Adenomyosis: Usual and Unusual Imaging Manifestations, Pitfalls, and Problem-solving MR Imaging Techniques[1]

Mayumi Takeuchi, MD, PhD • Kenji Matsuzaki, MD, PhD

ONLINE-ONLY CME

See www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Describe the various MR imaging manifestations of adenomyosis.
- List problem-solving MR imaging techniques for accurate diagnosis of adenomyosis.
- Discuss the diagnostic clues that allow differentiation of adenomyosis from its mimics.

TEACHING POINTS

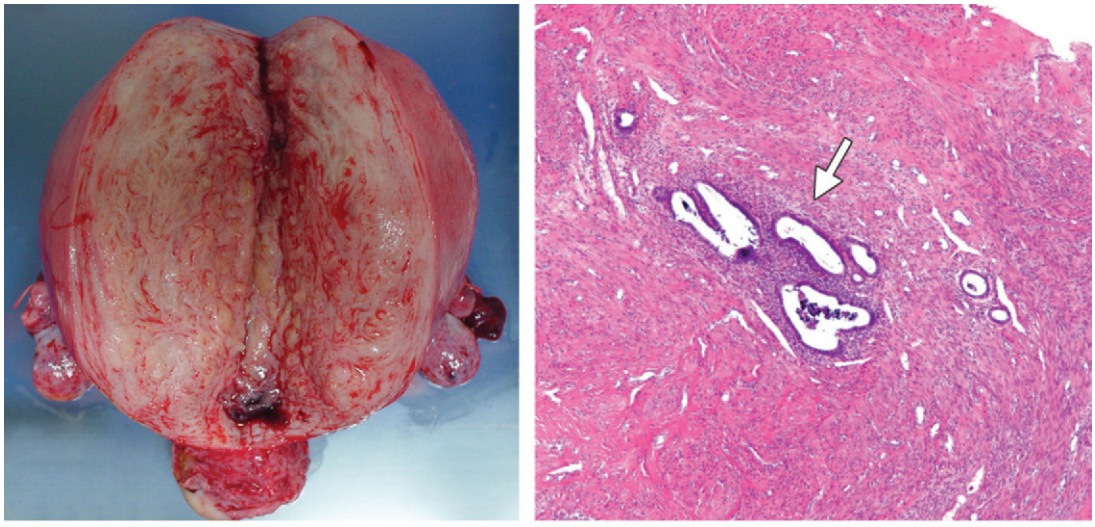
See last page

Adenomyosis is a common nonneoplastic gynecologic disease characterized by the presence of ectopic endometrium within the myometrium. On T2-weighted magnetic resonance (MR) images, typical adenomyosis appears as an ill-demarcated low-signal-intensity lesion with uterine enlargement. However, various physiologic or pathologic states such as amount of functional endometrial tissue, phase of the menstrual cycle, endogenous hormonal abnormality, and exogenous hormonal stimulation may affect the MR imaging appearance of adenomyosis and may result in a tumorlike appearance. Problem-solving MR imaging techniques used in diagnosis of adenomyosis include diffusion-weighted imaging, susceptibility-weighted imaging, hydrogen 1 MR spectroscopy, cine MR imaging, and high-resolution MR imaging at 3 T. Adenomyotic lesions that show high signal intensity relative to the outer myometrium on T2-weighted images mimic malignancies such as leiomyosarcoma and endometrial stromal sarcoma. In these cases, a relatively high apparent diffusion coefficient at diffusion-weighted imaging and a low choline peak at MR spectroscopy are suggestive of a benign lesion. Small hemorrhagic foci suggestive of an adenomyotic lesion are well demonstrated as signal voids at susceptibility-weighted imaging. Cine MR imaging is useful in differentiating transient myometrial contraction from focal adenomyosis. High-resolution MR imaging at 3 T demonstrates anatomically detailed structures and may improve diagnostic accuracy in differentiating adenomyosis from its mimics, such as low-grade endometrial stromal sarcoma.

Abbreviations: ADC = apparent diffusion coefficient, LG-ESS = low-grade endometrial stromal sarcoma

RadioGraphics 2011; 31:99–115 • **Published online** 10.1148/rg.311105110 • **Content Codes:** GU MR OB

[1]From the Department of Radiology, University of Tokushima, 3-18-15 Kuramoto-cho, Tokushima 770-8503, Japan. Presented as an education exhibit at the 2009 RSNA Annual Meeting. Received April 20, 2010; revision requested May 28 and received July 8; accepted July 28. For this CME activity, the authors, editors, and reviewers have no relevant relationships to disclose. **Address correspondence to** M.T. (e-mail: *mayumi@clin.med.tokushima-u.ac.jp*).



a. b.

Figure 1. Adenomyosis in a 47-year-old woman. **(a)** Photograph of the cut surface of the gross specimen shows diffusely thickened myometrium. **(b)** Low-power photomicrograph (hematoxylin-eosin stain) shows ectopic endometrial glands and stroma (arrow) surrounded by hypertrophied smooth muscle.

Introduction

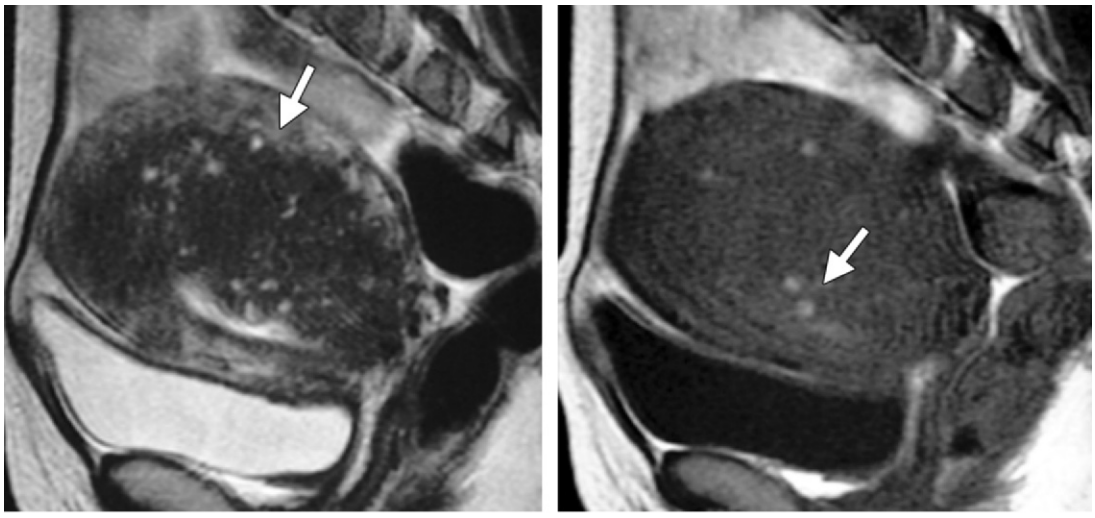
Adenomyosis is a common nonneoplastic gynecologic disease characterized by the presence of ectopic endometrium within the myometrium (1–3). Adenomyosis typically affects multiparous, premenopausal women over 30 years of age and may cause dysmenorrhea, menorrhagia, and abnormal genital bleeding (3–5). Magnetic resonance (MR) imaging is a noninvasive modality with high sensitivity and specificity for diagnosis of adenomyosis (4–12). In cases of an enlarged uterus revealed with ultrasonography, MR imaging allows differentiation of adenomyosis from leiomyoma or other pathologic conditions owing to its excellent tissue contrast resolution (4–12). On T2-weighted images, typical adenomyosis appears as an ill-demarcated low-signal-intensity lesion with uterine enlargement. However, various physiologic or pathologic states may affect the MR imaging appearance of adenomyosis and may result in a tumorlike appearance (4–12).

In this article, we present various MR imaging manifestations of adenomyosis and describe key findings for diagnosis of adenomyosis by using problem-solving MR imaging techniques. Specific topics discussed are MR imaging manifestations of typical adenomyosis, problem-solving MR imaging techniques, atypical MR imaging manifestations of adenomyosis, pitfalls in diagnosis of adenomyosis, atypical morphologic appearances of adenomyosis, and coexisting endometrial cancer or malignant transformation.

MR Imaging Manifestations of Typical Adenomyosis

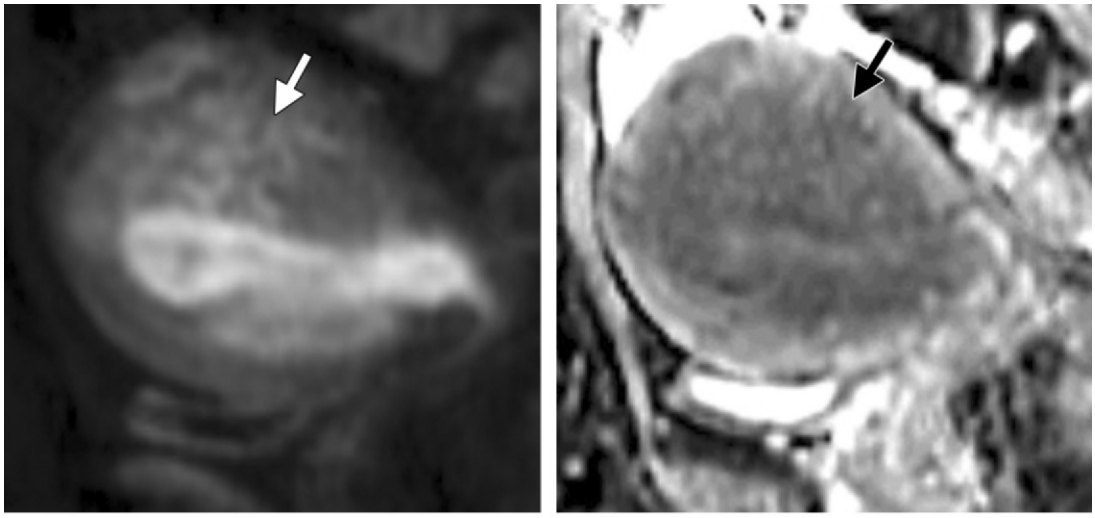
At pathologic analysis, adenomyosis is characterized by the presence of ectopic endometrial glands and stroma within the myometrium with hypertrophy and hyperplasia of smooth muscle (1–3). Adenomyosis may affect the uterine myometrium diffusely and result in a diffusely enlarged uterus, or it may be localized as an adenomyoma. A cut section of a diffusely adenomyotic uterus shows thickened myometrium due to the ill-defined adenomyosis; the thickened myometrium is composed of haphazardly distributed hypertrophied muscular trabeculae surrounding ectopic endometrial tissue (Fig 1) (3). Brownish old hemorrhagic foci corresponding to hemolysed blood and hemosiderin pigment deposits may be contained within the area of adenomyosis (3).

