intensity (high signal intensity), T2 signal intensity (high signal intensity), ascites (large amount), and pathologic tumor type (fibrothecoma, thecoma). Otherwise no significant correlation was found between tumor size and the detection rate of ipsilateral ovary (Table 2).

Imaging features were recorded separately according to pathologic subtype; fibroma group and fibrothecoma/thecoma group (Table 1). There was no statistically significant difference between two pathologic groups in imaging features including morphology, T1 and T2 signal intensity, ascites, and ipsilateral ovary detection (Table 3).

Clinical and pathologic features

On review of the clinical features, a broad spectrum of symptoms and presentations was found, ranging from incidental detection to bleeding and dysmenorrhea. Ten of the 26 included patients (38%) had indications for further evaluation of detected lesions from previous imaging studies with ultrasound or CT.

On review of the pathologic features, the tumor was located in the right adnexa in 16 patients, in the left adnexa in 8, and in both adnexa in two patients.

Table 2. Relationship between size and imaging and pathologic features

Imaging Findings and Pathologic diagnosis	Size		p value
	>6 cm (n = 12)	≤6 cm (n = 16)	
Conventional MR (n = 28)			
Morphology			
Mixed solid/cystic & predominantly cystic	41.7% (5/12)	6.3% (1/16)	0.023
Signal intensity			
High SI on T1WI	33.3% (4/12)	0% (0/16)	0.024
High SI on T2WI	58.3% (7/12)	12.5% (2/16)	0.017
Ascites (large amount)	41.7% (5/12)	0% (0/16)	0.008
Ipsilateral ovary detection	83.3% (10/12)	87.5% (14/16)	1.000
Pathologic diagnosis (n = 28)			
Fibroma	41.7% (5/12)	87.5% (14/16)	0.017
Fibrothecoma and thecoma	58.3% (7/12)	12.5% (2/16)	0.017

Histopathologic examination revealed that all tumors, including four cases that ipsilateral ovary was not detectable by imaging, had a variable volume of remaining normal ipsilateral ovarian tissue.

Discussion

The objective of the present study was to investigate the MR imaging features of fibrothecomas using both conventional techniques and novel diffusion- and perfusion-weighted imaging. MR imaging has been previously suggested as a useful tool for differentiating fibrothecomas from subserosal leiomyomas and malignant ovarian tumors. Non-degenerative uterine leiomyomas are well-circumscribed masses with low signal intensity on both T1- and T2-weighted MR images. Detection of a pedicle extending toward the uterus and vascular signal voids between the uterus and tumor mass, as well as a careful evaluation of the relationship between the ipsilateral ovary and the tumor can facilitate the diagnosis of uterine subserosal leiomyomas [2].

Fibrothecomas are known to predominantly show low signal intensity on T2-weighted images and low to intermediate signal intensity on T1-weighted images. In a recent study by Shinagare et al., 91% (32/35) and 77% (27/35) of the fibrothecomas presented with iso- to hypointensity on T1- and T2-weighted images, respectively [4]. In the present study, majority of lesions showed homogeneous low to intermediate signal intensity on T1-weighted (24/28, 86%) and low signal intensity on T2-weighted (19/28, 68%) images, with 79% (22/28) of the lesions presenting a predominantly solid appearance, which is comparable result with previous reports [1, 2, 4]. While these characteristic MR imaging features can be helpful in diagnosis, a number of fibrothecomas exhibit atypical MR imaging features that can mimic malignant adnexal tumors. Several studies have evaluated the relationship between size and signal characteristics in fibrothecomas [1, 4]. Atypical imaging features including degeneration, edematous change, peripheral cystic areas, heterogeneous T2-signal intensity, and heterogeneous enhancement are reported to be more common in larger tumors (>6 cm), accordingly mimic malignant lesions [1, 4]. In the present study, fibrothecomas larger than 6 cm were more likely to show the mixed solid/cystic or cystic mass, high T1 or T2 signal intensities, and large amount of ascites ($p < 0.05$). High or heterogeneous signal intensity on T2-weighted image is possibly owing to stromal edema resulting from mismatch between arterial supply and venous, lymphatic drainage in large tumors [11]. Degenerative changes or foci of thecal cells are also suggested cause of heterogeneous T2-signal intensity and enhancement [4].

