

MRI of Benign Female Pelvis

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Owing to multiplanar imaging capabilities and excellent tissue characterization, MRI can facilitate definitive diagnosis of benign conditions of the female pelvis. The purpose of this chapter is to review the spectrum of common benign conditions of the female pelvis and to illustrate the MRI features of these conditions, with an emphasis on the key imaging characteristics to suggest accurate diagnoses.

MRI Technique for Evaluating the Benign Female Pelvis

Field strengths of 1.5 T and, increasingly, 3 T are being used for evaluating the female pelvis. The current standard of care utilizes the pelvic multicoil array, which offers good signal-to-noise ratio and anatomic resolution. Voiding before scanning is usually suggested to minimize motion due to bladder peristalsis and patient discomfort. In pelvic MRI, three-planar T2-weighted images are the mainstay because they show both the normal anatomy and pathologic processes very well owing to the inherent differences in water content of different tissues, with pathology usually being depicted as an increase in water content [1, 2]. T1-weighted images are not useful for anatomic detail but are helpful to differentiate soft tissue from fat. Fat suppression on both T1- and T2-weighted images can be helpful for confirmation of fatty lesions. For the benign female pelvis, IV gadolinium-based contrast material is not usually necessary, with the exception of uterine fibroid evaluation. However, because we are not often certain of a benign disease process at the outset, contrast material is often used, shortening T1—with vascular structures, inflammation, and neovascularity consequently being higher in signal intensity (SI).

Physiologic Cystic Ovarian Lesions

Because the majority of cystic ovarian lesions are benign, particularly in premenopausal patients, it is important to be aware of the imaging characteristics of physiologic ovarian lesions commonly encountered on MRI studies. Although sonography is a cost-effective first line of pelvic imaging in symptomatic patients, MRI can be used as a valuable adjunct modality to further evaluate indeterminate, equivocal, or complex lesions and to guide patient management.

Ovarian Follicles

The ovary contains millions of immature follicles, many of which cyclically enlarge in response to follicle-stimulating hormone. Multiple fluid-filled follicles, of high SI on T2-weighted images, appear as sharply marginated unilocular cysts of less than 1 cm in diameter, thereby allowing the identification of ovarian parenchyma on MRI. One or more of these follicles will dominate and grow to 2–2.5 cm in size during the proliferative phase of the menstrual cycle and will subsequently rupture at ovulation.

Corpus Luteum Cysts

After ovulation, there is hypertrophy of the granulosa and theca cells and increased vascularization of the cyst wall, resulting in formation of the corpus luteum

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during the secretory phase of the menstrual cycle. If the corpus luteum fails to regress, a corpus luteum cyst may form, usually at the end of the luteal phase or in pregnancy. These cysts usually have a thick, irregular, avidly enhancing wall on T1-weighted imaging after contrast administration, are single, and range from 2.5 cm to 6 cm in size [3]. They may also contain complex fluid SI owing to blood products formed at the time of ovulation.

Follicular Cysts

On occasion, a mature follicle will fail to ovulate and release the oocyte and will continue to enlarge into the next menstrual cycle. The typical appearance of these follicular cysts is a unilocular cyst of uniform high SI on T2-weighted imaging, which can sometimes (but only rarely) attain size of 5 cm or more [4] (Fig. 1). These cysts have thin walls and sharply defined borders. The cyst wall may have a thin enhancing rim on contrast-enhanced MRI. A follow-up examination after one or two menstrual cycles should reveal involution of these follicular cysts.

Hemorrhagic Cysts

Any time during the menstrual cycle when hemorrhage occurs into either a follicular cyst or a corpus luteal cyst, a hemorrhagic cyst forms. Patients with hemorrhagic cysts

commonly present with acute-onset abdominal pain. The MRI characteristics may vary depending on the stage of hemorrhage and clot retraction. Hemorrhagic cysts usually have high SI on T1-weighted images (Fig. 1). Because they usually resolve spontaneously, short-interval follow-up can be recommended to confirm resolution and exclude pathologic entities such as an endometrioma.

Benign Ovarian Neoplasms

Benign Germ Cell Neoplasm (Dermoid Cyst or Mature Cystic Teratoma)

The mature cystic teratoma (also known as a “dermoid cyst” or “dermoid”) is by far the most common germ cell tumor and is composed of at least two of the three germ cell layers (endoderm, mesoderm, and ectoderm). This is a common benign tumor in young women and is often incidentally detected. Bilateral lesions are noted in approximately 20% of patients with these tumors. Because the cyst is usually lined with ectoderm, it fills with desquamated keratin and sebaceous secretions, with resultant SI similar to that of fat on all sequences on MRI [5] (Fig. 2). The signal pattern of fat may be similar to that of hemorrhage in endometrial cysts or hemorrhagic ovarian cysts; thus, a fat-suppression MRI technique can be used to differentiate among these tumors [6]. In cases where the dermoid is predominantly cystic and contains only