Typical adenomyosis appears as an ill-demarcated low-signal-intensity area on T2-weighted images owing to abundant smooth muscle proliferation (Fig 2) (4–12). Because adenomyotic endometrium looks like the basalis endometrium, which seldom responds to hormonal stimuli, cyclic changes including degeneration, bleeding, and regeneration are less common in adenomyosis than in endometriosis (1–3). On T2-weighted MR images, ectopic endometrium appears as small high-signal-intensity areas like normal endometrium (Fig 2). Small cysts may



a. b.

Figure 2. Adenomyosis in a 46-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows an enlarged uterus with an ill-defined low-signal-intensity lesion (arrow) in the posterior myometrium. The lesion contains multiple small high-signal-intensity areas, which represent ectopic endometrial tissue and small cysts. **(b)** Sagittal T1-weighted spin-echo MR image shows high-signal-intensity spots (arrow), which correspond to some of the small high-signal-intensity areas seen on the T2-weighted image. The high-signal-intensity spots represent hemorrhage within the ectopic endometrial tissue.



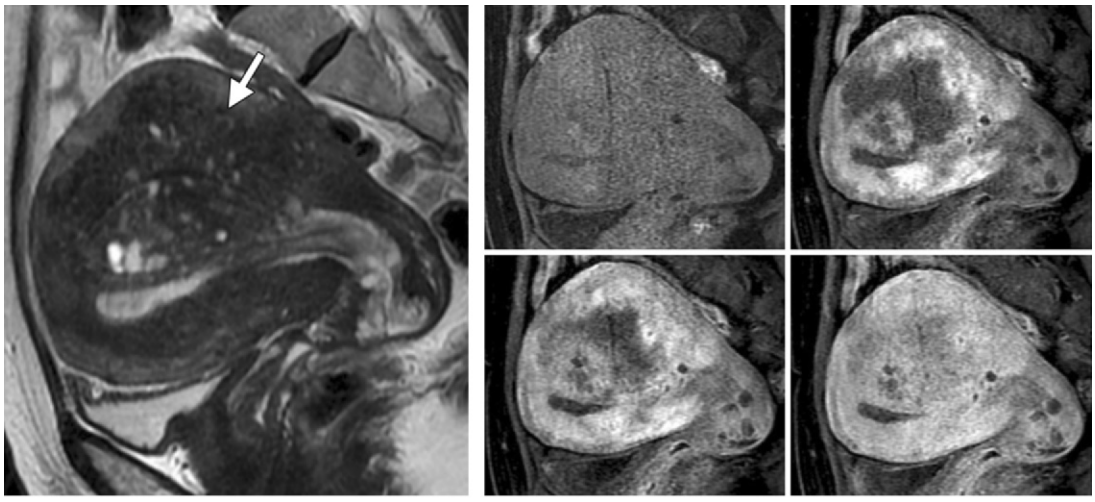
a. b.

Figure 3. Adenomyosis in a 42-year-old woman. **(a)** Sagittal diffusion-weighted echo-planar MR image (b = 800 sec/mm^2) shows an enlarged uterus with an ill-defined lesion of low to intermediate signal intensity (arrow) in the posterior myometrium. **(b)** Corresponding apparent diffusion coefficient (ADC) map shows no prominent decrease of ADC value in the area of adenomyosis (arrow).

also appear as high-signal-intensity spots on T2-weighted images. Sometimes, hemorrhagic foci appear as 1–3-mm high-signal-intensity foci on T1-weighted images owing to the T1-shortening effects of methemoglobin (Fig 2) (4–12).

Teaching Point

Susceptibility-weighted imaging is sensitive for old hemorrhagic foci, which appear as spotty signal voids owing to the T2*-shortening effects of hemosiderin (13,14). At diffusion-weighted imaging, adenomyosis has low to intermediate signal intensity, a finding consistent with its benign, nonneoplastic nature (Fig 3) (15). However, there



a. b.

Figure 4. Adenomyosis in a 47-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows an enlarged uterus with an ill-defined low-signal-intensity lesion (arrow) in the posterior myometrium. The lesion contains multiple small high-signal-intensity areas. **(b)** Unenhanced (upper left), early arterial phase (upper right), late arterial phase (lower left), and venous phase (lower right) images, obtained with a dynamic gadolinium-enhanced three-dimensional fast spoiled gradient-echo sequence with fat suppression, show heterogeneous and gradual enhancement of the lesion.

is no direct correlation between signal intensity at diffusion-weighted imaging and malignancy; most malignant tumors have very high signal intensity at diffusion-weighted imaging, a finding that reflects the long T2 relaxation time and restricted diffusion due to high cellularity.

Because adenomyosis may show various degrees of enhancement after administration of contrast medium, contrast-enhanced study does not contribute to diagnostic accuracy (Fig 4) (12). Dynamic contrast-enhanced imaging may have greater accuracy than T2-weighted imaging when adenomyosis and endometrial cancer coexist (16). However, the heterogeneous enhancement of adenomyosis may cause inaccuracy when evaluating the depth of myometrial invasion by coexisting endometrial cancer; diffusion-weighted imaging may be helpful in accurately determining the depth of myometrial invasion (17).

Problem-solving MR Imaging Techniques

Diffusion-weighted Imaging

Diffusion-weighted imaging allows visualization of the local microstructural characteristics of water diffusion. The signal intensity seen on diffusion-weighted images is a combination of the degree of water diffusion and the signal intensity of the underlying T2-weighted images. In oncologic imaging, various malignant tumors may show high signal intensity at diffusion-weighted imaging due to their high cellularity and long T2 relaxation time (15,18–20).

ADC measurement yields quantitative information about tissue structure that is based on the molecular motion of water. Malignant lesions with increased cellularity show low ADC values, whereas relatively hypocellular benign lesions and normal structures tend to show relatively higher ADC values (15,18–20). A high ADC value correlates with the presence of necrosis or a cystic area. Therefore, when evaluating ADC value, the region of interest should be placed on the solid portion of the lesion so as to avoid necrotic or cystic areas as much as possible; this can be achieved by referring to T2-weighted images or contrast-enhanced T1-weighted images (18).

Tamai et al (21) studied use of diffusion-weighted imaging with ADC measurement for differentiation of uterine sarcomas from benign leiomyomas. In their study, uterine sarcomas and cellular leiomyomas showed high signal intensity with a low ADC value, whereas degenerated leio-

myomas showed low signal intensity with a high ADC value. Takeuchi et al (15) reported that ADC measurement may be helpful in differentiating uterine sarcomas, cellular leiomyomas, and degenerated leiomyomas that show high signal intensity on T2-weighted images.

Susceptibility-weighted Imaging

Susceptibility-weighted imaging combines magnitude and phase information. In susceptibility-weighted imaging, the magnetic susceptibility effects generated by local inhomogeneity of the magnetic field caused by hemosiderin or deoxyhemoglobin are seen as signal voids (22,23). Susceptibility-weighted imaging is more sensitive to the susceptibility differences between tissues than is conventional T2*-weighted imaging. In body imaging, susceptibility-weighted imaging is performed by using both magnitude and phase images obtained with a two-dimensional fast spoiled gradient-recalled acquisition in the steady state sequence (13,14). To enhance the visibility of signal voids caused by the magnetic susceptibility effects, postprocessing is applied to the magnitude images with multiplication by means of a phase mask generated from the filtered phase data.

Small hemorrhagic foci (hemosiderin deposition), which are barely detectable on T2-weighted images, can be demonstrated as signal voids on susceptibility-weighted images (13,14,22,23). Takeuchi et al (13) reported that susceptibility-weighted imaging can contribute to the diagnosis of endometrioma by depicting hemosiderin deposition in the cyst wall. These authors also reported that susceptibility-weighted imaging is useful in diagnosis of extraovarian endometriosis and adenomyosis by demonstrating hemosiderin deposition (14).

^{1}H MR Spectroscopy

Hydrogen 1 MR spectroscopy is used to measure various metabolites in body tissues and provides information on tumor metabolites in patients (24–26). In gynecologic tumors, the choline peak (3.2 ppm) reflects the metabolic activity of cell membrane in solid tumors (25,26). High-grade malignant tumors tend to show higher choline peaks, which reflect high cellular proliferating activity (24). Takeuchi et al (27) reported that high choline peaks were observed in uterine myometrial malignant tumors (sarcomas and malignant lymphoma), whereas usual and degenerated leiomyomas showed low to moderate choline peaks.

Cine MR Imaging

Cine MR imaging, which is cine mode display of serial T2-weighted images obtained at an interval of a few seconds by using an ultrafast sequence, allows visualization of uterine motion (19,28–31). Cine MR imaging is useful in differentiating a transient myometrial contraction from focal adenomyosis and in determining the origin of exophytic uterine lesions (19,28–31).

