Uterine Leiomyomas: Histopathologic Features, MR Imaging Findings, Differential Diagnosis, and Treatment[1]

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Leiomyomas are the most common uterine neoplasm and are composed of smooth muscle with varying amounts of fibrous connective tissue. As leiomyomas enlarge, they may outgrow their blood supply, resulting in various types of degeneration: hyaline or myxoid degeneration, calcification, cystic degeneration, and red degeneration. Leiomyomas are classified as submucosal, intramural, or subserosal; the latter may become pedunculated and simulate ovarian neoplasms. Although most leiomyomas are asymptomatic, patients may present with abnormal uterine bleeding, pressure on adjacent organs, pain, infertility, or a palpable abdominal-pelvic mass. Magnetic resonance (MR) imaging is the most accurate imaging technique for detection and localization of leiomyomas. On T2-weighted images, nondegenerated leiomyomas appear as well-circumscribed masses of decreased signal intensity; however, cellular leiomyomas can have relatively higher signal intensity on T2-weighted images and demonstrate enhancement on contrast material–enhanced images. Degenerated leiomyomas have variable appearances on T2-weighted images and contrast-enhanced images. The differential diagnosis of leiomyomas includes adenomyosis, solid adnexal mass, focal myometrial contraction, and uterine leiomyosarcoma. For patients with symptoms, medical or surgical treatment may be indicated. MR imaging also has a role in treatment of leiomyomas by assisting in surgical planning and monitoring the response to medical therapy.

Abbreviations: GnRH = gonadotropin-releasing hormone, SE = spin echo

Index terms: Leiomyoma, 854.315 • Uterine neoplasms, diagnosis, 854.315 • Uterine neoplasms, MR, 854.1214, 854.315 • Uterine neoplasms, therapy, 854.315

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■ INTRODUCTION

Leiomyomas, also known as myomas or fibroids, are the most common gynecologic neoplasm, occurring in 20%–30% of women of reproductive age, and account for approximately 30% of all hysterectomies performed in the United States (1–4). Magnetic resonance (MR) imaging is the most accurate imaging technique for detection and localization of leiomyomas. The differential diagnosis at MR imaging includes adenomyosis, solid adnexal mass, focal myometrial contraction, and uterine leiomyosarcoma.

In this article, the histopathologic features, classification, symptoms, MR imaging findings, differential diagnosis, and treatment of uterine leiomyomas are described. In addition, the lesions that resemble leiomyomas in the female pelvis are illustrated.

■ HISTOPATHOLOGIC FEATURES

Leiomyomas are benign tumors composed predominantly of smooth muscle cells separated by variable amounts of fibrous connective tissue (5,6). Although there is no true capsule, these tumors are well circumscribed and surrounded by a pseudocapsule (7). The cut surface has a characteristic whorl-like, trabeculated appearance. The size of uterine leiomyomas is variable, ranging from microscopic to large tumors that fill the abdomen. Leiomyomas may be single or, more frequently, multiple.

Although little is known about the factors responsible for the initial neoplastic transformation, it is hypothesized that each leiomyoma arises from a single cell in the myometrium (8). Several observations suggest that estrogens and progesterone play an important role in the growth of leiomyomas: Leiomyomas occur in women of reproductive age, often enlarge during pregnancy or during oral contraceptive use, and regress after menopause (9).

As leiomyomas enlarge, they may outgrow their blood supply. The result is various types of degeneration: hyaline or myxoid degeneration, calcification, cystic degeneration, and red (hemorrhagic) degeneration. Most of these histopathologic findings are unrelated to the clinical symptoms. Hyaline degeneration involves the presence of homogeneous eosinophilic bands or plaques in the extracellular space, which represent accumulation of proteinaceous tissue (6,10). Myxoid degeneration involves the presence of gelatinous intratumoral foci at gross examination that contain hyaluronic acid–rich mucopolysaccharides (5). Red degeneration is a subtype of hemorrhagic infarction of leiomyomas that often occurs during pregnancy. It is characterized by a red (hemorrhagic) appearance of the leiomyomas at gross examination. Red degeneration occurs secondary to venous thrombosis within the periphery of the tumor or rupture of intratumoral arteries (11). Sarcomatous transformation of a preexisting leiomyoma does occur but is reportedly rare; most leiomyosarcomas arise independently (5,7). Rapid growth of a leiomyoma is not a reliable indication of sarcomatous degeneration (12). In a retrospective review of 580 leiomyosarcomas, less than 3% of patients had a rapidly enlarging uterus (12). In the same review, only one leiomyosarcoma was found in 371 women operated on for rapidly growing leiomyomas.

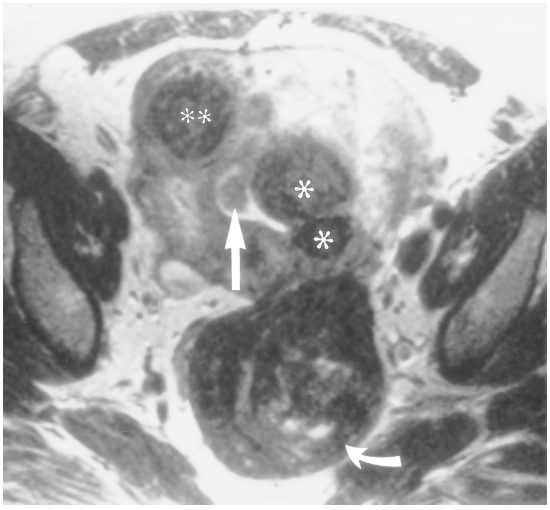
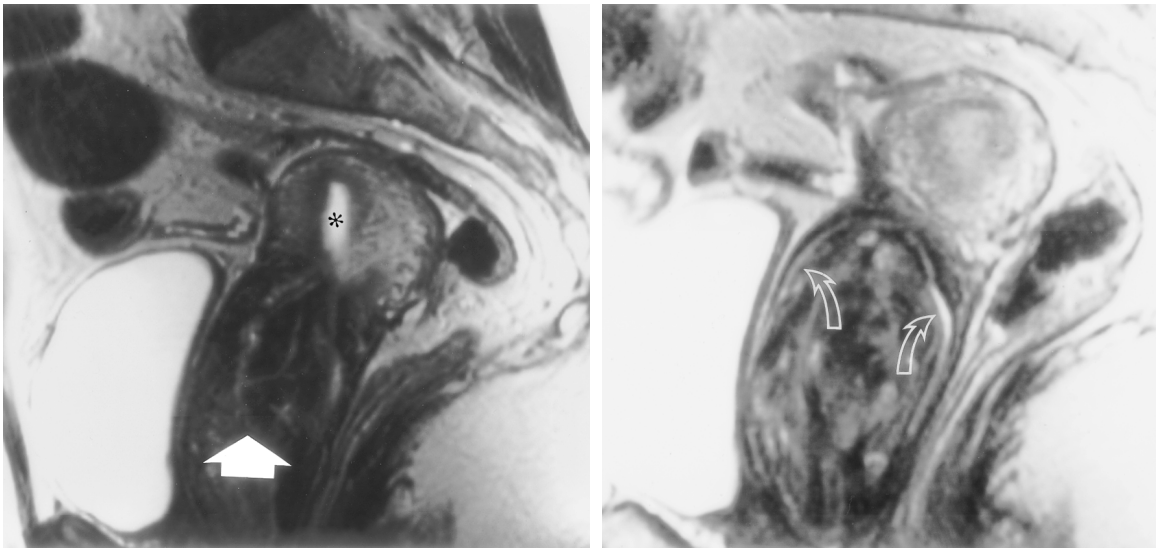


Figure 1. Submucosal, intramural, and subserosal leiomyomas in a 43-year-old woman. Axial T2-weighted fast spin-echo (SE) MR image shows submucosal (large *), intramural (small *), intracavitary (straight arrow), and subserosal (curved arrow) leiomyomas. The latter manifested as a suspected adnexal mass at both rectal examination and an outside ultrasonographic (US) examination. MR imaging was requested to exclude an ovarian neoplasm. The left ovary was identified on other images (not shown).

■ CLASSIFICATION

Leiomyomas most commonly involve the myometrium of the uterine corpus but may also occur in the cervix (~8% of cases). According to their location, leiomyomas are classified as submucosal (projecting into the endometrial canal), intramural (within the substance of the myometrium), or subserosal (beneath the serosa) (Fig 1) (7). This classification is of clinical sig-



a. **b.**

Figure 2. Prolapsed pedunculated leiomyoma manifesting as a vaginal mass in a 57-year-old woman. Sagittal T2-weighted fast SE MR images show a mass of low to intermediate signal intensity (arrow in **a**) within a distended vaginal canal (arrows in **b**), which is continuous superiorly with the endometrial canal (∗ in **a**).

nificance because the symptoms and treatment vary among these subtypes of leiomyomas. Although submucosal leiomyomas are the least common, representing approximately only 5% of uterine leiomyomas, they are most commonly symptomatic; these lesions may be associated with dysmenorrhea, menorrhagia, and infertility (13,14). In rare instances, submucosal leiomyomas may become pedunculated and protrude into the cervical canal or vagina (Fig 2) (15); the prevalence of such submucosal leiomyomas is estimated to be 2.5% (16,17). Intramural leiomyomas, which are the most common, are most often asymptomatic. However, they can occasionally be associated with menorrhagia and infertility. Infertility can occur secondary to extrinsic compression of the fallopian tube (18). Menstrual irregularities are hypothesized to be secondary to the loss of symmetric uterine contractions (14).