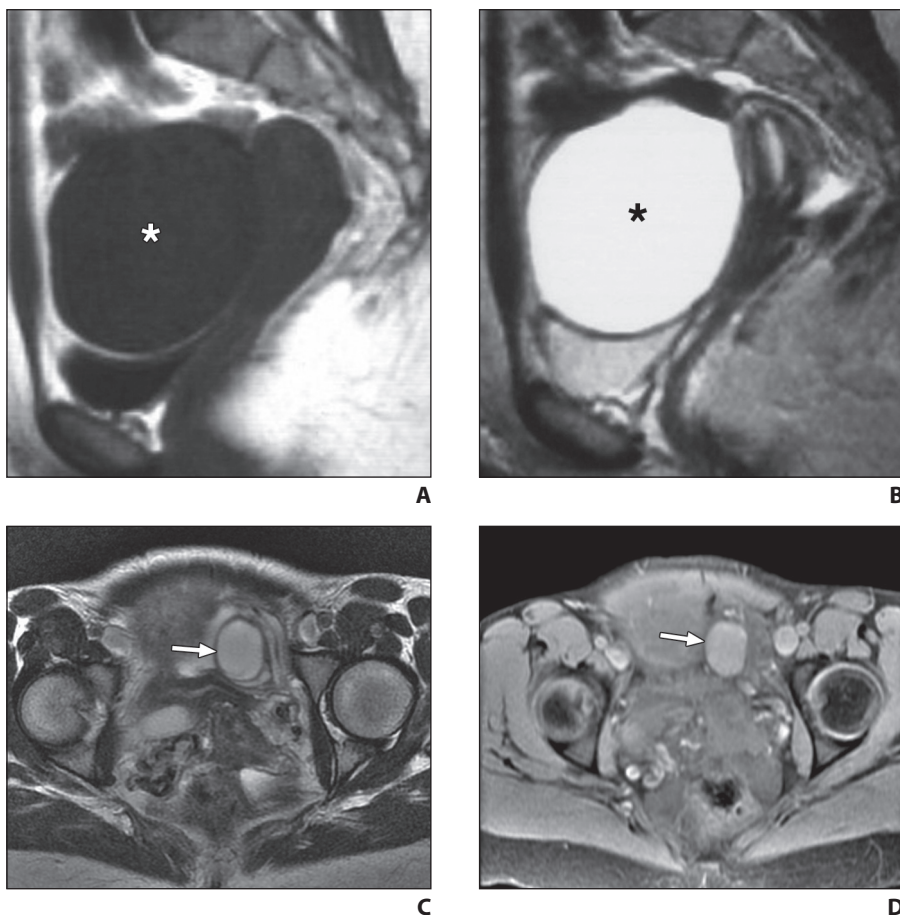


Fig. 1—Cystic ovarian lesions.

A and B, Sagittal T1-weighted (**A**) and sagittal T2-weighted (**B**) images show large, simple well-defined lesion (*asterisk*) of fluid attenuation that is separate from uterus. This is a serous cystadenoma. A large follicular cyst may also be considered, but they rarely attain this size, and usually resolve on follow-up. **C and D**, Axial T2-weighted (**C**) and T1-weighted fat-saturated (**D**) images after IV gadolinium administration show adnexal lesion (*arrow*) of high signal intensity on T2-weighted imaging but which remains of high signal intensity on T1 fat-saturated images without enhancement, consistent with hemorrhagic cyst.