High-Resolution MR Imaging at 3 T

Kataoka et al (32) reported that image contrast on T2-weighted images in the uterine cervix and vagina was significantly higher at 3 T than at 1.5 T, although there was no significant difference in the overall image quality or contrast in the uterine zonal appearance. The increase in signal-to-noise ratio at 3 T allows high-resolution MR imaging. Anatomically detailed structures are visualized on high-resolution MR images, and this may improve diagnostic accuracies in differential diagnosis, in detection of small lesions, and in evaluation of tumor extent for cancer staging.

Atypical MR Imaging Manifestations of Adenomyosis

Various physiologic or pathologic states may affect the MR imaging appearance of adenomyosis: amount of functional endometrial tissue, phase of the menstrual cycle, endogenous hormonal abnormality, and exogenous hormonal stimulation (4–12). Secretory transformation of adenomyotic endometrium including stromal decidualization may cause a heterogeneous increase in signal intensity on T2-weighted images (3,11). This phenomenon may be encountered during gestation and exogenous progestational therapy or even in patients without specific hormonal stimulation (3,11). Congestion or edematous change may also increase the signal intensity of adenomyosis diffusely or focally on T2-weighted images (Fig 5). In such conditions, MR imaging manifestations may fluctuate, and follow-up MR imaging may be helpful for diagnosis. Gonadotropin-releasing

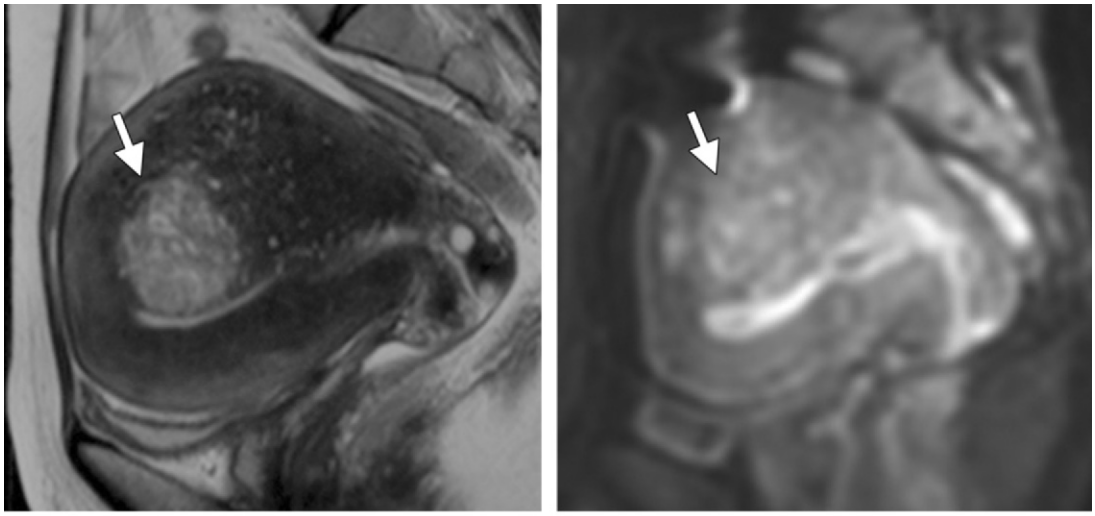


Figure 5. Adenomyosis with focal edema in a 54-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows an enlarged uterus with an ill-defined low-signal-intensity lesion in the posterior myometrium. The low-signal-intensity lesion contains a focal high-signal-intensity masslike area (arrow). **(b)** On a sagittal diffusion-weighted echo-planar MR image (b = 800 sec/mm^2), the high-signal-intensity masslike area in **a** shows no increase in signal intensity (arrow). **(c)** On an image from MR spectroscopy, the high-signal-intensity masslike area in **a** shows a low choline peak *(Cho)* at 3.2 ppm. Biopsy revealed benign adenomyotic tissue with stromal edema. The signal intensity of the masslike area in **a** decreased on follow-up T2-weighted images obtained 3 months later.

hormone analog is used in the treatment of adenomyosis. After hormonal therapy or menopause, an area of adenomyosis may shrink with decreased signal intensity on T2-weighted images (Fig 6) (11).

Teaching Point

Diffusion-weighted imaging with ADC measurement may provide another clue for the diagnosis, because these conditions (secretory transformation, decidualization, congestion or edema) usually increase the ADC in tissues. A relatively high ADC in adenomyotic lesions with high signal intensity on T2-weighted images may allow differentiation from malignant lesions, which have a low ADC due to their high cellularity (Fig 5) (15). MR spectroscopy may also provide a clue for the diagnosis, because these benign adenomyotic conditions do not show high metabolic activity. A relatively low choline peak in adenomyotic lesions may allow differentiation from malignant tumors, which show a high choline peak due to their high metabolic activity (Fig 5) (27).

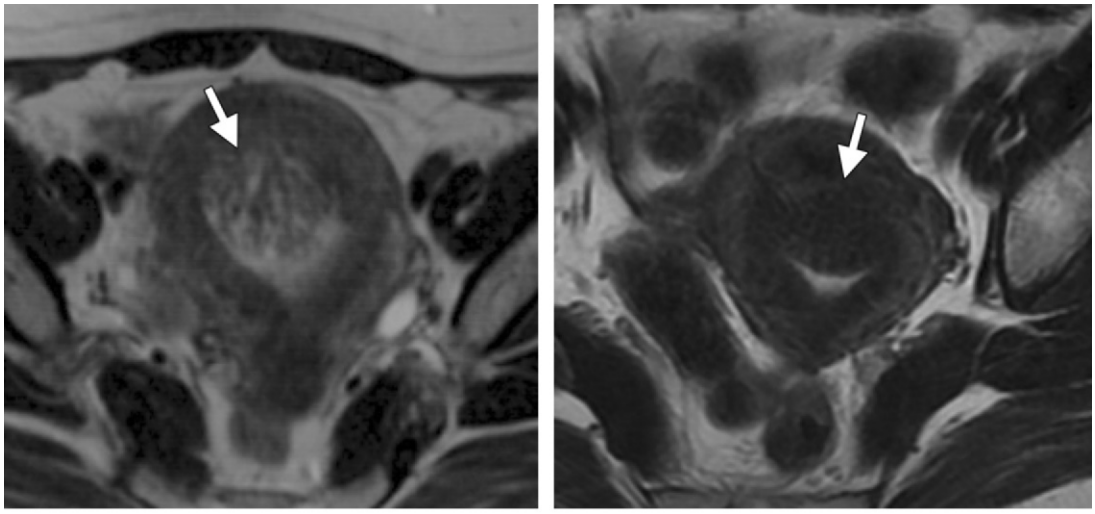
Teaching Point

Pitfalls in Diagnosis of Adenomyosis

Physiologic Changes in the Uterine Body during the Menstrual Cycle

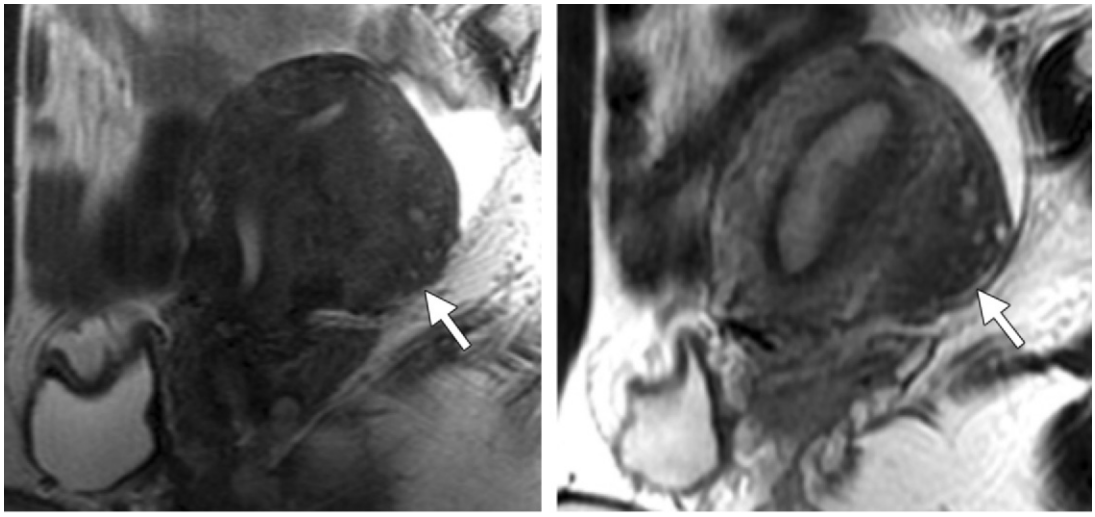
The uterine body may show physiologic changes during the menstrual cycle. The low-signal-intensity junctional zone and adenomyosis are well visualized due to increased signal intensity of the myometrium in the secretory phase (luteal phase). Decreased signal intensity of the myometrium in the menstrual–early proliferative phase (follicular phase) may cause widening of the junctional zone, which mimics diffuse adenomyosis. Therefore, MR imaging for the evaluation of a uterine myometrial lesion should be performed in the late proliferative–secretory phase (Fig 7) (31).

Teaching Point



a. b.

Figure 6. Adenomyosis in a 50-year-old woman before and after hormonal therapy with gonadotropin-releasing hormone analog. **(a)** Axial T2-weighted fast spin-echo MR image shows adenomyosis as an ill-defined heterogeneous low-signal-intensity lesion with linear or reticular high-signal-intensity areas in the anterior myometrium (arrow). **(b)** Axial T2-weighted fast spin-echo MR image obtained after hormonal therapy shows decreased volume and signal intensity of the area of adenomyosis (arrow).



a. b.

Figure 7. Subserosal adenomyosis-like lesion (invasive solid endometriosis) in a 33-year-old woman during different phases of the menstrual cycle. **(a)** Sagittal T2-weighted fast spin-echo MR image obtained in the early proliferative phase shows decreased signal intensity of the myometrium. The boundary between the myometrium and a subserosal adenomyosis-like lesion (arrow) is obscure. **(b)** Sagittal T2-weighted fast spin-echo MR image obtained in the late secretory phase shows increased signal intensity of the myometrium. The low-signal-intensity junctional zone and the subserosal adenomyosis-like lesion (arrow) are clearly visualized.