Subserosal leiomyomas are usually asymptomatic; however, pedunculated subserosal leiomyomas may undergo torsion, which results in infarction accompanied by pain (2,6). Lateral growth of subserosal leiomyomas may extend between the folds of the broad ligament (intraligamentous leiomyoma) and simulate an ovarian mass at both clinical and imaging examinations. Rarely, a pedunculated lesion may become attached to an adjacent structure, where it may derive a new blood supply and become detached from the uterus (parasitic leiomyoma) (6).

■ SYMPTOMS

It has been estimated that 20%–50% of women with leiomyomas present with symptoms such as menorrhagia, dysmenorrhea, pressure, urinary frequency, pain, infertility, or a palpable abdominal-pelvic mass (19). The clinical presentation is variable, depending on the size, location, and number of tumors. The four major symptoms of leiomyomas that are appropriate indications for intervention are bleeding, pressure on adjacent organs, pain, and infertility (14).

● Bleeding

The most frequent symptom of leiomyomas is abnormal uterine bleeding. This bleeding may manifest as menorrhagia or menometrorrhagia, which may result in anemia. Submucosal leiomyomas are often associated with ulceration of the overlying endometrium. Bleeding may also be caused by interference of intramural leiomyomas with normal uterine contractility, which presumably plays a role in limiting uterine bleeding during menstruation (2).

● Pressure on Adjacent Organs

As leiomyomas enlarge, they may produce pressure on surrounding structures. Anterior leiomyomas may cause compression of the bladder with resultant urinary frequency or incontinence.

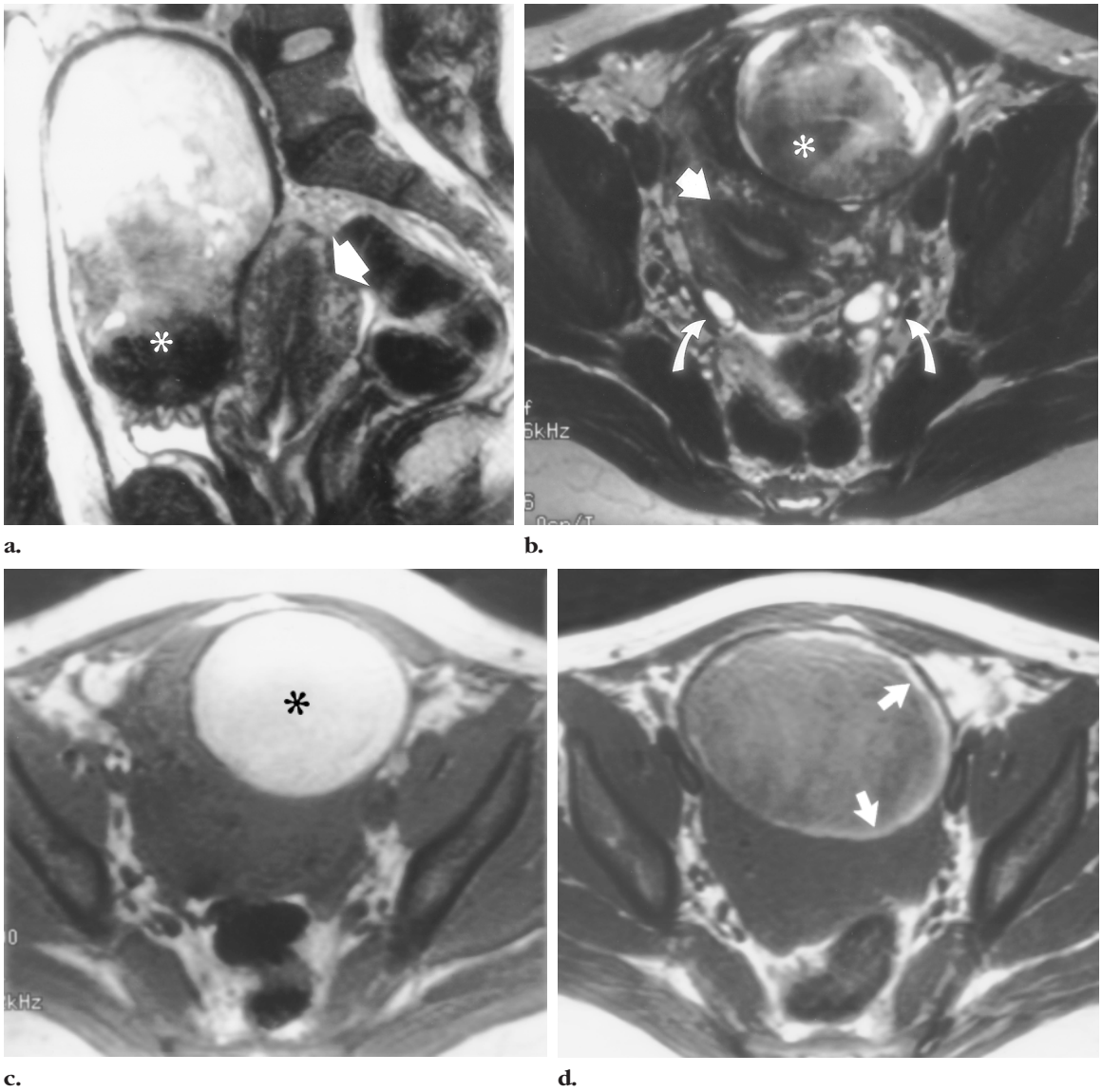


Figure 3. Maturing hemorrhagic leiomyoma in a postpartum 34-year-old woman with lower abdominal discomfort and a palpable mass. **(a, b)** Sagittal **(a)** and axial **(b)** T2-weighted fast SE MR images show a normal uterus (arrow in **a**, straight arrow in **b**) and ovaries (curved arrows in **b**). There is a large, heterogeneous subserosal leiomyoma (*) that extends superiorly from the anterior body and fundus of the uterus. **(c)** Axial T1-weighted spoiled gradient-echo MR image obtained at the same level as **b** shows diffuse very high signal intensity within the mass (*); the very high signal intensity represents methemoglobin from subacute hemorrhage. **(d)** Axial T1-weighted SE MR image obtained 4 months later shows maturation of the hemorrhage with high signal intensity confined to the rim (arrows). Both patterns of high signal intensity have been described in hemorrhagic degeneration of leiomyomas.

Similarly, posterior leiomyomas that impinge on the rectosigmoid may cause constipation. Intraligamentous lesions may compress the ureter along the pelvic wall, resulting in hydroureter or hydronephrosis (2,19).

• Pain

Pain occurs in approximately 30% of women with uterine leiomyomas and is usually the result of acute degeneration (18). Red degeneration, which is most commonly observed during pregnancy, results from hemorrhagic infarction of a leiomyoma (Fig 3). Such degeneration may result in systemic symptoms, such as abdominal