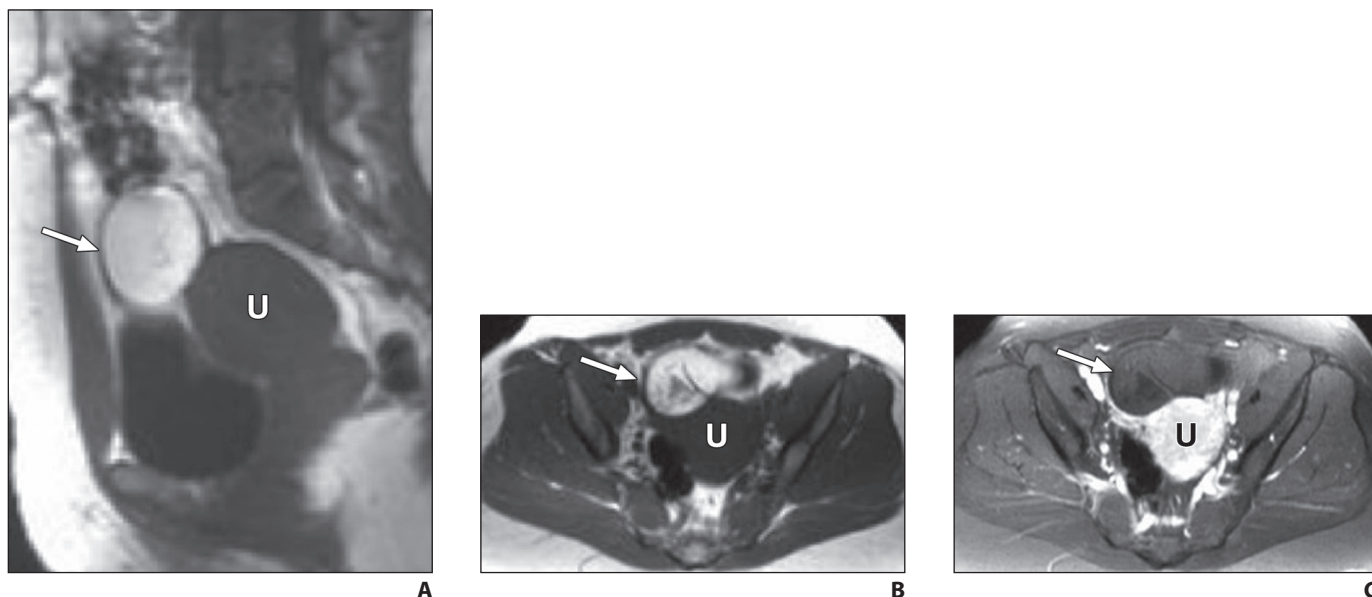


Fig. 2—Ovarian dermoid.

A–C, Sagittal T1-weighted (**A**), axial T1-weighted (**B**), and axial T1-weighted fat-saturated (**C**) images after IV gadolinium administration show mass (*arrow*) that is separate from uterus (**U**) and has signal intensity similar to fat on all sequences (i.e., high signal intensity on T1-weighted images and low signal intensity on T1-weighted fat-saturated images), consistent with ovarian dermoid.

microscopic fat, chemical-shift (in phase and opposed phase) imaging may be useful [7]. MRI may also prove beneficial by revealing complications of dermoids, such as rupture, which may be identified as sebaceous material of fat intensity floating in the peritoneal cavity.

Benign Sex Chord Stromal Tumor (Ovarian Fibroma or Thecoma)

Ovarian fibromas are benign mesenchymal tumors of the ovary, most commonly occurring in peri- or postmenopausal women. Because they are composed of fibroblasts and abundant collagenous tissue, these tumors typically show SI similar to smooth muscle on MRI, are usually of low SI on T2- and T1-weighted images, and enhance to the same degree as muscle after contrast administration (Fig. 3). Fibromas have an average size of 6 cm [8] but can grow much larger. Infrequently, ovarian fibromas, particularly when larger than 10 cm, can be associated with ascites and pleural effusion (Meigs syndrome), which subsequently resolve after resection of the fibroma. Sometimes, when the ipsilateral ovary is not readily apparent, these tumors can be difficult to differentiate from an exophytic uterine fibroid.

Ovarian fibroma should also be distinguished from ovarian fibromatosis. This is a rare benign condition that manifests as bilateral ovarian masses that have a dominant fibrous component, showing low SI on T2-weighted images. However, in ovarian fibromatosis, there are usually ovarian follicles apparent between the fibrous tissue and the lesions are bilateral [9].

Benign Epithelial Ovarian Neoplasm

Epithelial tumors account for at least 60% of all ovarian neoplasms. The most common are serous epithelial tumors,

also known as “cystadenomas,” and of these, approximately 60% are benign. Serous cystadenomas of the ovary commonly appear as unilocular, thin-walled cysts filled with simple fluid, which are usually 5–10 cm in size but may be much larger (Fig. 1). The size of the lesion, in addition to the presence of papillary mural projections, best correlates with risks of malignancy and tumor aggressiveness. In general, smaller, simple-appearing cystic lesions are managed by observation, whereas those larger than 10 cm are thought to be at greater risk of malignancy and are removed.

The second most common epithelial tumors are mucinous epithelial tumors, representing about 20–25% of ovarian tumors. Approximately 80% of these are benign. Mucinous cystadenomas typically show characteristic multilocular masses with varying signal intensities in the locules (stained-glass appearance) on MRI (Fig. 4) and tend to be larger at presentation than their serous counterparts, often around 20 cm at diagnosis [6]. Usually, the presence of thick septations suggests borderline lesions, whereas the presence of more solid components suggests carcinoma.