In the present study, lesions larger than 6 cm were more likely to be fibrothecoma or thecoma, than smaller tumor group (<6 cm) ($p < 0.05$). Moreover, atypical imaging features including mixed solid and cystic or cystic morphology, high signal intensity on T1- or T2-weighted image and large amount of ascites were more frequent in fibrothecoma/thecoma group, although not statistically significant. To our knowledge, the relationship between pathologic subtype and size or imaging features has not been studied. However, the previous study regarding 19 thecomas reported that they can be considered when a large, mildly enhancing, iso- to slightly hyperintense solid mass is observed with cystic areas [12]. The slightly high T2- signal intensity of thecoma could be owing to little fibrosis and collagen component, compared to that of fibrothecoma or fibroma [4, 12]. Therefore, thecomas or fibrothecomas that contains varying portion of thecal cells might manifest as larger tumors with higher signal intensity and more frequent necrosis and degeneration than fibromas. Both two thecomas included this study were large mass (10 and 7.5 cm) with atypical imaging features with hemorrhagic changes, ascites, and high signal intensity on DWI, which was consistent with previous study and could potentially lead to a misdiagnosis as a malignant ovarian tumor (Figs. 3 and 5) [12].

Despite these features observed in conventional MR imaging approaches, it is still difficult to distinguish fibrothecomas from malignant ovarian tumors. DWI and

Table 3. Image analysis according to pathologic diagnosis

Imaging findings and pathologic diagnosis	Pathologic diagnosis		p value
	Fibroma	Fibrothecoma/thecoma	
Conventional MR (n = 28)			
Morphology			
Mixed solid/cystic and predominantly cystic	15.8% (3/19)	33.3% (3/9)	0.352
Signal intensity			
High SI on T1WI	5.3% (1/19)	33.3% (3/9)	0.084
High SI on T2WI	26.3% (5/19)	44.4% (4/9)	0.407
Ascites (large amount)	15.8% (3/19)	22.2% (2/9)	1.000
Ipsilateral ovary detection	94.7% (18/19)	66.7% (6/9)	0.084

the calculated apparent diffusion coefficient (ADC) are frequently used to differentiate between tumor types potential use of DWI to improve the diagnostic accuracy of MR imaging in adnexal masses, although the clinical applications of this approach are still controversial [9, 10, 13, 14]. However, to our knowledge, there are very few report that applied DWI in fibrothecomas in the English literature [14]. In the present study, 73% (16/22) of cases showed low signal intensity on DWI which tends to reflect benign tumors. In the study by Zhang et al., that analyzed DWI and ADC values of 18 fibrothecomas, 61% (11/18) of the cases showed intermediate signal intensity (similar to that of myometrium), which result was comparable with our study [14]. The inclusion of fibromas in the present study group would have contributed to the higher proportion of hypointense lesions on DWI (73% vs. 61%). Bakir et al. also reported that high signal intensities were observed more frequently in malignant than in benign adnexal masses, despite the overlap of ADC values between malignant and benign lesions. Thomassin-Naggara et al. also reported the usefulness of DWI in distinguishing benign from malignant complex adnexal lesions [9, 10]. However, in studies by Zhang et al. and Bakir et al., ADC values were not significantly differ between benign and malignant adnexal tumors [13, 14]. They explain that "T2 black out effect" or densely arrayed spindle cells and thecal cells may explain the low ADC value in fibrothecoma [13, 14]. Several studies suggested that PWI could aid in differentiating fibrothecomas from uterine subserosal leiomyomas or malignant adnexal lesions [4, 10, 15]. Visualization of the arterial vessels between the uterus and tumor mass was more frequent in uterine subserosal leiomyomas, and the enhancement of fibrothecomas was significantly lower than that of leiomyomas [4, 15]. In a more recent study by Thomassin-Naggara et al., the addition of DWI and PWI to the conventional MR imaging protocol improved the diagnostic accuracy of the characterization of adnexal masses, especially for benign masses ($p < 0.01$) but not for malignant masses [10]. The same study also reported that the type 3 time-signal intensity curve was the most significant features predictive of malignancy [10]. We evaluated the time-signal intensity curve on PWI in 7 patients. All of the 7 cases (100%) showed either type 1 or type 2 curves, which favors a diagnosis of a benign lesion. Considering high proportion of low DWI signal intensity (73%) and type 1 or 2 time-signal intensity curve (100%), the addition of DWI and PWI to a conventional MR might help to predict benignity in fibrothecoma cases and consequently improve the accuracy of preoperative diagnosis.