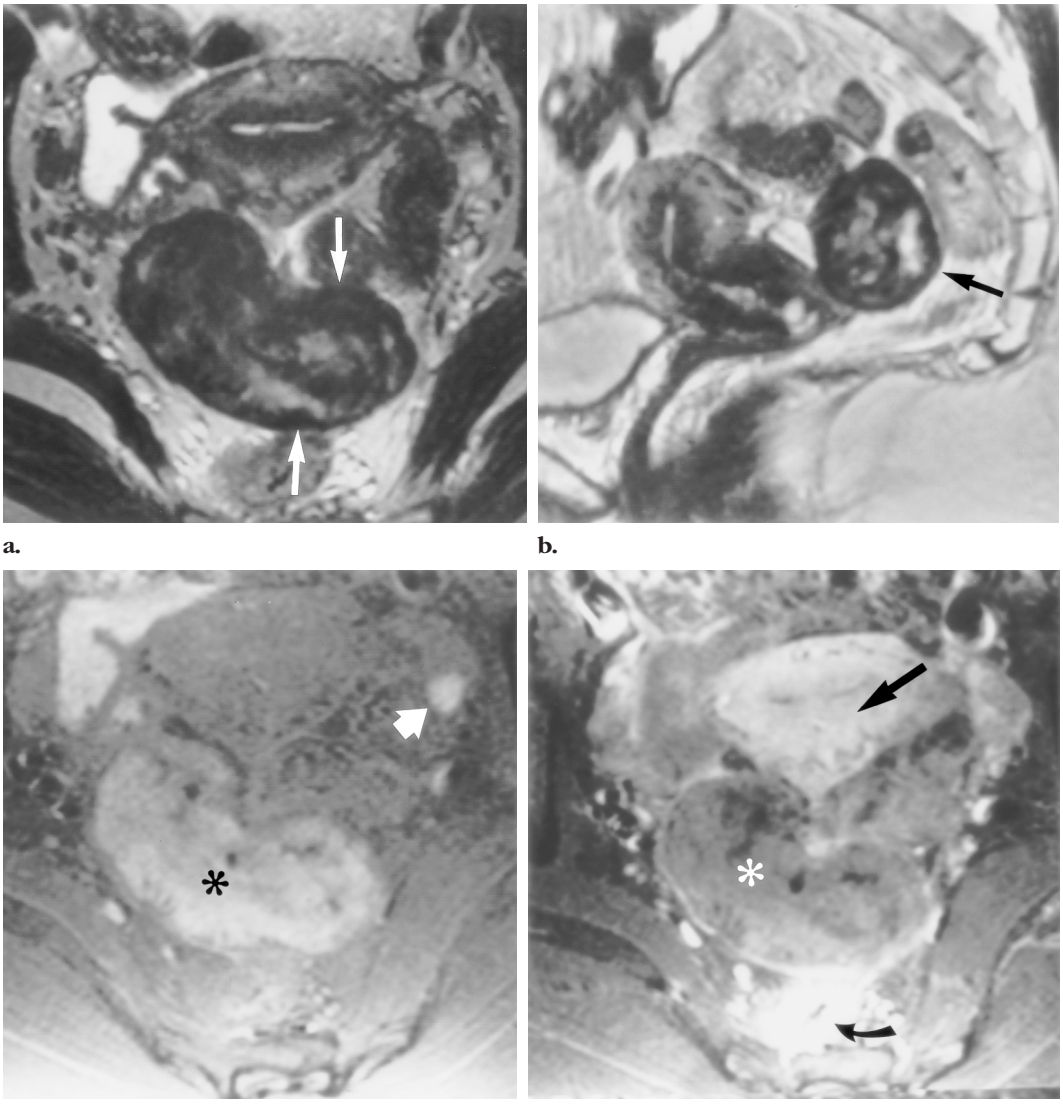


Figure 4. Hyaline degeneration and ischemic necrosis in a surgically confirmed, chronically twisted subserosal leiomyoma in a 47-year-old woman with chronic pelvic pain. **(a, b)** Axial **(a)** and sagittal **(b)** T2-weighted fast SE MR images show an ovoid mass in the cul-de-sac (arrows) with heterogeneous predominantly low to intermediate signal intensity relative to that of the outer myometrium. No connection to the uterus was demonstrated. **(c)** Axial fat-saturated T1-weighted SE MR image shows high signal intensity within the cul-de-sac mass (*); the high signal intensity represents subacute to chronic hemorrhage. A hemorrhagic cyst or endometrioma is present in the left ovary (arrow). **(d)** Contrast material–enhanced axial fat-saturated T1-weighted SE MR image shows enhancement of the myometrium (straight arrow) and rectal wall (curved arrow) but no enhancement of the cul-de-sac mass (*).

pain, low-grade fever, and leukocytosis (11). Pain may also occur with torsion of pedunculated subserosal leiomyomas (Fig 4) or prolapse of pedunculated submucosal leiomyomas (2).

• Infertility

Leiomyomas are an infrequent primary cause of infertility. Infertility may be caused by compromise of the patency of the fallopian tube or distortion of the endometrial cavity. Intramural leiomyomas located in the cornual regions of the uterus may obstruct the interstitial portion of the tube; intraligamentous leiomyomas may also impinge sufficiently on the tubal lumen to cause tubal obstruction. Patients with submucosal leiomyomas may have an increased prevalence of early abortion resulting from faulty implantation (19).

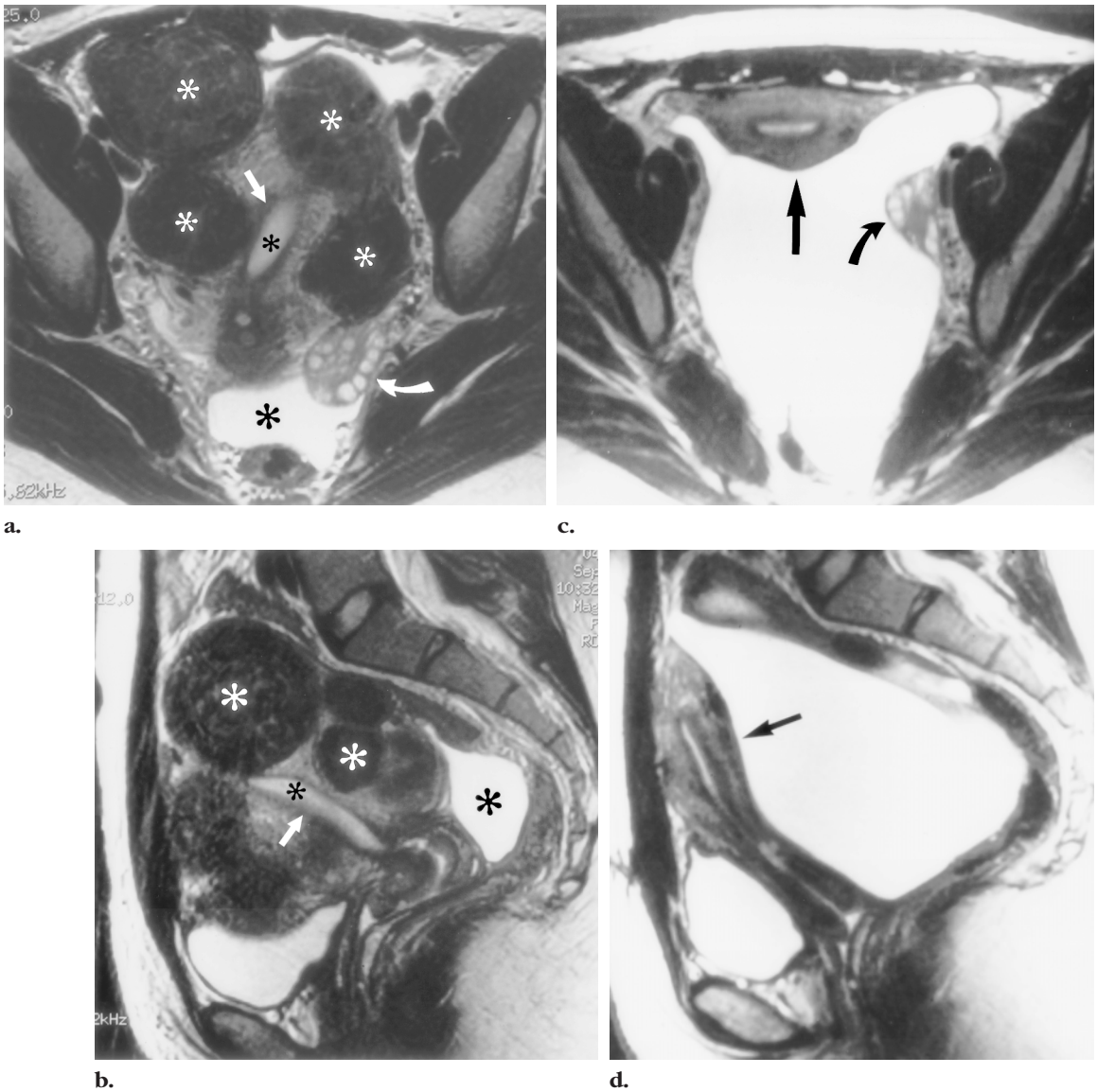
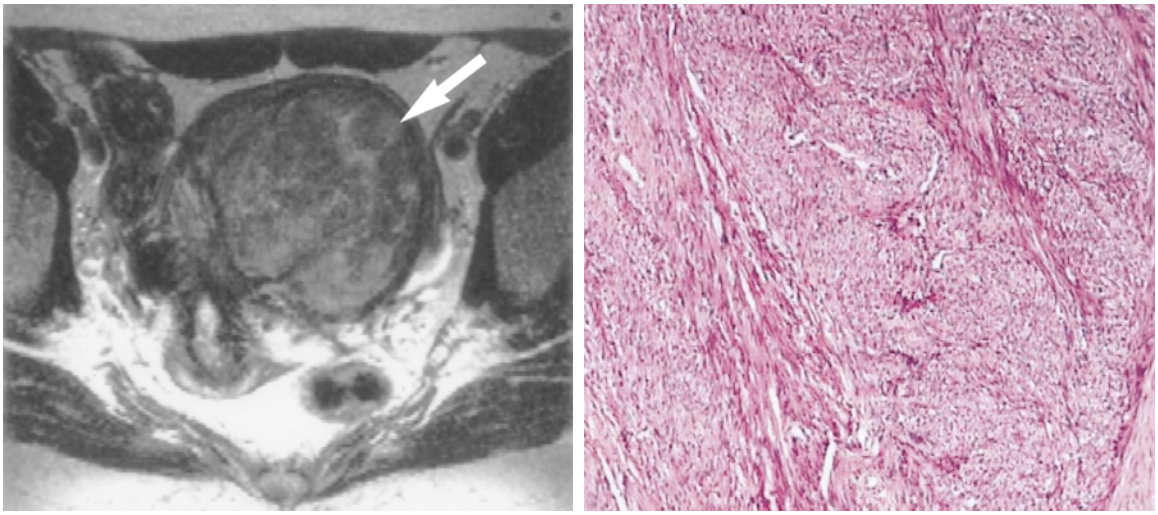