Benign Disease Processes Involving the Female Pelvis

Endometriosis

Endometriosis occurs when endometrial tissue implants outside the uterine cavity and responds to cyclic hormonal stimulation. In endometriosis, the most common implantation site is along the serosal surface of the uterus and along the ovaries. It also has a predilection for scar tissue in women who have had prior cesarean section or other uterine surgeries. However, endometrial deposits can involve any peritoneal surface within

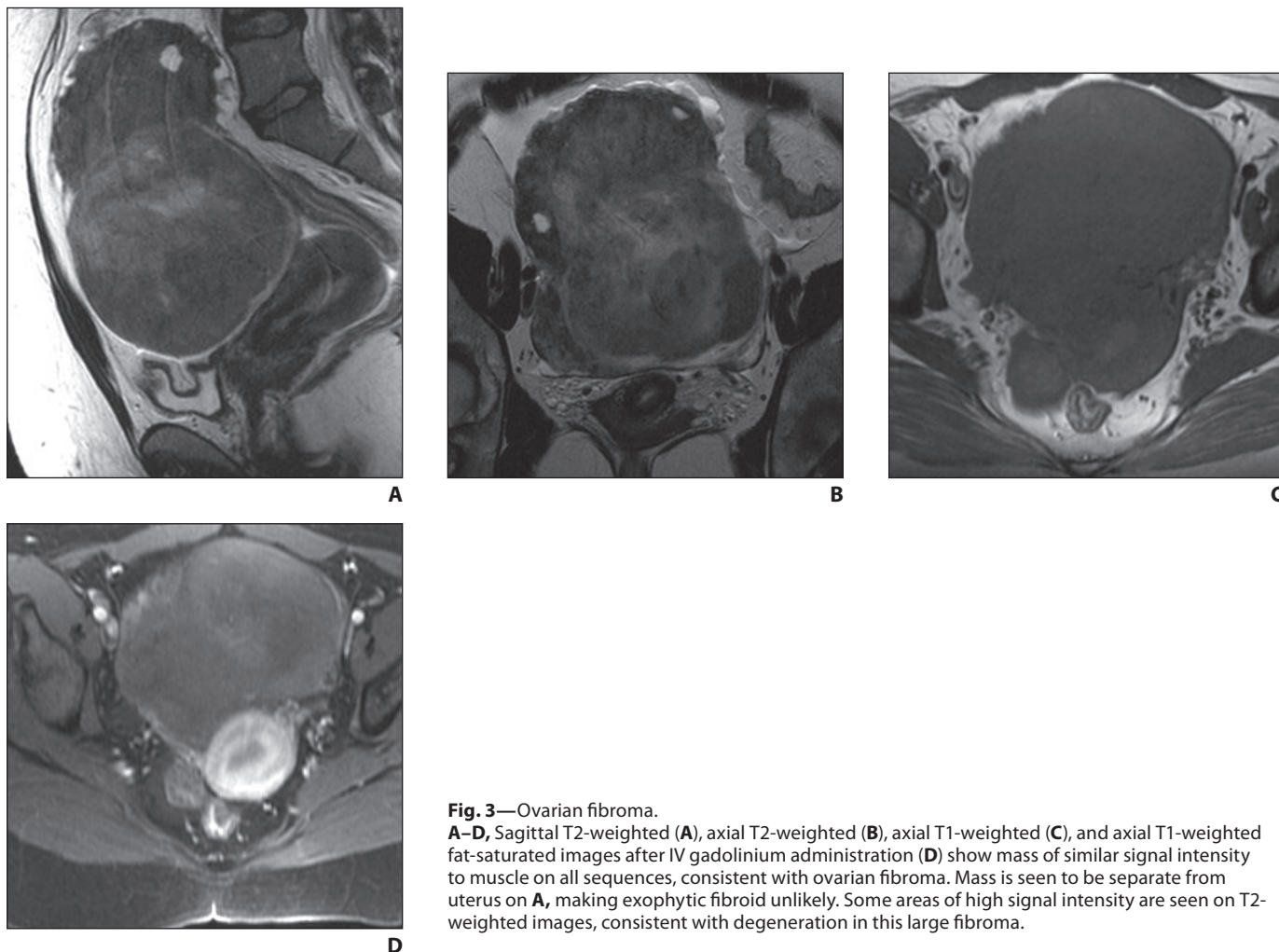


Fig. 3—Ovarian fibroma.

A–D, Sagittal T2-weighted (**A**), axial T2-weighted (**B**), axial T1-weighted (**C**), and axial T1-weighted fat-saturated images after IV gadolinium administration (**D**) show mass of similar signal intensity to muscle on all sequences, consistent with ovarian fibroma. Mass is seen to be separate from uterus on **A**, making exophytic fibroid unlikely. Some areas of high signal intensity are seen on T2-weighted images, consistent with degeneration in this large fibroma.

the abdomen and pelvis and very rarely can occur within the lungs and CNS. A commonly cited hypothesis is that retrograde menstruation occurs with migration of endometrial cells into the peritoneal cavity through the fallopian tubes [10].