Benign and Malignant Mimics of Adenomyosis

Teaching Point

Various benign conditions and malignant tumors may mimic adenomyosis: physiologic myometrial contraction, myometrial involvement by pelvic endometriosis, low-grade endometrial stromal sarcoma (LG-ESS), and myometrial metastases (11,28–31,33,34).

Transient myometrial contraction as a physiologic phenomenon may mimic adenomyosis; this appearance may disappear on subsequent

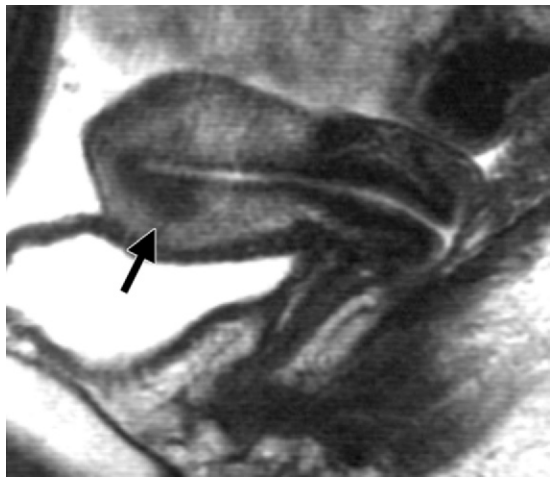
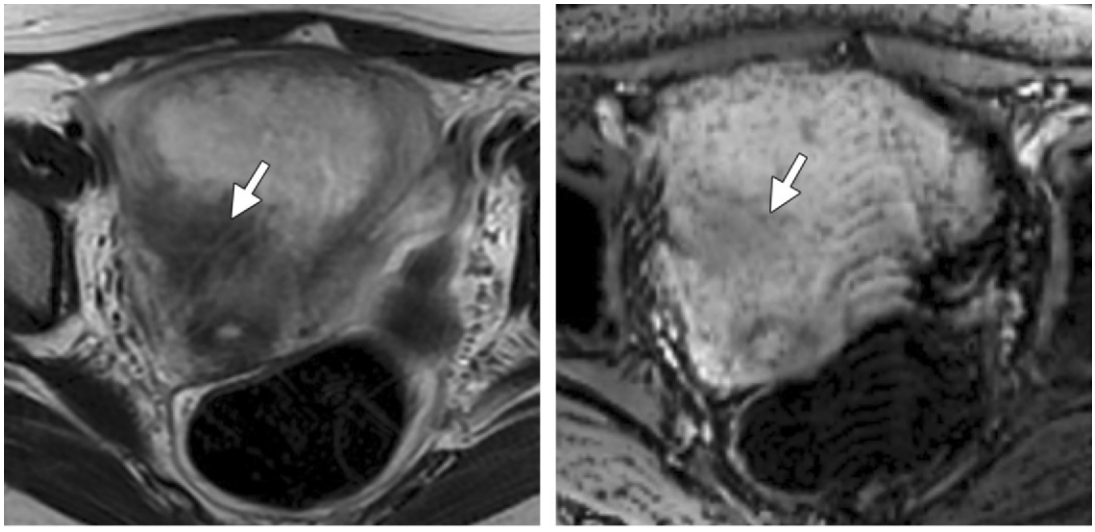


Figure 8. Physiologic transient myometrial contraction in a 32-year-old woman. Sagittal T2-weighted fast spin-echo MR image shows focal low-signal-intensity bulging of the myometrium (arrow), a finding that mimics adenomyosis. This finding disappeared on subsequent T2-weighted images.

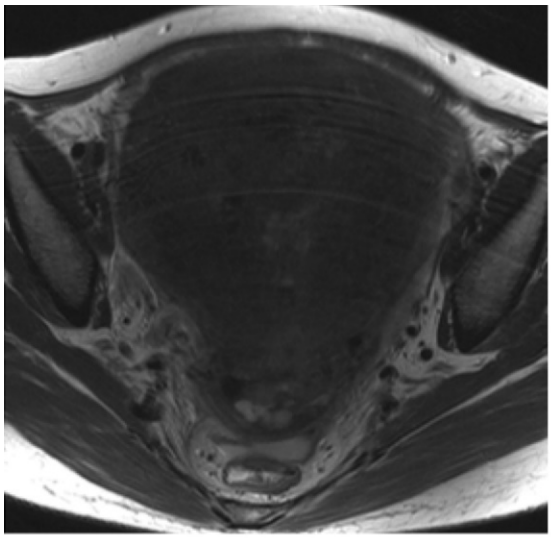


a. **b.**

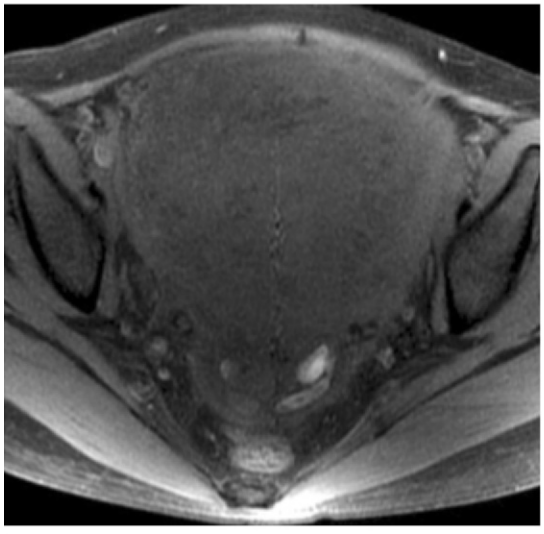
Figure 9. Transient myometrial contraction during pregnancy in a 31-year-old woman. **(a)** Axial T2-weighted fast spin-echo MR image shows a localized area of low signal intensity (arrow) in the uterus, a finding that mimics adenomyosis. Because a rapid T2-weighted sequence (eg, half-Fourier acquisition single-shot turbo spin-echo or single-shot fast spin-echo) was not used, depiction of the embryo-fetus is poor. **(b)** Axial susceptibility-weighted gradient-echo MR image shows absence of signal voids (arrow) within the low-signal-intensity area in **a**. However, absence of signal voids at susceptibility-weighted imaging should not be considered to exclude adenomyosis. To establish the diagnosis of a contraction, it would be critical to show resolution of the low-signal-intensity area on subsequent T2-weighted images.

images or at cine MR imaging, whereas focal adenomyosis persists on subsequent images or at cine MR imaging (Fig 8) (28–31). In the pregnant uterus, myometrium adjacent to the implant site may show low signal intensity, which reflects blood supplying a contraction; this finding mimics physiologic contraction or focal adenomyosis (Fig 9) (31). Contractions in the pregnant uterus are commonly seen and usually do not present a diagnostic dilemma; however, radiologists who are not familiar with MR imaging of pregnant women may misdiagnose the contraction. Susceptibility-weighted imaging can show small hemorrhagic foci in adenomyosis as spotty signal voids and may be helpful in differentiating adenomyosis from focal contraction (Fig 10) (14). On the other hand, absence of signal voids at susceptibility-weighted imaging should not be considered to exclude adenomyosis.

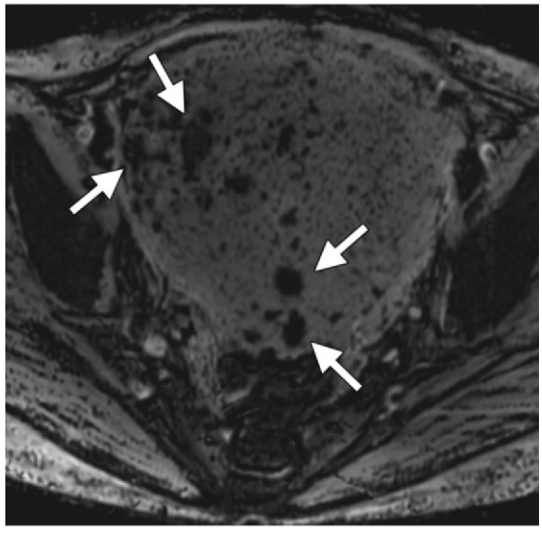
Adenomyosis is due to benign invasion of the myometrium by ectopic endometrium and is a different entity from endometriosis (33). However, some adenomyosis-like lesions may be situated in the subserosal region apart from the junctional zone (Figs 7, 11). These lesions may be due to myometrial involvement by pelvic



a.



b.



c.

Figure 10. Adenomyosis in a 46-year-old woman. **(a)** Axial T2-weighted fast spin-echo MR image shows a diffusely enlarged uterus with low signal intensity. **(b)** Axial fat-saturated T1-weighted spin-echo MR image shows absence of high-signal-intensity hemorrhagic foci within the uterus. **(c)** Axial susceptibility-weighted gradient-echo MR image shows multiple spotty signal voids (arrows), which are due to hemosiderin deposits and reflect old hemorrhagic foci.