Figure 5. Multiple intramural and subserosal leiomyomas in a 31-year-old woman. **(a, b)** Axial **(a)** and sagittal **(b)** T2-weighted fast SE MR images show a normal endometrial stripe (small black ∗) and junctional zone (straight arrow). Multiple relatively homogeneous leiomyomas of low to intermediate signal intensity are evident (white ∗), as are a normal-appearing left ovary (curved arrow in **a**) and physiologic cul-de-sac fluid (large black ∗). Two months after surgery, the patient returned for additional imaging because of pelvic pain. **(c, d)** Axial **(c)** and sagittal **(d)** T2-weighted fast SE MR images show that the leiomyomas have been removed. There is a large, unilocular fluid collection within the cul-de-sac that also abuts the left ovary (curved arrow in **c**) and displaces the uterus anteriorly (straight arrow). The fluid collection was confirmed to be a postprocedural peritoneal inclusion cyst.



a. b.

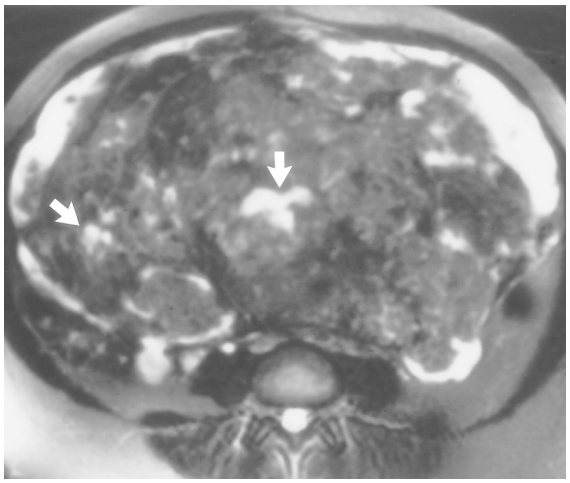
Figure 6. Cellular leiomyoma in a 28-year-old woman. **(a)** Axial T2-weighted fast SE MR image shows a well-circumscribed, heterogeneous leiomyoma on the left side of the uterine body (arrow). **(b)** Photomicrograph (original magnification, ×100; hematoxylin-eosin stain) shows a uniform cellular neoplasm composed of whorls of smooth muscle cells with little intervening collagen.

■ MR IMAGING FINDINGS

MR imaging is currently considered the most accurate imaging technique for detection and localization of leiomyomas (20,21). Because of its ability to clearly demonstrate individual tumors, MR imaging has been shown to be more sensitive than US in detection of leiomyomas (22). Unlike with MR imaging, accurate assessment of an enlarged, myomatous uterus (>140 cm^3) is not consistently possible with US because of the limited field of view (23). The capability of MR imaging for excellent demonstration of the uterine zonal anatomy enables accurate classification of individual masses as submucosal, intramural, or subserosal (21). MR imaging has been shown to be more accurate than US or hysterosalpingography for determining the presence and location of leiomyomas in infertile women prior to myomectomy (22).

Nondegenerated uterine leiomyomas have a typical appearance at MR imaging: well-circumscribed masses of homogeneously decreased signal intensity compared with that of the outer myometrium on T2-weighted images (Figs 1, 5) (21,24,25). At histologic examination, nondegenerated leiomyomas are composed of whorls of uniform smooth muscle cells with various amounts of intervening collagen (5,26). Cellular leiomyomas, which are composed of compact smooth muscle cells with little or no collagen, can have relatively higher signal intensity on T2-weighted images (Fig 6) and demonstrate enhancement on contrast-enhanced images (26).

Degenerated leiomyomas have variable appearances on T2-weighted images and contrast-enhanced images (27). Leiomyomas with hyaline or calcific degeneration have low signal intensity on T2-weighted images, an appearance similar to that of standard leiomyomas. Leiomyomas with cystic degeneration show high signal intensity on T2-weighted images, and the cystic areas do not enhance (Fig 7). Leiomyomas with



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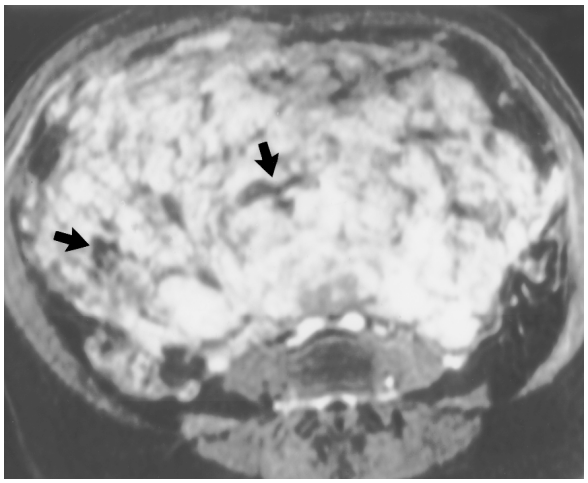

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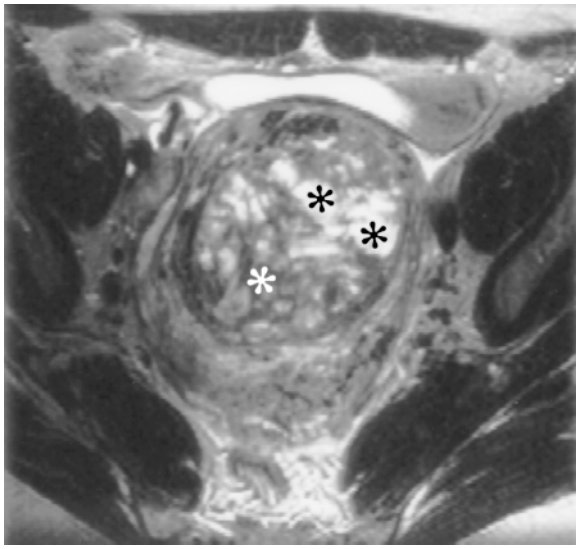

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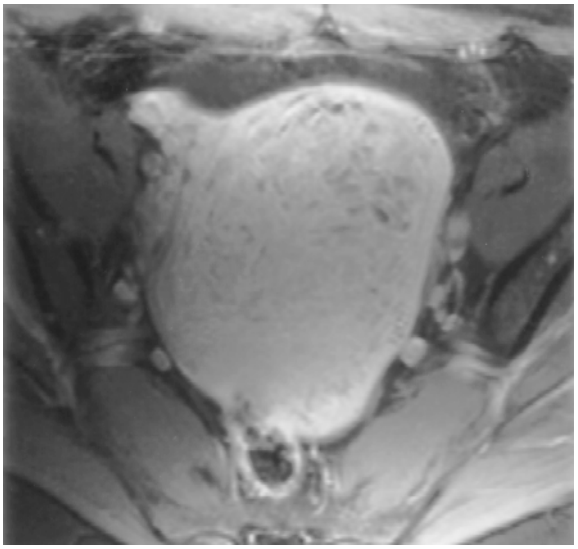

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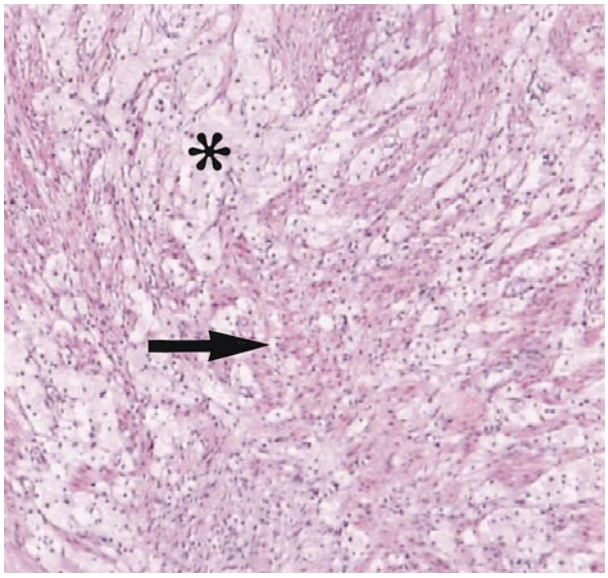