Two forms of endometriosis have been described: the more common, diffuse form, wherein scattered implants (some of which may be very small) occur; and a focal form, wherein discrete collections of blood form, called “endometriomas” or “chocolate cysts” (because of appearance at pathology). Endometriomas contain blood products of varying chronicity, a phenomenon known as “shading” that is best appreciated on T2-weighted images (Fig. 5). Classically, endometriomas are adnexal lesions of high SI on T1-weighted images and low SI on T2-weighted images (Fig. 5), but they can be of high SI on both T1- and T2-weighted images, depending on the age of the blood products and the presence of methemoglobin. Endometrial cysts have a strong tendency to rupture, after which blood reaccumulates and the cyst ruptures again, resulting in multiple cysts adherent to each other; this phenomenon is known as “multiplicity,” which can be a diagnostic clue. Endometriomas may have a low-SI peripheral rim consistent

with a fibrous capsule. Enhancement of the capsule or of adjacent peritoneal surfaces may occur. Small solid endometrial implants may be more difficult to diagnose. Their location may be a diagnostic clue, because they are more commonly found in the dependent parts of the pelvis, such as along the pelvic ligaments and the rectouterine pouch. These nodules

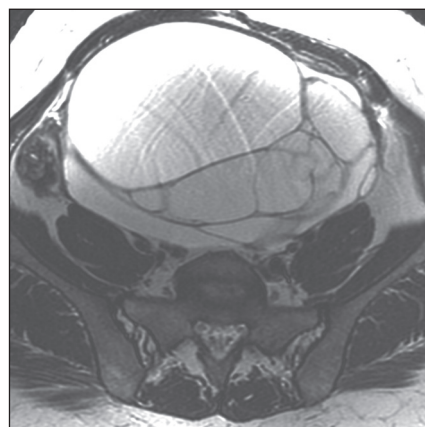


Fig. 4—Mucinous cystadenoma. Axial T2-weighted image shows various amounts of mucin within locules, resulting in varying signal intensity (stained-glass appearance). (Courtesy of Sadow C, Brigham and Women’s Hospital, Boston, MA)