Several studies evaluated the presence and shape of ipsilateral ovaries in fibrothecoma cases [1, 4, 16]. Ipsilateral ovary was identified in 46% and 89% of the cases in studies by Oh et al. and Shinagare et al., respectively [4, 16]. In the present study, the detection rate of ipsilateral ovaries (24/28 of the cases, 86%) was higher than that in a previous study by Oh et al., despite the application of same criteria for the detection of ovarian tissue (demonstrable follicles in the presumed ovarian tissue on T2-weighted images). The younger mean age and larger proportion of pre-menstrual women of this study group compared with those of population studied by Oh et al. (mean age, 44.3 years vs. 49.3 years; pre-menopausal/total ratio, 61.5% versus 47.8%) would have facilitated the detection of follicles in the ipsilateral ovary [16, 17]. Fifty-four percent of identifiable ovaries were arranged in a crescent shape along the periphery of the lesion, suggesting that fibrothecomas grow within the ovary. The remaining 46% of identifiable ovaries exhibited a normal-appearing ovoid configuration, suggesting exophytic growth from the periphery of the ovary. The presence of normal ovarian tissue adjacent to an ovarian lesion is considered to be a useful morphological feature that can help exclude invasive ovarian malignancy [18]. The detection of the ovary on the same side as the fibrothecoma on MR imaging significantly correlated with the patient's menopausal status ($p < 0.05$, more detectable in pre-menopausal women), but there was no significant correlation between the tumor size and the detection rate of ipsilateral ovary, though the ipsilateral ovary detection rate was higher in smaller fibrothecoma group (Table 2), which is consistent with previous study by Oh et al. [16]. The correct diagnosis rate for ovarian fibrothecomas was 75% (21/28) in the present study. Considering that 5 out of 7 falsely diagnosed lesions were initially diagnosed as malignancy, differentiation between malignant tumors and atypical fibrothecomas which mimic malignant tumor was the most problematic issue in these cases. In retrospective analysis of 5 malignancy mimicking lesions, one case was performed both DWI and PWI and 2 cases were performed DWI. Two of the three cases showed low signal intensity on diffusion-weighted image and one of which showed type 2 curve on PWI. Therefore, evaluating DWI and PWI in addition to conventional imaging could help to anticipate benignity in 2 cases.

There are limitations that need to be considered in interpreting the presented findings. First, our study was a retrospective consensus review, with inevitable selection bias. Second, not all cases underwent diffusion- and perfusion-weighted imaging in our study, so our results may not accurately reflect the full range of diffusion- and perfusion-weighted imaging characteristics of these tumors. Third, our study performed semi-quantitative measurements on diffusion-weighted imaging instead of quantitative ADC measurements. Further prospective study including both DWI and PWI with quantitative analysis of ADC values will be needed to overcome these limitations. Fourth, there was no direct comparison of the imaging findings between fibrothecomas and other mimicking lesions such as uterine subserosal leiomyomas or malignant ovarian tumors.

Nonetheless, we believe that our study has a number of positive features. First, to our knowledge, this study is one of very few investigations of the MR imaging characteristics of fibrothecomas, with second largest sample size among reported studies [1, 4, 14, 16]. Second, this is the first to use both DWI and PWI to study the imaging features of fibrothecomas and thecomas. Third, ours is the first study to analyze MR imaging features that included full spectrum of three histologic types; fibromas, fibrothecomas, and thecomas and compared MR imaging features each other.

In summary, most ovarian fibrothecomas typically show homogenously low to intermediate signal intensity on T1-weighted images and low signal intensity on T2-weighted images, and appear predominantly solid. However, they often show atypical imaging features that mimic malignant lesions. We can determine the diagnostic clues and increase the diagnostic accuracy by detecting ipsilateral ovary on T2-weighted images with conventional MR imaging and using additional diffusion- or perfusion-weighted imaging. Combining conventional morphologic and signal intensity characteristics with the findings from DWI or PWI might help differentiate atypical cases of ovarian fibroma, fibrothecoma, and thecoma from ovarian malignancy, although further prospective larger scale study using DWI and PWI is needed.

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