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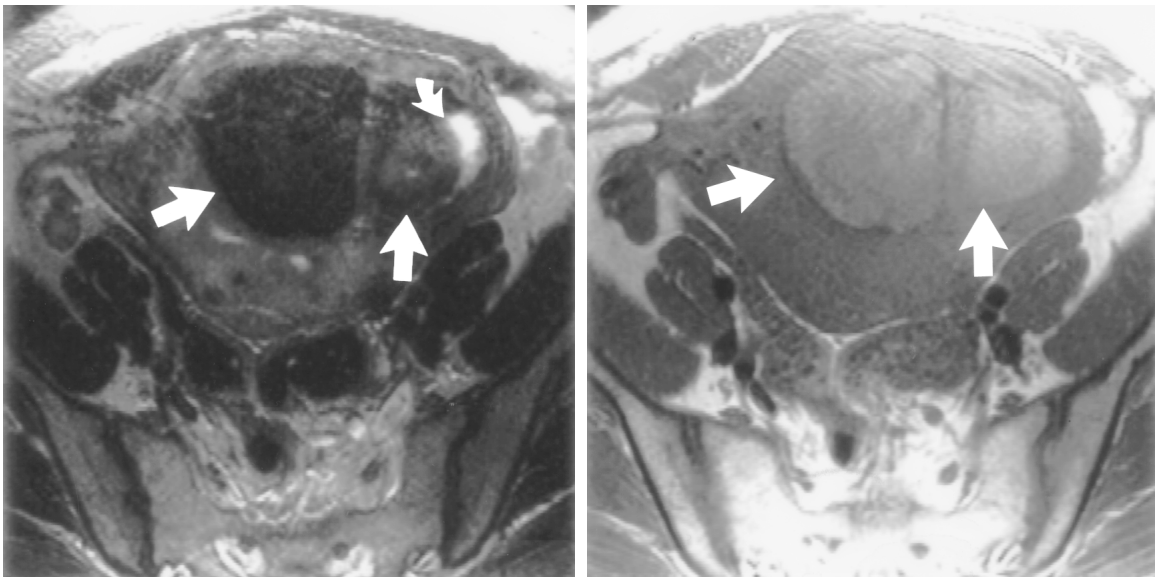

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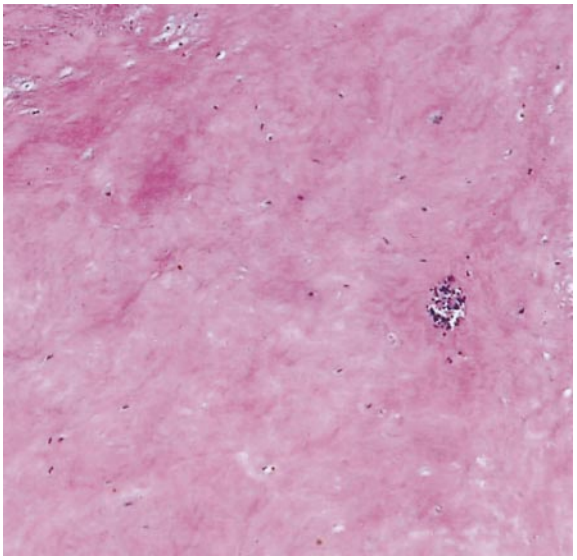


c.

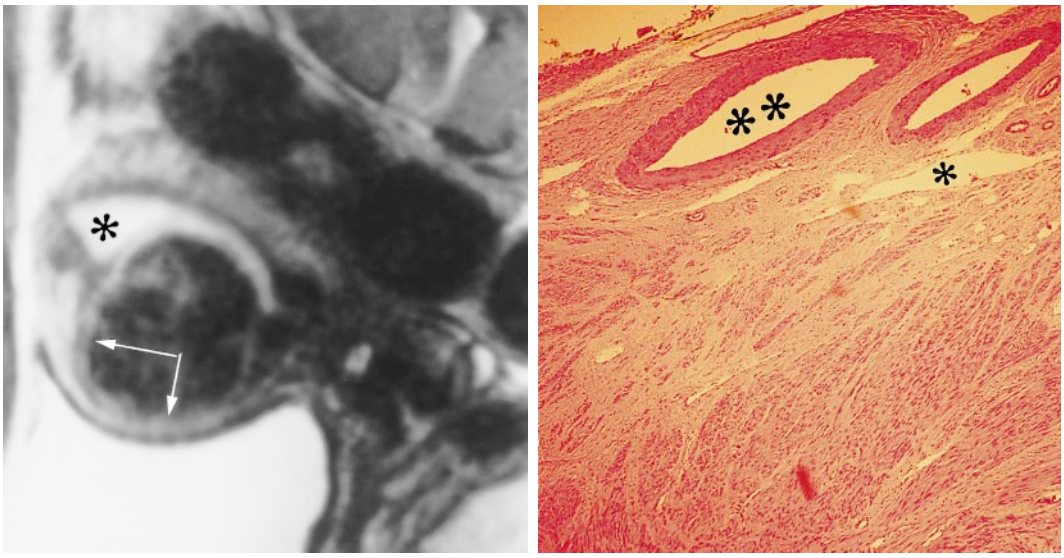
Figure 9. Leiomyomas with coagulative necrosis in a 38-year-old woman. **(a, b)** Axial T2-weighted fast SE MR image **(a)** and T1-weighted SE MR image **(b)** show two intramural leiomyomas (straight arrows), which have lower signal intensity than the myometrium on the T2-weighted image **(a)** and higher signal intensity on the T1-weighted image **(b)**. A small amount of liquefactive degeneration is present in the lateral aspect of the left-sided tumor (curved arrow). **(c)** Photomicrograph (original magnification, ×40; hematoxylin-eosin stain) of the larger myoma shows a homogeneous matrix without recognizable cells, findings that correspond to coagulative necrosis.

myxoid degeneration show very high signal intensity on T2-weighted images and enhance minimally on contrast-enhanced images (Fig 8).

Necrotic leiomyomas that have not liquefied (ie, hyaline or coagulative necrosis) have variable signal intensity on T1-weighted images and low signal intensity on T2-weighted images (Fig 9).

Leiomyomas with red degeneration may exhibit an unusual signal intensity pattern at MR imaging: peripheral or diffuse high signal intensity on T1-weighted images (Fig 3) and variable signal intensity with or without a low-signal-intensity rim on T2-weighted images (28). The high signal intensity on T1-weighted images is

Figures 7, 8. **(7)** Massive subserosal leiomyoma with cystic degeneration in a 46-year-old woman. Sagittal images (not shown) demonstrated continuity of the mass with the uterine fundus. Axial T2-weighted fast SE MR image **(a)** and corresponding contrast-enhanced fat-suppressed T1-weighted gradient-echo MR image **(b)** show a large, heterogeneous pelvic mass. Most of the mass is of low to intermediate signal intensity on the T2-weighted image **(a)**, an appearance suggestive of a leiomyoma. Several small foci of very high signal intensity on the T2-weighted image **(a)** and no enhancement on the contrast-enhanced image **(b)** represent cystic degeneration (arrows). **(8)** Leiomyoma with myxoid degeneration in a 49-year-old woman. **(a)** Axial T2-weighted fast SE MR image shows a well-circumscribed mass of the anterior uterus that has components of both low signal intensity (white *) and high signal intensity (black *) compared with that of the outer myometrium. **(b)** Contrast-enhanced fat-saturated T1-weighted gradient-echo MR image (repetition time msec/echo time msec = 500/3.3, 90° flip angle) obtained at the same level as **a** shows that some of the intratumoral tissue with high signal intensity on the T2-weighted image **(a)** enhances. The enhancement indicates that this tissue does not represent intratumoral cysts or necrosis. **(c)** Photomicrograph (original magnification, ×40; hematoxylin-eosin stain) of a myxoid leiomyoma in another patient shows loose, water-laden myxoid tissue (*), which contrasts with the denser smooth muscle bundles (arrow).



a. b.

Figure 10. Intramural-submucosal leiomyoma with peritumoral high signal intensity in a 36-year-old woman. **(a)** Sagittal T2-weighted fast SE MR image shows a well-circumscribed mass of low signal intensity within the anterior uterine body that distorts the endometrial canal (*). The mass has a thin rim of high signal intensity (arrows). **(b)** Photomicrograph (original magnification, ×20; hematoxylin-eosin stain) of the periphery of the myoma shows blood vessels (large *), lymphatic vessels (small *), and subjacent compact regions of smooth muscle.