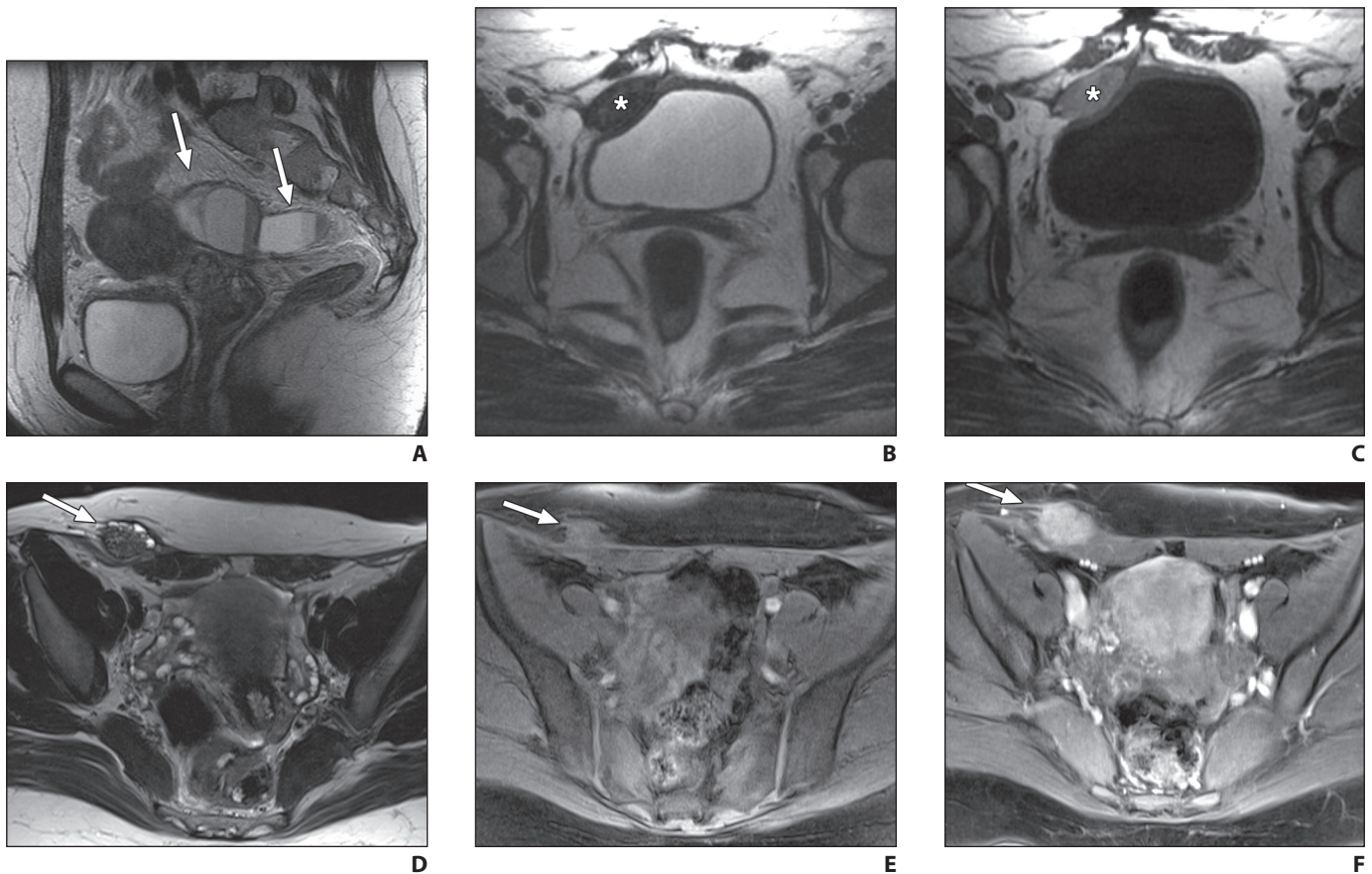


Fig. 5—Endometriosis.

A, Sagittal T2-weighted image (**A**) shows multiple cysts adherent to each other, demonstrating blood products of varying age (*arrows*) and resultant layering, known as “shading,” consistent with endometriosis.

B and **C**, Axial T2-weighted (**B**) and axial T1-weighted (**C**) images of endometrioma along right anterolateral aspect of urinary bladder (*asterisk*) show signal intensity consistent with blood.

D–F, Endometriosis can also be seen in scar tissue (*arrow*), as shown on axial T2-weighted image (**D**). Small areas of shading are seen along lateral aspect of scar tissue in right anterior abdominal wall in **D**, which avidly enhances after administration of IV gadolinium (**F**), as compared with unenhanced image (**E**).

vary in SI depending on the composition of glandular material and the presence of a fibrotic reaction. Solid endometriosis in scar tissue of the anterior abdominal wall usually enhances avidly and may be clinically palpable (Fig. 5).

Adenomyosis

Adenomyosis is a condition in which heterotopic endometrial stroma and glands are found within the myometrium. The invasion into the myometrium results in reactive overgrowth of the musculature surrounding the endometrial glands. It is this smooth muscle hypertrophy that leads to the appearance of an enlarged globular uterus. Adenomyosis is a common condition, though often difficult to clinically diagnose owing to overlap of symptoms with other uterine pathologies. The pathogenesis of adenomyosis is unknown; however, theories have been proposed, including disruption of the endometrial-myometrial interface, perhaps resulting from increased intra-uterine pressure or myometrial injury. Adenomyosis is more commonly associated with multiparous women and uterine trauma or surgery [11]. Adenomyosis has two forms: diffuse

adenomyosis and focal adenomyosis, which most commonly involves the posterior uterine wall.

MRI usually offers a definitive diagnosis of adenomyosis, owing to its superior inherent tissue contrast and characterization. T2-weighted imaging, which provides greatest anatomic detail of the zones of the uterus, is the most useful sequence. The most common finding is widening of the junctional zone (Fig. 6), which is the innermost layer of the myometrium. The junctional zone is normally of low SI on T2-weighted images, which is attributed to its high nuclear-to-cytoplasmic ratio [12], differentiating it from the inner, high-SI endometrium and outer, intermediate-SI myometrium. A threshold of 12 mm or greater [13] is commonly used to diagnose adenomyosis, this thickening being diffuse or focal. Punctate foci of high SI on T2-weighted images are also a defining characteristic of adenomyosis, thought to be due to the ectopic endometrial tissue.

The most common differential diagnosis for a focal adenomyoma is a uterine leiomyoma, or fibroid. However, the border of the fibroid is usually well defined and has a pseudocapsule, whereas the contour of an adenomyoma is more ill

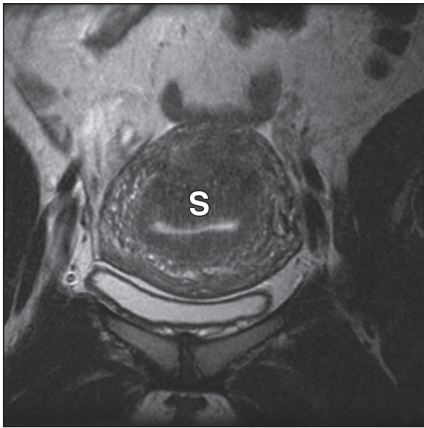


Fig. 6— Adenomyosis. Coronal T2-weighted image shows thickening of dark junctional zone along superior wall (S) as compared with inferior wall, with punctate high-signal-intensity T2 foci within widened junctional zone, all indicative of adenomyosis.