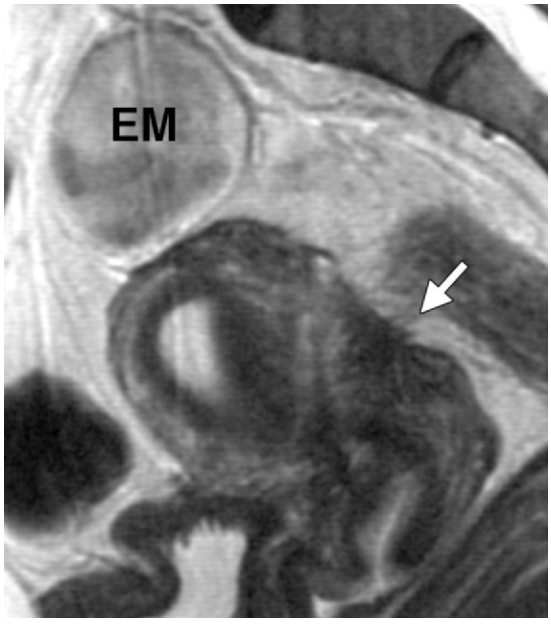


Figure 11. Subserosal adenomyosis-like lesion (invasive solid endometriosis) in a 41-year-old woman. Sagittal T2-weighted fast spin-echo MR image shows a low-signal-intensity adenomyosis-like lesion (arrow) situated in the subserosal region apart from the junctional zone. The lesion may be due to myometrial involvement by pelvic endometriosis. The uterus is deformed due to adhesions. *EM* = endometrioma.

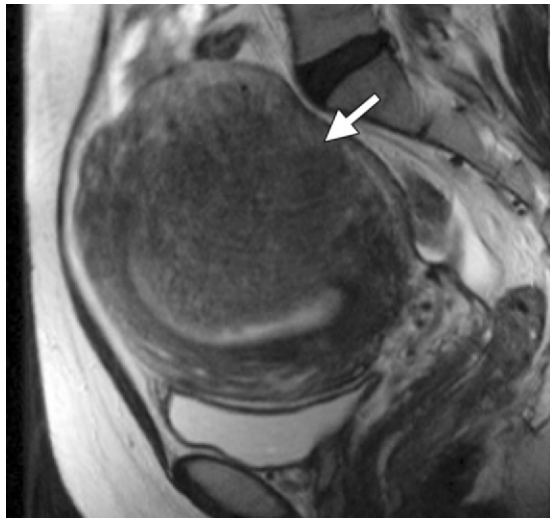


Figure 12. LG-ESS mimicking adenomyosis in a 39-year-old woman. Sagittal T2-weighted fast spin-echo MR image shows a low-signal-intensity adenomyosis-like mass (arrow) in the posterior wall.

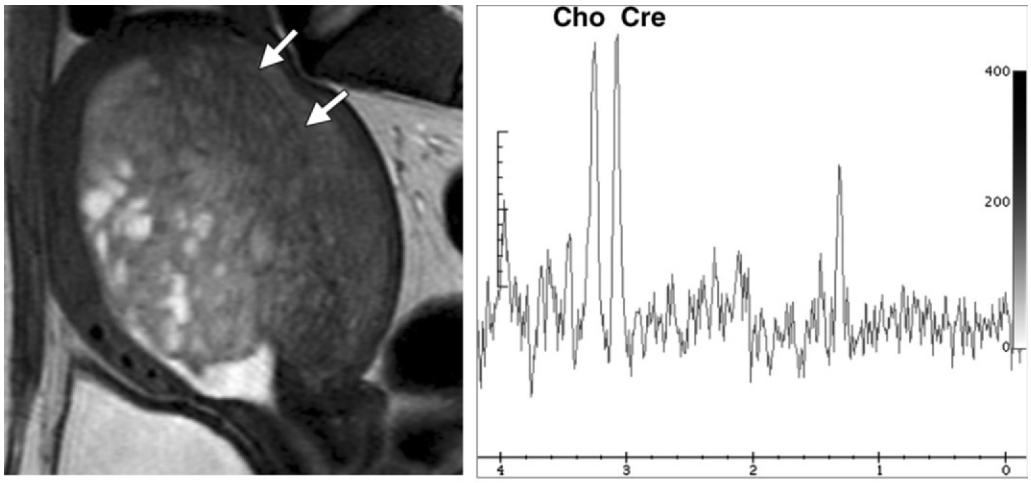


Figure 13. LG-ESS in a 37-year-old woman. **(a)** Sagittal high-resolution T2-weighted fast spin-echo MR image obtained at 3 T shows a large endometrial-myometrial mass. Characteristic worm-like low-signal-intensity muscle fibers (arrows) are clearly seen. **(b)** Image from MR spectroscopy shows a high choline peak *(Cho)* at 3.2 ppm, which reflects high cellular proliferating activity, and a high creatine peak *(Cre)* at 3 ppm, which is possibly due to residual myometrium.

endometriosis (invasive solid endometriosis); patients tend to experience severe menstrual pain due to adhesions (33).

Some primary or secondary malignant tumors may appear as ill-demarcated myometrial masses with uterine enlargement, findings that mimic adenomyosis (11,34). LG-ESS is a rare malignant mesenchymal tumor affecting young women and usually occurs in the endometrium with extensive myometrial invasion. LG-ESS may occasionally be situated almost within the myometrium (Fig 12). Myometrial invasion by LG-ESS is very infiltrative, and preserved low-signal-intensity muscle

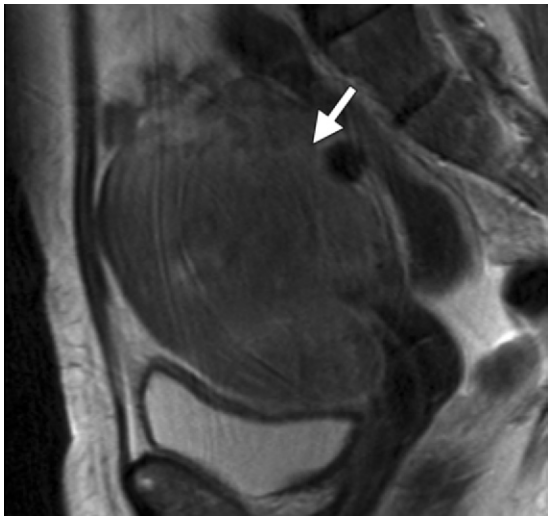


Figure 14. Malignant lymphoma in a 59-year-old woman. Sagittal T2-weighted fast spin-echo MR image shows a diffusely enlarged uterus (arrow). The normal zonal architecture is obscure due to diffuse involvement by malignant lymphoma.

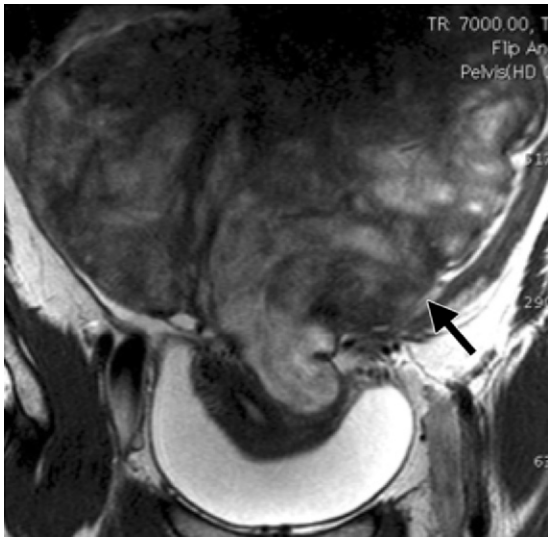


Figure 15. Subserosal polypoid adenomyoma in a 39-year-old woman. Coronal T2-weighted fast spin-echo MR image shows a huge, exophytic, subserosal uterine mass (arrow) with heterogeneous signal intensity, an appearance that mimics uterine sarcoma.

bundles within the high-signal-intensity tumor on T2-weighted images are a characteristic MR imaging finding (34). However, intramyometrial tumor may simulate adenomyosis, and preoperative diagnosis is occasionally difficult (11). High-resolution T2-weighted imaging at 3 T is helpful for diagnosis of LG-ESS by demonstrating preserved fine muscular fibers within the tumor as worm-like low-signal-intensity structures (Fig 13). High signal intensity with decreased ADC at diffusion-weighted imaging and a high choline peak at MR spectroscopy are other clues for diagnosis of this rare malignant tumor (Fig 13) (27). Diffusion-weighted imaging is also useful in evaluating tumor extension along the vessels, which is another characteristic of LG-ESS (35).

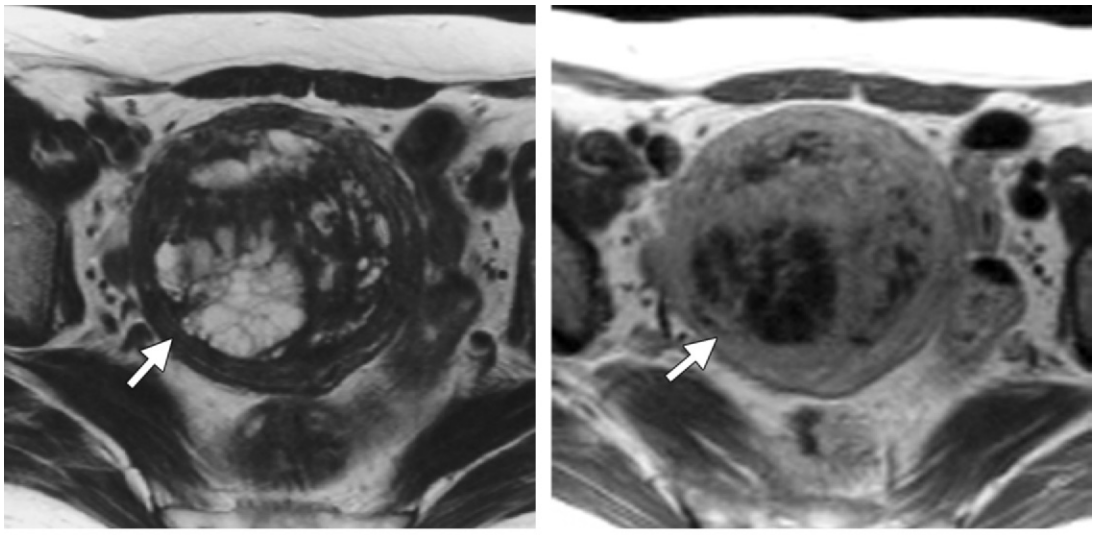
Secondary myometrial involvement by malignant tumors may also mimic adenomyosis (11). In particular, breast cancer, gastric cancer, and malignant lymphoma may cause diffuse infiltrative myometrial involvement with uterine enlargement. Destruction of normal structures such as the endometrium and junctional zone on T2-weighted images may suggest the malignant nature of a diffusely enlarged uterus due to secondary involvement by these tumors (Fig 14). High signal intensity at diffusion-weighted imaging with decreased ADC and a high choline peak at MR spectroscopy may also be useful for diagnosis of malignant uterine involvement (27).