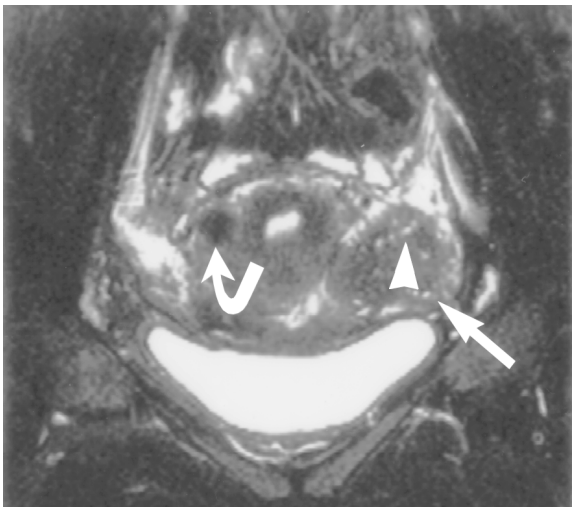
likely secondary to the proteinaceous content of the blood or the T1-shortening effects of methemoglobin (29). When high signal intensity is isolated to the rim of the leiomyoma, it has been hypothesized that the blood products are confined to thrombosed vessels that surround the tumor (28).

Some leiomyomas have a high-signal-intensity rim on T2-weighted images, which represents a pseudocapsule of dilated lymphatic vessels, dilated veins, or edema (Fig 10) (30). These histologic findings have been shown to correspond to peritumoral rim enhancement on contrast-enhanced images (31).

■ DIFFERENTIAL DIAGNOSIS

● Adenomyosis

At histopathologic analysis, adenomyosis is characterized by the presence of ectopic endometrial glands and stroma within the myometrium, which are associated with reactive hypertrophy of the surrounding myometrial smooth muscle (32). Adenomyosis most likely results from direct invasion of the myometrium by basal endometrium, although the cause of such migration is not known. Adenomyosis is most commonly a diffuse abnormality but may also occur as a focal mass, which is known as an adenomyoma (32). The clinical presentation may include dysmenorrhea and menorrhagia, a presentation similar to that of uterine leiomyomas. At MR imaging, the diffuse form of adenomyosis appears as a thickened junctional zone (inner myometrium) on T2-weighted images (33,34). Although various normal ranges have been suggested, a junctional zone 12 mm thick or thicker is highly predictive of adenomyosis (35). The low signal intensity of adenomyosis on T2-weighted images is due to the reactive, dense smooth muscle hypertrophy that surrounds the imbedded endometrial glands (Fig 11) (36). Small foci of high signal intensity on T2-weighted images represent the endometrial glands (Fig 11). Some of these



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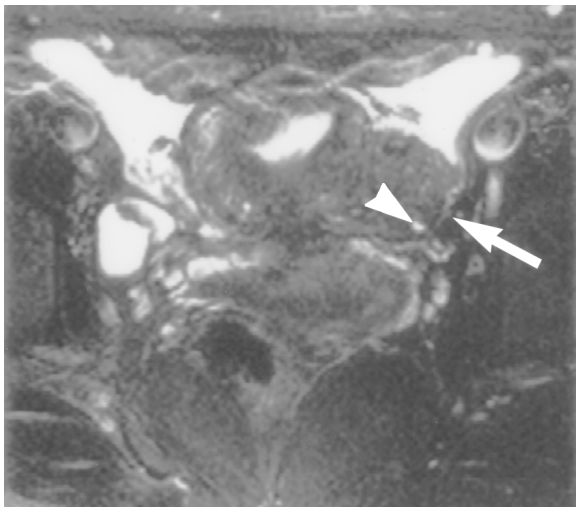

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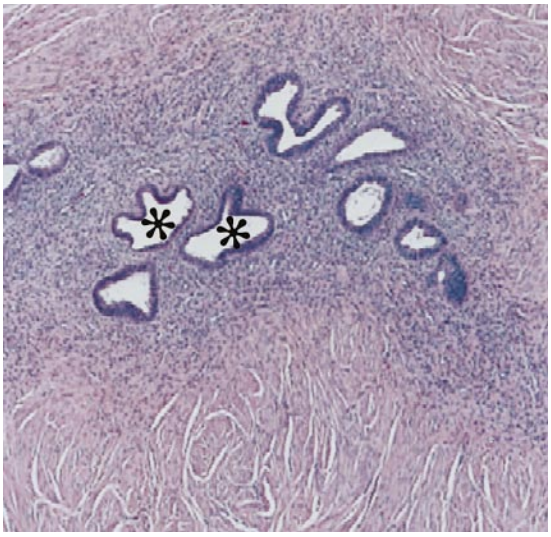


c.

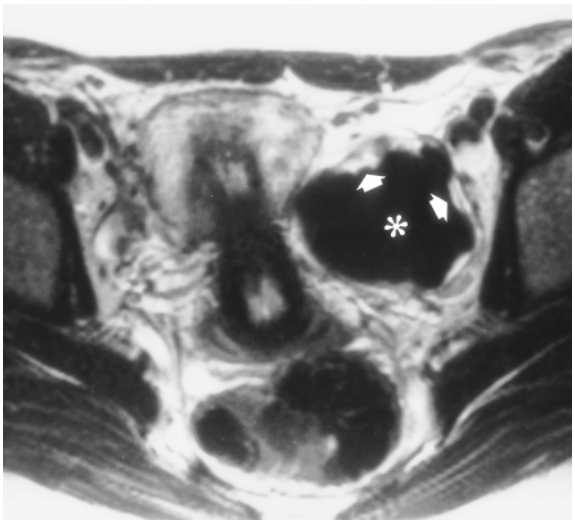
Figure 11. Focal adenomyosis mimicking a subserosal leiomyoma in a 42-year-old woman. **(a, b)** Axial **(a)** and coronal **(b)** T2-weighted fast SE MR images show a poorly marginated, heterogeneous mass (straight arrow) with punctate foci of high signal intensity (arrowhead) adjacent to the left side of the uterine body. There is mild thickening of the inner myometrium, a finding suggestive of adenomyosis. There is also a small, right-sided intramural mass, an appearance typical of a small leiomyoma (curved arrow in **a**). **(c)** Photomicrograph (original magnification, ×40; hematoxylin-eosin stain) of the resected adnexal mass shows several islands of ectopic endometrial glands (*) surrounded by whorled hypertrophic smooth muscle.

ectopic foci of endometrium also have high signal intensity on T1-weighted images, a finding that corresponds to hemorrhage (36,37).

The distinction between adenomyosis and leiomyomas is of clinical importance because, unlike leiomyomas, which may be treated with myomectomy, adenomyosis can be extirpated only with hysterectomy. MR imaging allows easy differentiation between diffuse adenomyosis and leiomyoma (37). In its focal form, adenomyosis appears as an ill-defined, poorly marginated area of low signal intensity within the myometrium on T2-weighted images (Fig 11) (33,36), whereas leiomyomas often appear as well-circumscribed masses.

• Solid Adnexal Mass

MR imaging allows detection and characterization of pedunculated leiomyomas and differentiation of such leiomyomas from other types of



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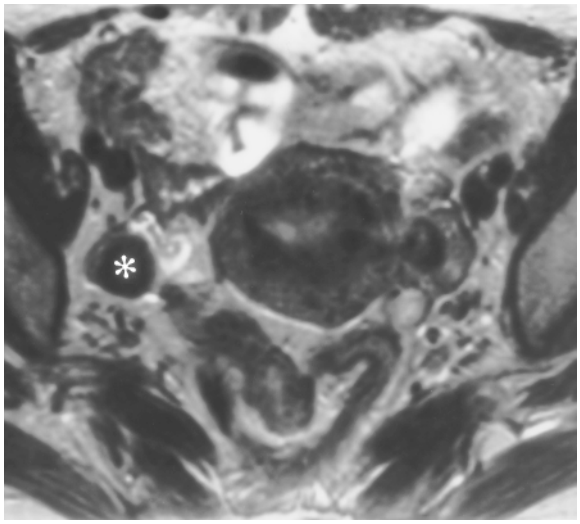

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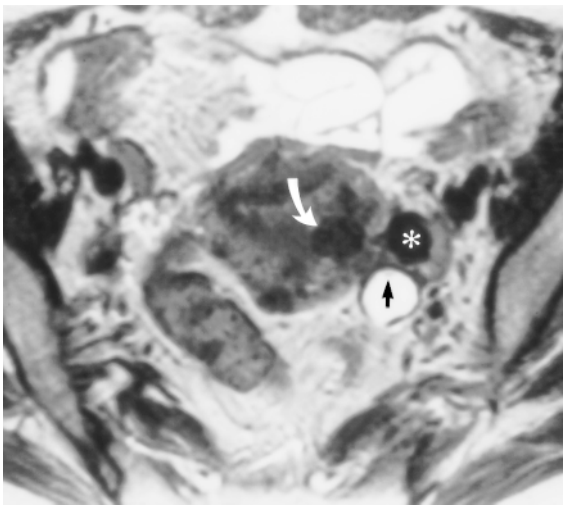