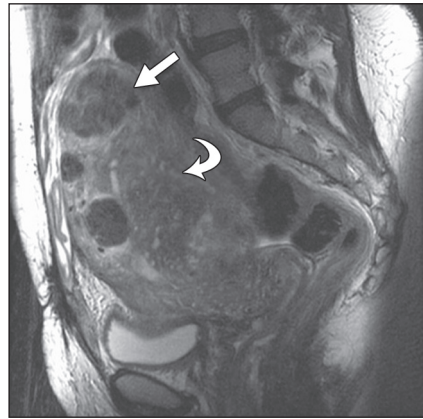


Fig. 7— Comparison between uterine fibroid and adenomyosis. Sagittal T2-weighted image shows well-demarcated typical low-signal-intensity uterine fibroid (straight arrow) and less well-defined area of thickened junctional zone (curved arrow), consistent with adenomyosis.

defined and infiltrative (Fig. 7). Another differentiating feature is that uterine fibroids may exert a mass effect on the uterus, whereas focal adenomyosis does not. Although adenomyosis can have tiny punctate foci of high SI within the widened junctional zone, areas of high SI in degenerating uterine fibroids are usually larger, owing to cystic degeneration. Uterine contractions can also mimic adenomyosis, but these are transient and are not confirmed on all T2-weighted imaging planes.

Uterine Fibroids

Uterine fibroids, a significant cause of morbidity for women of reproductive age, are the most common benign neoplasm of the uterus [14]. They are benign clonal tumors of the smooth muscle cells. The estimated cumulative incidence by 50 years old is thought to be in excess of 80% for African American women and approaching 70% for white women [15]. The exact pathophysiology of uterine fibroids has not been clearly elucidated, but there are several well-established risk factors including delayed menopause, exogenous hormone replacement therapy, and African American ethnicity [16]. Uterine fibroids are the single largest indication for hysterectomy, and MRI often plays a decisive role in treatment choice.

MRI can provide details about fibroid size, location, SI, and enhancement characteristics. Because uterine fibroids are sharply demarcated from surrounding myometrium by a pseudocapsule of light areolar tissue or compressed myometrial tissue,

precise measurements can be made with three-planar MRI on T2-weighted images. Fibroids are categorized by their location as being intramural (entirely or mostly contained within the myometrium), submucosal (projecting into the endometrial cavity, including those that are pedunculated), or subserosal (extending outward from the serosal surface of the uterus; these may also be pedunculated); fibroids may also be cervical in location or, rarely, ligamentous. Fibroid location and size are important contributing factors that determine treatment options for patients. For example, small submucosal fibroids may best be removed by hysteroscopic resection, whereas pedunculated subserosal fibroids may be appropriately treated by myomectomy. These pedunculated subserosal fibroids with a small stalk of attachment would not be good candidates for uterine artery embolization or MRI-guided focused ultrasound surgery, because of risk of fibroid sloughing.

As outlined in Table 1, fibroids typically are well-defined masses of low SI on T2-weighted images and enhance after administration of contrast material. Uterine fibroids are sharply demarcated from surrounding myometrium by a pseudocapsule of light areolar tissue or compressed myometrial tissue (Fig. 7). A less common group are those showing high SI on T2-weighted images (Fig. 8), thought to represent hypercellular fibroids, composed of compact smooth muscle cells without intervening collagen. As they increase in size, fibroids may undergo hyaline degeneration, resulting in either a low SI on

TABLE 1: Uterine Fibroid Characteristics on MRI

Underlying Pathogenesis	Signal Intensity		Contrast Enhancement Pattern on T1-Weighted Imaging
	T2-Weighted Imaging	T1-Weighted Imaging	
Typical fibroid	Hypointense	Isointense to muscle	Enhances similar to muscle
Hypercellular fibroid	Hyperintense	Isointense to muscle	Enhances similar to muscle
Hyaline degeneration	Heterogeneous whorled pattern	Usually isointense to muscle	Heterogeneous enhancement
Hemorrhagic (carneous/red) degeneration ^a	Hypointense	Hyperintense or isointense depending on age of blood	No enhancement
Lipoleiomyoma	Hyperintense with hypointense amorphous areas	Hyperintense (which suppresses on fat-suppressed images) with hypointense amorphous areas	Enhancement of amorphous areas

Note—This table was published in [17], copyright Elsevier 2011.

^aSimilar pattern is seen after uterine artery embolization. Hemorrhagic degeneration is also known as red or carneous degeneration.