Atypical Morphologic Appearances of Adenomyosis

Adenomyoma

Adenomyoma is characterized as a solid, mass-like, localized form of adenomyosis. Adenomyoma may appear as an intracavitary or subserosal polypoid mass or as an intramyometrial mass. Subserosal polypoid adenomyoma may mimic subserosal leiomyoma or leiomyosarcoma (Fig 15) (11,36–38). Adenomyomatous polyp, which is often associated with tamoxifen therapy, is an endometrial polyp with significant amounts of smooth muscle and is histologically identical to polypoid adenomyoma in the uterine cavity (Fig 16) (11,38–40).

Like adenomyosis, adenomyoma may show heterogeneous signal intensity on T2-weighted images and may mimic uterine sarcomas. Relatively low signal intensity at diffusion-weighted imaging with high ADC and a low choline peak



a. b.

Figure 16. Adenomyomatous polyp (polypoid adenomyoma) in a 64-year-old woman treated with tamoxifen. **(a)** Axial T2-weighted fast spin-echo MR image shows a large polypoid mass (arrow) in the endometrial cavity. Low-signal-intensity fibrous-muscular components and high-signal-intensity cystic dilated glands are observed. **(b)** Axial gadolinium-enhanced T1-weighted spin-echo MR image shows intense enhancement of the fibrous-muscular components and no enhancement of the cystic dilated glands in the mass (arrow).

at MR spectroscopy are suggestive of its benign nature and allow differentiation of adenomyoma from sarcomas, which have high signal intensity at diffusion-weighted imaging with low ADC and a high choline peak at MR spectroscopy (27).

Adenomyotic Cyst

Adenomyotic cyst (cystic adenomyosis) is a rare variation of adenomyosis that appears as an endometrioma-like intramyometrial hemorrhagic cystic mass surrounded by adenomyotic tissue (11,41,42). Adenomyotic cyst may appear as an intracavitary or subserosal polypoid cystic mass or as an intramyometrial mass (11).

The characteristic appearance is a high-signal-intensity hemorrhagic cyst on T1-weighted images surrounded by a low-signal-intensity cyst wall on T2-weighted images; the low-signal-intensity cyst wall corresponds to adenomyotic tissue (Fig 17) (11,41,42). A subserosal adenomyotic cyst may

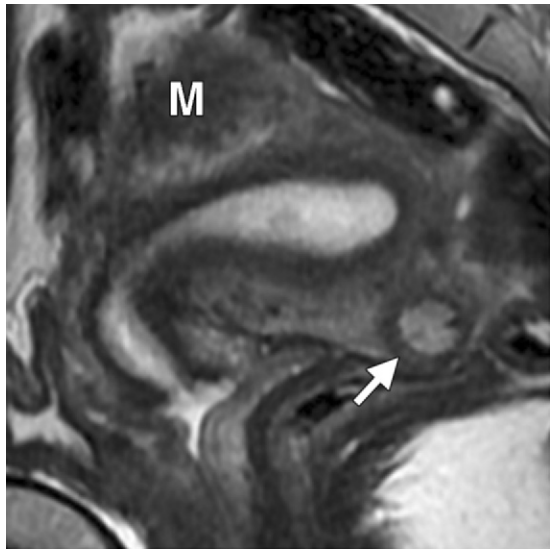
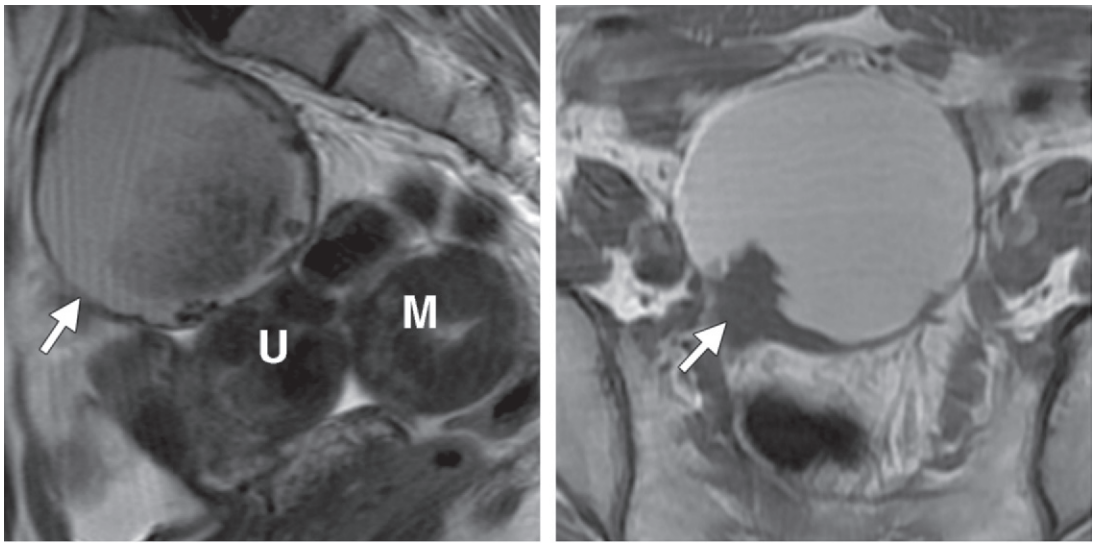
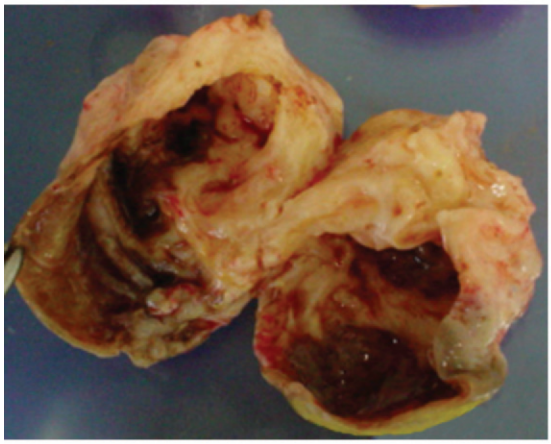


Figure 17. Adenomyotic cyst in a 39-year-old woman. Sagittal T2-weighted fast spin-echo MR image shows an intramyometrial hemorrhagic cyst surrounded by a low-signal-intensity area of adenomyosis (arrow). *M* = myoma uteri.



a. b.



c.

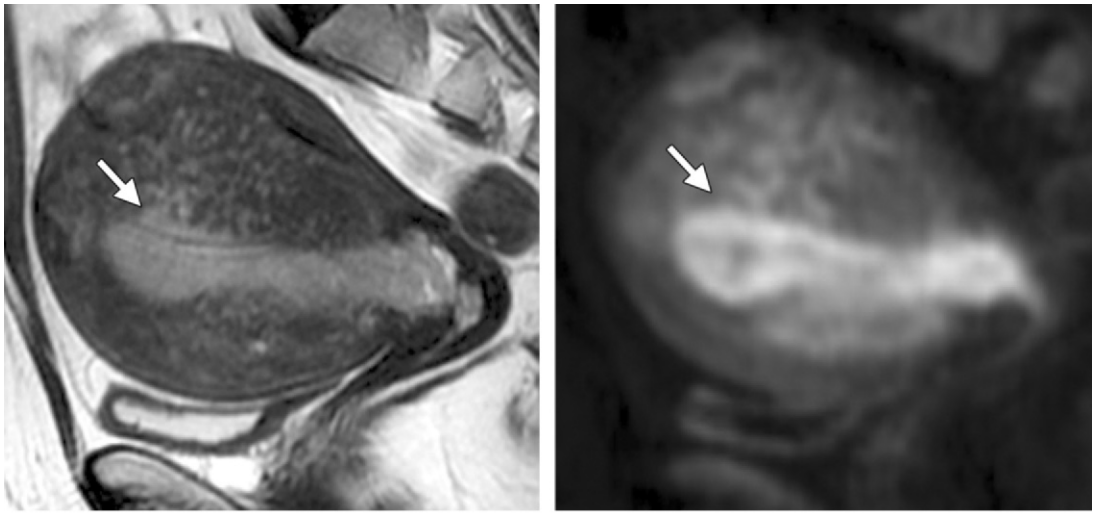
Figure 18. Adenomyotic cyst in a 46-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows a subserosal hemorrhagic cyst (arrow). *M* = myoma uteri, *U* = uterus. **(b)** Axial T1-weighted spin-echo MR image shows the high-signal-intensity hemorrhagic cyst. Clots and a fibrous scar (arrow) are observed in the cystic mass. Macroscopic evaluation of the surgical specimen revealed that the cystic mass was continuous with the myometrium, a finding suggestive of its uterine origin. **(c)** Photograph of the cut surface of the gross specimen shows that the cyst contains chocolate-like old hemorrhagic material.

mimic an ovarian tumor (Fig 18). The finding of continuity with the myometrium in the form of the "beak sign" is suggestive of its uterine origin. Synchronous motion of the cystic mass and uterus at cine MR imaging is also suggestive of the diagnosis of subserosal adenomyotic cyst (31).

Pseudowidening of the Endometrium

On T2-weighted images, the endometrial junction may be obscured due to high-signal-intensity linear striations radiating from the endometrium to the area of adenomyosis. Occasionally, pseudowidening of the endometrium may occur as a result of the blending of striations (7,11). This phenomenon may fluctuate according to the hormonal state of the patient.