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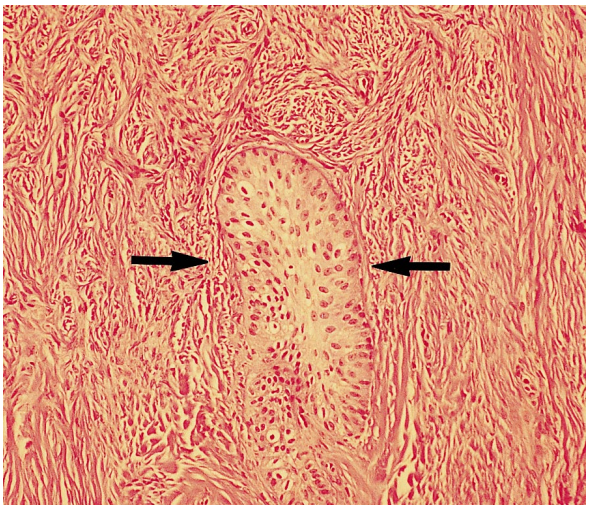
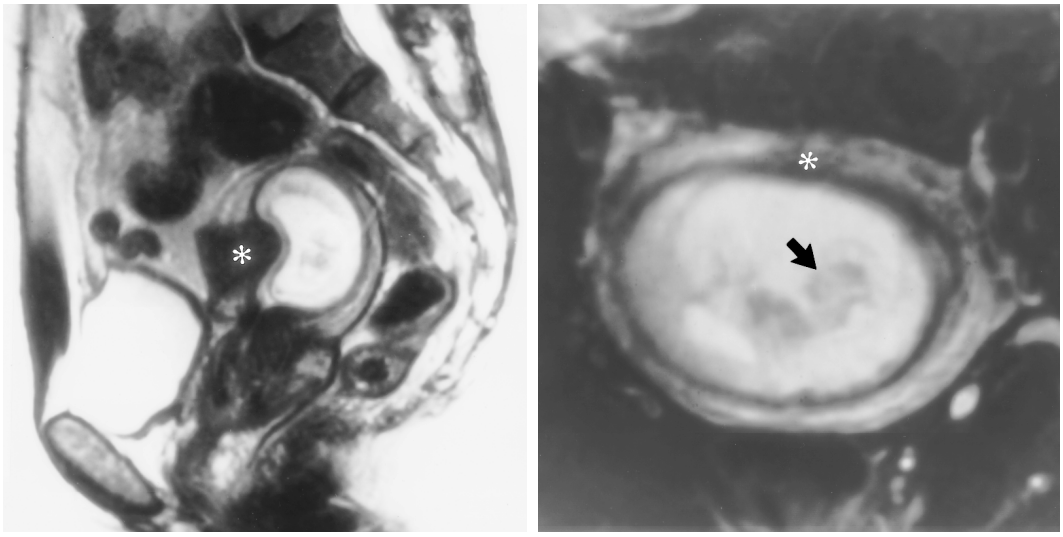


13c.

Figures 12, 13. **(12)** Left ovarian fibroma in a 41-year-old woman with pelvic pain and a palpable pelvic mass. Axial T2-weighted fast SE MR image shows a 5-cm-diameter adnexal mass with very low signal intensity (*) surrounded by attenuated ovarian stroma and follicles (arrows). The mass is separate from the uterus. Because MR imaging demonstrated that the mass was contained within the ovary, a diagnosis of leiomyoma of the broad ligament could be excluded. Histologic sections (not shown) revealed dense fibrous tissue admixed with foci of calcium. Ovarian fibromas contain focal or diffuse calcium in less than 10% of cases (43–45); along with fibrous tissue, calcium can result in low signal intensity on T2-weighted images. **(13)** Bilateral Brenner tumors and a left-sided serous cystadenoma with papillary projections in a 51-year-old woman. **(a, b)** Consecutive axial T2-weighted fast SE MR images (**a** obtained at a higher level than **b**) show bilateral adnexal masses (*) with lower signal intensity than an adjacent intramural-submucosal leiomyoma (curved arrow). There is an additional left adnexal mass with a thickened posterior wall and a small papillary projection along the anterior wall (straight arrow). The intraovarian location of this lesion and the difference in signal intensity between this lesion and the leiomyoma suggest a diagnosis of a fibrous adnexal neoplasm. Brenner tumors can be bilateral and are associated with other ovarian neoplasms in 30% of cases (42). **(c)** Photomicrograph (original magnification, ×40; hematoxylin-eosin stain) of the solid left adnexal mass shows a focus of transitional cells (arrows) surrounded by reactive fibrous tissue. The nests of transitional cells are too small to be depicted as foci of intratumoral high signal intensity on T2-weighted images.



a. b.

Figure 14. Focal myometrial contraction mimicking an intramural leiomyoma in a 38-year-old pregnant woman. **(a)** Sagittal T2-weighted fast SE MR image shows a well-circumscribed mass of low signal intensity within the anterior uterine wall (*). **(b)** Axial T2-weighted fast SE MR image obtained 20 minutes later shows almost complete resolution of the mass (*), thus allowing exclusion of a diagnosis of leiomyoma. An embryo is shown in the sagittal plane (arrow).

adnexal masses. If MR imaging can demonstrate continuity of an adnexal mass with the adjacent myometrium, then a diagnosis of leiomyoma can be established (Fig 1) (25,38,39). The ability of MR imaging to demonstrate normal ovaries, even in the presence of an enlarged, myomatous uterus, may aid in determining the origin of pelvic masses by excluding a diagnosis of ovarian neoplasm (23). Ovarian fibromas (40,41) and Brenner tumors (42) are benign ovarian neoplasms that have a large fibrous component and can have signal intensity similar to that of a pedunculated leiomyoma. MR imaging can show fibromas and Brenner tumors surrounded by ovarian stroma and follicles, thus establishing the ovarian origin of the mass and excluding a diagnosis of leiomyoma (Figs 12, 13). Differentiation between leiomyomas and adnexal masses is particularly important in pregnant patients because a confident diagnosis of a uterine leiomyoma may eliminate the need for surgery during pregnancy (46).

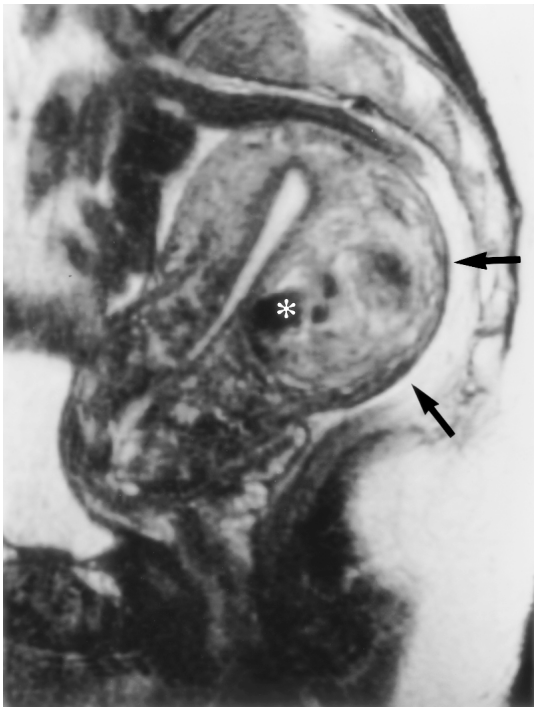
• Focal Myometrial Contraction

Uterine contractions can appear as a myometrial mass of low signal intensity on T2-weighted images and may simulate leiomyomas or focal adenomyosis at MR imaging. Because the contractions are transient, resolution of the mass at subsequent imaging allows the diagnosis to be established (Fig 14) (47,48).