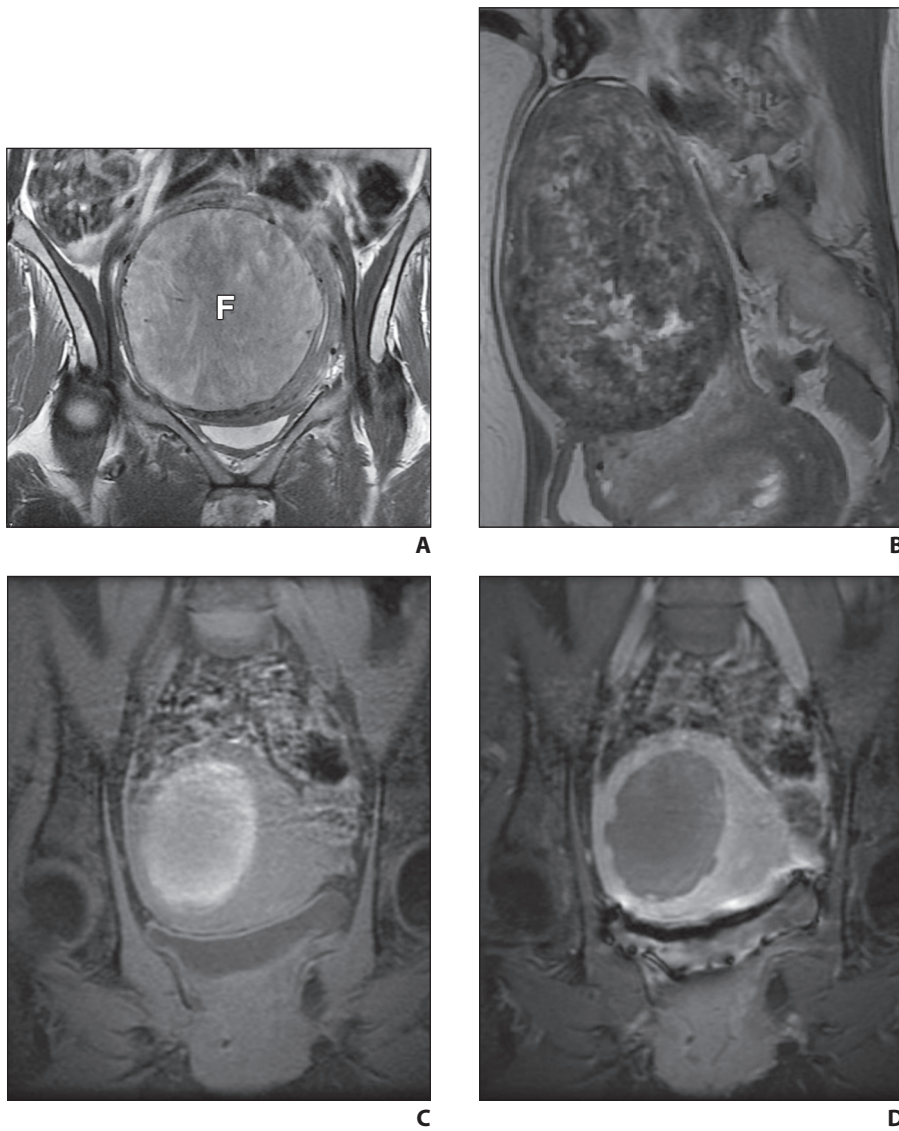


Fig. 8—Uterine fibroid.

A, Coronal T2-weighted image shows less common, hypercellular uterine fibroid (F) of high signal intensity, surrounded by low-signal-intensity myometrium.

B, Sagittal T2-weighted image shows hyaline degeneration with speckled areas of low and high signal intensity.

C and D, Coronal T1-weighted fat-saturated images before (C) and after (D) IV gadolinium administration show high signal intensity before contrast administration, consistent with blood products, and lack of enhancement after contrast administration, consistent with hemorrhagic (also known as red or carneous) degeneration.

T2-weighted images (i.e., lower SI than is seen with usual fibroids) or a speckled pattern of low SI and high SI (Fig. 8). Findings indicating hemorrhagic degeneration may depend on the time since degeneration, but usually hemorrhagic degeneration is seen as high SI on T1-weighted images within the entire fibroid and lack of enhancement after administration of contrast material (Fig. 8). Calcification along the periphery of the fibroid can occur and is best appreciated on gradient-echo T1-weighted images. A rare variation is the lipoleiomyoma, consisting of mature adipose tissue interspersed with smooth muscle cells and fibrous tissue.

Details of the variable imaging characteristics on MRI can also play important roles in determining the optimal treatment. Because uterine artery embolization exerts its treatment effect through the release of microparticles into the feeding vessels of the fibroid and MRI-guided focused ultrasound surgery causes temperature elevation in fibroid tissue with resultant cell death, both of these treatment options require an intact blood

supply to the fibroid before treatment. SI on T2-weighted imaging is also an important detail that may determine optimal treatment; for example, it is usually easier to induce sufficient temperature elevations in typical fibroids (i.e., those of low SI on T2-weighted images) through MRI-guided focused ultrasound surgery, and these have a better outcome than hypercellular fibroids.

Summary

Because of inherent tissue contrast, MRI offers much information on benign physiologic and pathologic processes in the female pelvis. Although often not the first line of imaging for benign pelvic disease, MRI can facilitate definitive diagnosis once key imaging characteristics of the physiologic or pathologic process are known.

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