When endometrial cancer coexists adjacent to adenomyosis, the pseudowidening phenomenon may cause overstaging when evaluating the depth of myometrial invasion. Diffusion-weighted imaging may be helpful in achieving correct staging (Fig 19) (17).



a. b.

Figure 19. Adenomyosis with coexisting endometrial cancer in a 53-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows a uterus with adenomyosis and endometrial thickening. Striated high-signal-intensity areas cause pseudowidening of the endometrium (arrow), an appearance that simulates myometrial invasion by endometrial carcinoma. **(b)** Sagittal diffusion-weighted echo-planar MR image (b = 800 sec/mm^2) shows the high-signal-intensity tumor margin clearly. There is no obvious myometrial invasion (arrow).

Coexisting Endometrial Cancer or Malignant Transformation

Coexisting Endometrial Cancer

Because adenomyosis may show heterogeneous signal intensity on T2-weighted images and gadolinium-enhanced T1-weighted images, the boundaries between an endometrial cancer and adjacent adenomyosis may be obscure. This phenomenon may cause staging errors when evaluating the depth of myometrial invasion (11,16). Diffusion-weighted imaging can demonstrate the tumor margins clearly and may improve the accuracy of staging (Fig 20) (17).

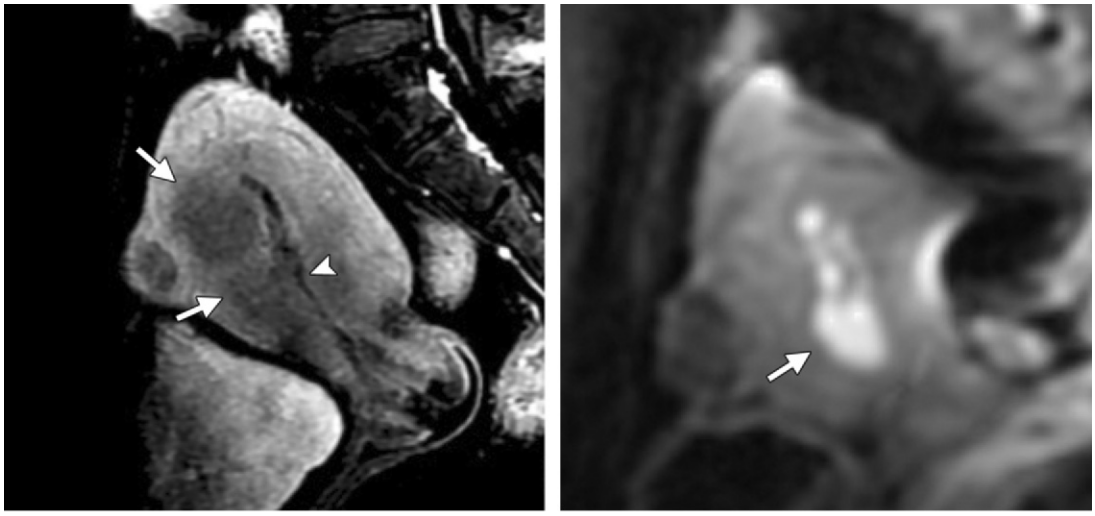
Malignant Transformation of Adenomyotic Lesions

Malignant transformation of adenomyosis is quite rare and may manifest as a predominantly intramyometrial mass (Fig 21) (11). Imaging findings of an adenomyotic cyst with malignant transformation are similar to those of an endometrial cyst with malignant transformation.

Diffusion-weighted imaging can demonstrate the malignant foci as areas of high signal intensity. High-signal-intensity hemorrhagic fluid in the adenomyotic cyst on T1-weighted images may mask the enhancement of malignant mural nodules; therefore, contrast-enhanced subtraction imaging may be useful for detection of malignant transformation (43).

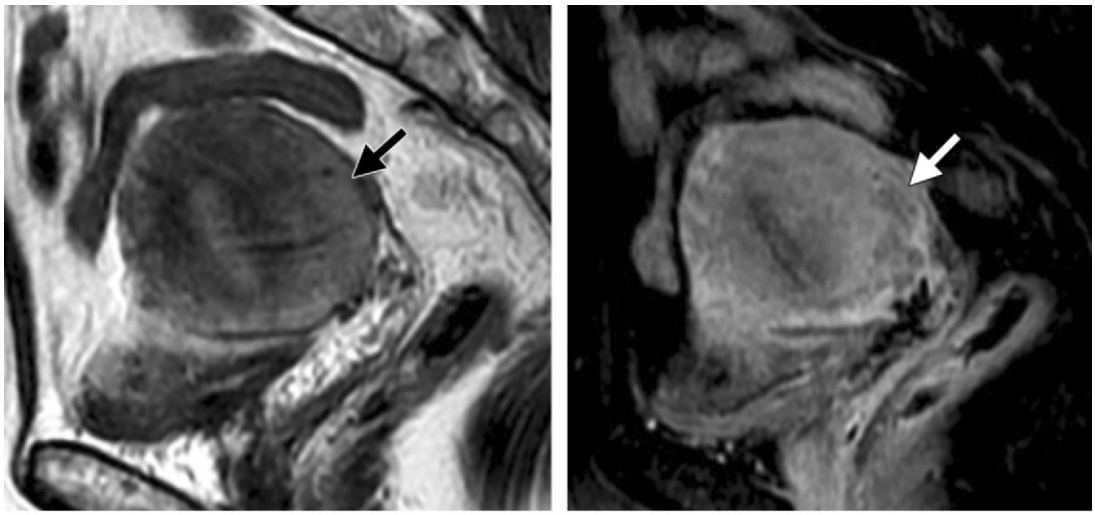
Summary

On T2-weighted images, typical adenomyosis appears as an ill-demarcated low-signal-intensity lesion with uterine enlargement. However, various physiologic or pathologic states such as amount of functional endometrial tissue, phase of the menstrual cycle, endogenous hormonal abnormality, and exogenous hormonal stimulation may affect the MR imaging appearance of adenomyosis and may result in a tumorlike appearance. Recognition of the various MR imaging manifestations of adenomyosis and accurate diagnosis of this condition are important for appropriate management and can be achieved by using problem-solving MR imaging techniques: diffusion-weighted imaging, susceptibility-weighted imaging, MR spectroscopy, cine MR imaging, and high-resolution MR imaging at 3 T.

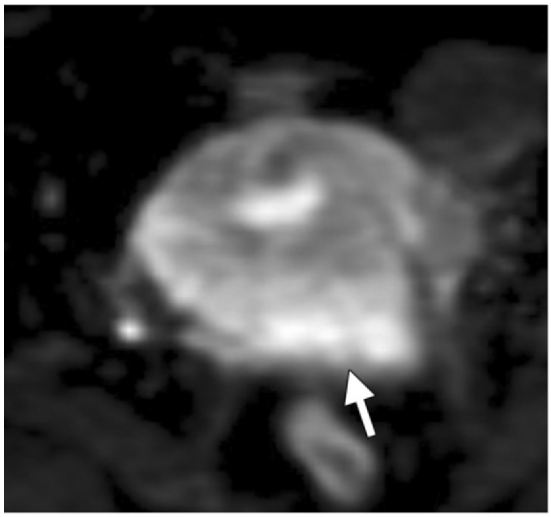


a. b.

Figure 20. Adenomyosis with coexisting endometrial cancer in a 49-year-old woman. **(a)** Sagittal gadolinium-enhanced fat-suppressed T1-weighted spin-echo MR image shows a weakly enhancing endometrial mass (arrowhead). An adjacent area of adenomyosis demonstrates heterogeneous weak enhancement (arrows). The tumor margin is unclear, which may result in overestimation of myometrial invasion. **(b)** Sagittal diffusion-weighted echo-planar MR image (b = 800 sec/mm^2) shows the high-signal-intensity tumor margin clearly. There is no obvious myometrial invasion (arrow).



a. b.



c.

Figure 21. Malignant transformation of adenomyosis in a 72-year-old woman. **(a)** Sagittal T2-weighted fast spin-echo MR image shows an enlarged uterus with adenomyosis. There is an area of ill-defined high signal intensity (arrow) in the posterior myometrium. **(b)** On a sagittal gadolinium-enhanced fat-suppressed T1-weighted spin-echo MR image, the area of ill-defined high signal intensity in **a** appears as ill-defined weakly enhancing areas (arrow). **(c)** On an axial diffusion-weighted echo-planar MR image (b = 800 sec/mm^2), the area of ill-defined high signal intensity in **a** also appears as an ill-defined high-signal-intensity area (arrow). The diagnosis of endometrioid carcinoma arising from adenomyosis was histologically confirmed.

Relatively high ADC at diffusion-weighted imaging and a low choline peak at MR spectroscopy are suggestive of benign adenomyotic lesions. Small hemorrhagic foci suggestive of an adenomyotic lesion are well demonstrated as signal voids at susceptibility-weighted imaging. Cine MR imaging is useful in differentiating transient myometrial contraction from focal adenomyosis. High-resolution MR imaging at 3 T shows anatomically detailed structures and may improve diagnostic accuracy in differentiating adenomyosis from its mimics.

References

1. Zoloudek C, Norris HJ. Mesenchymal tumors of the uterus. In: Kurman RJ, ed. Blaustein's pathology of the female genital tract. New York, NY: Springer-Verlag, 1994; 487–527.
2. Rosai J. Female reproductive system. In: Rosai J, ed. Ackerman's surgical pathology. 8th ed. St Louis, Mo: Mosby–Year Book, 1996; 1319–1564.
3. Matalliotakis IM, Kourtis AI, Panidis DK. Adenomyosis. Obstet Gynecol Clin North Am 2003;30(1): 63–82.
4. Togashi K, Ozasa H, Konishi I, et al. Enlarged uterus: differentiation between adenomyosis and leiomyoma with MR imaging. Radiology 1989;171 (2):531–534.
5. Togashi K. Adenomyosis. In: MRI of the female pelvis. Toyko, Japan: Igaku-shoin, 1993; 105–122.
6. Outwater EK, Siegelman ES, Van Deerlin V. Adenomyosis: current concepts and imaging considerations. AJR Am J Roentgenol 1998;170(2):437–441.
7. Reinhold C, Tafazoli F, Mehio A, et al. Uterine adenomyosis: endovaginal US and MR imaging features with histopathologic correlation. RadioGraphics 1999;19(spec no):S147–S160.
8. Byun JY, Kim SE, Choi BG, Ko GY, Jung SE, Choi KH. Diffuse and focal adenomyosis: MR imaging findings. RadioGraphics 1999;19(spec no):S161–S170.
9. Kido A, Togashi K, Koyama T, Yamaoka T, Fujiwara T, Fujii S. Diffusely enlarged uterus: evaluation with MR imaging. RadioGraphics 2003;23(6):1423–1439.
10. Ascher SM, Jha RC, Reinhold C. Benign myometrial conditions: leiomyomas and adenomyosis. Top Magn Reson Imaging 2003;14(4):281–304.
11. Tamai K, Togashi K, Ito T, Morisawa N, Fujiwara T, Koyama T. MR imaging findings of adenomyosis: correlation with histopathologic features and diagnostic pitfalls. RadioGraphics 2005;25(1):21–40.
12. Reinhold C, Zand KR. Adenomyosis. In: Hricak H, ed. Diagnostic imaging: gynecology. Salt Lake City, Utah: Amirsys, 2007; 192–197.
13. Takeuchi M, Matsuzaki K, Nishitani H. Susceptibility-weighted MRI of endometrioma: preliminary results. AJR Am J Roentgenol 2008;191(5):1366–1370.
14. Takeuchi M, Matsuzaki K, Nishitani H. Susceptibility-weighted imaging for the evaluation of gynecologic diseases [abstr]. In: Proceedings of the 17th meeting of the International Society for Magnetic Resonance in Medicine. Berkeley, Calif: International Society for Magnetic Resonance in Medicine, 2009; 4146.
15. Takeuchi M, Matsuzaki K, Nishitani H. Hyperintense uterine myometrial masses on T2-weighted magnetic resonance imaging: differentiation with diffusion-weighted magnetic resonance imaging. J Comput Assist Tomogr 2009;33(6):834–837.
16. Utsunomiya D, Notsute S, Hayashida Y, et al. Endometrial carcinoma in adenomyosis: assessment of myometrial invasion on T2-weighted spin-echo and gadolinium-enhanced T1-weighted images. AJR Am J Roentgenol 2004;182(2):399–404.
17. Takeuchi M, Matsuzaki K, Nishitani H. Diffusion-weighted magnetic resonance imaging of endometrial cancer: differentiation from benign endometrial lesions and preoperative assessment of myometrial invasion. Acta Radiol 2009;50(8):947–953.
18. Koh DM, Collins DJ. Diffusion-weighted MRI in the body: applications and challenges in oncology. AJR Am J Roentgenol 2007;188(6):1622–1635.
19. Koyama T, Togashi K. Functional MR imaging of the female pelvis. J Magn Reson Imaging 2007;25 (6):1101–1112.
20. Namimoto T, Awai K, Nakaura T, Yanaga Y, Hirai T, Yamashita Y. Role of diffusion-weighted imaging in the diagnosis of gynecological diseases. Eur Radiol 2009;19(3):745–760.

21. Tamai K, Koyama T, Saga T, et al. The utility of diffusion-weighted MR imaging for differentiating uterine sarcomas from benign leiomyomas. Eur Radiol 2008;18(4):723–730.
22. Haacke EM, Xu Y, Cheng YC, Reichenbach JR. Susceptibility weighted imaging (SWI). Magn Reson Med 2004;52(3):612–618.
23. Sehgal V, Delproposto Z, Haddar D, et al. Susceptibility-weighted imaging to visualize blood products and improve tumor contrast in the study of brain masses. J Magn Reson Imaging 2006;24(1):41–51.
24. Glunde K, Jacobs MA, Bhujwalla ZM. Choline metabolism in cancer: implications for diagnosis and therapy. Expert Rev Mol Diagn 2006;6(6):821–829.
25. Okada T, Harada M, Matsuzaki K, Nishitani H, Aono T. Evaluation of female intrapelvic tumors by clinical proton MR spectroscopy. J Magn Reson Imaging 2001;13(6):912–917.
26. Booth SJ, Pickles MD, Turnbull LW. In vivo magnetic resonance spectroscopy of gynaecological tumours at 3.0 Tesla. BJOG 2009;116(2):300–303.
27. Takeuchi M, Matsuzaki K, Harada M, Nishitani H. High intense myometrial tumors on T2-weighted images: differentiation with diffusion-weighted imaging and 1H-MR spectroscopy [abstr]. In: Proceedings of the 17th meeting of the International Society for Magnetic Resonance in Medicine. Berkeley, Calif: International Society for Magnetic Resonance in Medicine, 2009; 4142.
28. Togashi K, Kawakami S, Kimura I, et al. Uterine contractions: possible diagnostic pitfall at MR imaging. J Magn Reson Imaging 1993;3(6):889–893.
29. Ozsarlak O, Schepens E, de Schepper AM, Deckers F, Parizel PM, Campo R. Transient uterine contraction mimicking adenomyosis on MRI. Eur Radiol 1998;8(1):54–56.
30. Fujiwara T, Togashi K, Yamaoka T, et al. Kinematics of the uterus: cine mode MR imaging. RadioGraphics 2004;24(1):e19.
31. Takeuchi M, Matsuzaki K, Nishitani H. Manifestations of the female reproductive organs on MR images: changes induced by various physiologic states. RadioGraphics 2010;30(4):1147.
32. Kataoka M, Kido A, Koyama T, et al. MRI of the female pelvis at 3T compared to 1.5T: evaluation on high-resolution T2-weighted and HASTE images. J Magn Reson Imaging 2007;25(3):527–534.
33. Sakamoto A. Subserosal adenomyosis: a possible variant of pelvic endometriosis. Am J Obstet Gynecol 1991;165(1):198–201.
34. Koyama T, Togashi K, Konishi I, et al. MR imaging of endometrial stromal sarcoma: correlation with pathologic findings. AJR Am J Roentgenol 1999;173(3):767–772.
35. Fujii S, Kaneda S, Tsukamoto K, et al. Diffusion-weighted imaging of uterine endometrial stromal sarcoma: a report of 2 cases. J Comput Assist Tomogr 2010;34(3):377–379.
36. Connors AM, deSouza NM, McIndoe GA. Adenomyoma mimicking an aggressive uterine neoplasm on MRI. Br J Radiol 2003;76(901):66–68.
37. Yamashita Y, Torashima M, Hatanaka Y, et al. MR imaging of atypical polypoid adenomyoma. Comput Med Imaging Graph 1995;19(4):351–355.
38. Kitajima K, Imanaka K, Kuwata Y, Hashimoto K, Sugimura K. Magnetic resonance imaging of typical polypoid adenomyoma of the uterus in 8 patients: correlation with pathological findings. J Comput Assist Tomogr 2007;31(3):463–468.
39. Takeuchi M, Matsuzaki K, Uehara H, Yoshida S, Nishitani H, Shimazu H. Pathologies of the uterine endometrial cavity: usual and unusual manifestations and pitfalls on magnetic resonance imaging. Eur Radiol 2005;15(11):2244–2255.
40. Takeuchi M, Matsuzaki K, Uehara H, Shimazu H, Nishitani H. A case of adenomyomatous polyp of the uterus associated with tamoxifen therapy. Radiat Med 2005;23(6):432–434.
41. Kataoka ML, Togashi K, Konishi I, et al. MRI of adenomyotic cyst of the uterus. J Comput Assist Tomogr 1998;22(4):555–559.
42. Troiano RN, Flynn SD, McCarthy S. Cystic adenomyosis of the uterus: MRI. J Magn Reson Imaging 1998;8(6):1198–1202.
43. Takeuchi M, Matsuzaki K, Uehara H, Nishitani H. Malignant transformation of pelvic endometriosis: MR imaging findings and pathologic correlation. RadioGraphics 2006;26(2):407–417.

Adenomyosis: Usual and Unusual Imaging Manifestations, Pitfalls, and Problem-solving MR Imaging Techniques

Mayumi Takeuchi, MD, PhD • Kenji Matsuzaki, MD, PhD

RadioGraphics 2011; 31:99–115 • **Published online** 10.1148/rg.311105110 • **Content Codes:** GU MR OB

Page 101
Susceptibility-weighted imaging is sensitive for old hemorrhagic foci, which appear as spotty signal voids owing to the T2*-shortening effects of hemosiderin (13,14).

Page 104 (Figure 5 on page 104)
Diffusion-weighted imaging with ADC measurement may provide another clue for the diagnosis, because these conditions (secretory transformation, decidualization, congestion or edema) usually increase the ADC in tissues. A relatively high ADC in adenomyotic lesions with high signal intensity on T2-weighted images may allow differentiation from malignant lesions, which have a low ADC due to their high cellularity (Fig 5) (15).

Page 104 (Figure 5 on page 104)
A relatively low choline peak in adenomyotic lesions may allow differentiation from malignant tumors, which show a high choline peak due to their high metabolic activity (Fig 5) (27).

Page 104 (Figure 7 on page 105)
Therefore, MR imaging for the evaluation of a uterine myometrial lesion should be performed in the late proliferative–secretory phase (Fig 7) (31).

Page 105
Various benign conditions and malignant tumors may mimic adenomyosis: physiologic myometrial contraction, myometrial involvement by pelvic endometriosis, low-grade endometrial stromal sarcoma (LG-ESS), and myometrial metastases (11,28–31,33,34).