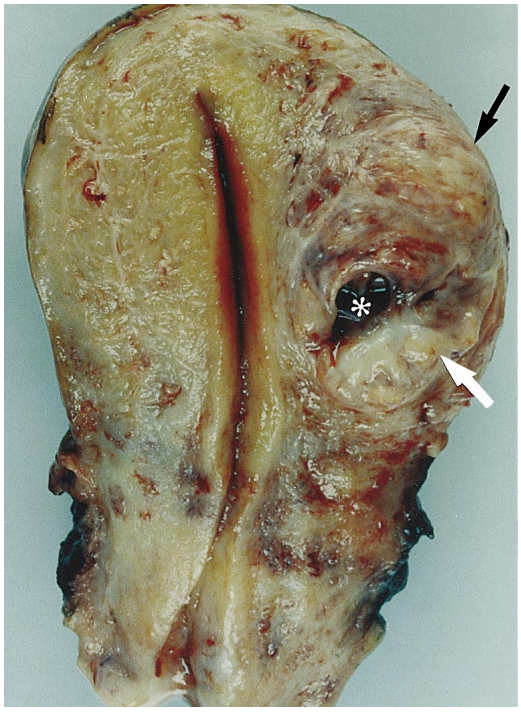
• Uterine Leiomyosarcoma

Leiomyosarcoma may arise in a previously existing benign leiomyoma (sarcomatous transformation) or independently from the smooth muscle cells of the myometrium. Although it has been suggested that an irregular margin of a uterine leiomyoma at MR imaging is suggestive of sarcomatous transformation (Fig 15) (50), the

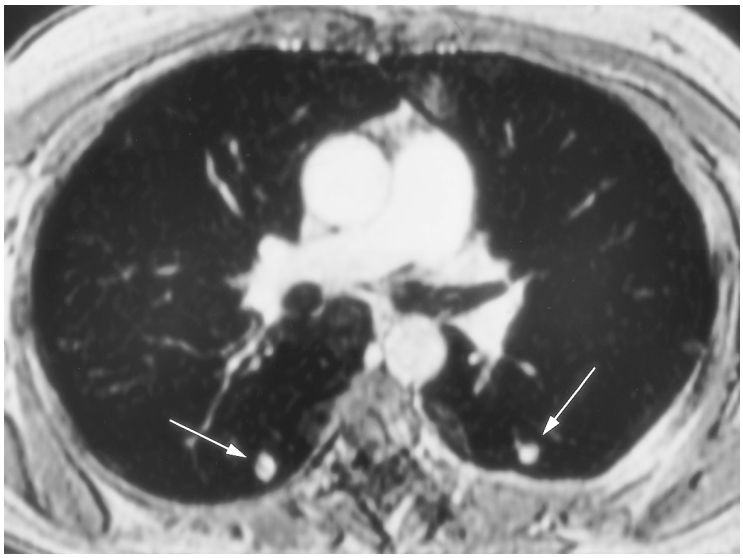
Figure 15. Metastatic uterine leiomyosarcoma in a 43-year-old woman. **(a)** Sagittal T2-weighted fast SE MR image shows a poorly marginated mass of the posterior uterine body (arrows). The region of low signal intensity in the anterior part of the mass (*) represents high-volume flow within a draining vein. **(b)** Contrast-enhanced axial T1-weighted spoiled gradient-echo MR image shows bilateral pulmonary nodules (arrows). The lungs and liver are the most common sites of metastatic spread of uterine leiomyosarcoma (6,49). **(c)** Photograph of the cut specimen shows good MR imaging–histopathologic correlation of the infiltrating sarcoma (arrows). * = draining vein.



a.



c.



b.

specificity of this finding has not been established. The ability of MR imaging to allow differentiation of cellular or degenerated leiomyoma from leiomyosarcoma of the uterus has not been assessed, to our knowledge. The diagnosis of leiomyosarcoma is often first established by a pathologist after surgical removal of a presumed benign uterine mass (6,51). A diagnosis of leiomyosarcoma is established histologically by noting the presence of infiltrative margins, nuclear atypia, and increased mitotic figures (12).

■ TREATMENT

Approximately 80% of leiomyomas are asymptomatic and therefore require no treatment (52). For patients with symptoms, either medical or surgical treatment may be indicated. In the past, gynecologic practice held that surgical intervention is necessary if the size of the uterus exceeds that at 12 weeks gestation regardless of the presence or absence of symptoms (19). The reasons cited include the inability to assess the ovaries adequately with physical examination and the increased risk of future surgical treatment if uterine growth continued. Currently, prophylactic interventions are not performed for two reasons. First, US and MR imaging allow evaluation of the adnexa in the presence of a myomatous uterus. Second, with current surgical techniques, there is no increase in morbidity among women with an enlarged uterus who undergo hysterectomy (12,53,54).

● Traditional Surgery

Hysterectomy.—Hysterectomy has traditionally been the primary treatment for symptomatic leiomyoma (9). Leiomyomas are the most frequent nonmalignant indication for hysterectomy in the United States (3). Hysterectomy should be reserved for women who have completed childbearing and no longer wish to preserve the uterus. The surgery can be performed via the vaginal or abdominal route. In selected cases, the uterus may be removed with a laparoscopic approach.

Myomectomy.—Myomectomy, enucleation of a leiomyoma with preservation of the uterus, is indicated in women with a history of second-trimester fetal loss, anemia secondary to hypermenorrhea, or pelvic pain (55). Abdominal myomectomy has been associated with more significant blood loss and higher morbidity than hysterectomy. However, with the recent improvements in surgical technique, the morbidity of myomectomy is now comparable with that of hysterectomy (56,57). The risk of recurrence after myomectomy has been estimated to be 27% after 10 years (58).

● New Surgical Interventions

Recent developments in surgical endoscopy have, in selected cases, allowed myomectomy to be performed with minimally invasive surgical procedures. These include hysteroscopic myomectomy, laparoscopic myomectomy, and laparoscopic myoma coagulation. These procedures offer several advantages, including shorter hospitalization, more rapid recovery, and cost savings per patient in hospital and surgical fees (59).

Hysteroscopic Myomectomy.—Hysteroscopic myomectomy is a potential treatment option in women with symptomatic submucosal or submucosal-intramural leiomyomas (14,52). In the case of a large submucosal leiomyoma with predominant intramural extension, two-step surgical hysteroscopy has been proposed (60). Laparoscopy can be performed simultaneously to reduce the possibility of uterine perforation. To guide therapy, MR imaging reports should always include the depth of normal myometrium present peripheral to a submucosal or intramural leiomyoma. In women with leiomyoma-associated infertility, a postprocedural pregnancy rate of almost 60% has been reported (61). Menorrhagia or dysmenorrhea resolved in the majority of women after submucosal myomectomy was performed for menstrual abnormalities (14).

Laparoscopic Myomectomy.—Laparoscopic myomectomy is especially useful in cases of pedunculated subserosal leiomyomas (62). Relative contraindications are somewhat arbitrary; in one surgeon's opinion, they include a leiomyoma larger than 7 cm in diameter, a leiomyoma adjacent to the uterine artery, or a leiomyoma near the tubal cornu if preservation of fertility is desired (52). Removal of the leiomyoma from the abdominal cavity is the most time-consuming part of this procedure, and the introduction of electromechanical morcellation may result in significant time savings (63). The late complications of uterine dehiscence or adhesion formation have not been reported (55).

Laparoscopic Myoma Coagulation.—Laparoscopic myoma coagulation (myolysis) is accomplished with a neodymium:yttrium-aluminum-garnet laser or bipolar needle electrodes, which may produce thermal injury resulting in protein denaturation, vascular destruction, and tumor degeneration. These effects lead to shrinkage of leiomyomas and symptomatic relief in many women. Laparoscopic myoma coagulation appears to be effective without regrowth of leiomyomas. This procedure may be associated with significant adhesion formation; however, recent experience indicates that there is minimal postoperative adhesion formation when bipolar needle electrodes are used (64).

• Medical Treatment

Gonadotropin-releasing Hormone Analogs.—Recently, therapy with gonadotropin-releasing hormone (GnRH) analogs has been advocated in the conservative treatment of various estrogen-dependent tumors, such as uterine leiomyomas and endometriosis. By inhibiting normal pituitary secretion of gonadotropins, GnRH analogs can induce a reversible hypoestrogenic state, resulting in amenorrhea and a reduction in the size of hormone-responsive leiomyomas. The maximum reduction is usually achieved with 12 weeks of GnRH analog treatment. However, after cessation of treatment, there is rapid regrowth of the tumor (65–67).

Use of GnRH analogs has been limited because of the potential risks of development of osteoporosis and other symptoms related to a prolonged hypoestrogenic state. Short-term therapy may be used preoperatively in the following situations: hysterectomy (68), myomectomy in women with a large uterus (>600 cm^3) (69), or new minimally invasive procedures, including hysteroscopic myomectomy (70). Reduction of tumor size and vascularity secondary to a hypoestrogenic state may facilitate surgery and decrease intraoperative blood loss. In patients with anemia secondary to hypermenorrhea, GnRH analog therapy may allow recovery of normal hemoglobin levels before surgery, thus minimizing the need for transfusion or allowing autologous blood donation (71,72). Short-term GnRH analog therapy may also be indicated in perimenopausal women in whom permanent regression of leiomyomas may be expected after menopause.

Uterine Artery Embolization.—Uterine artery embolization is a promising new method of treating symptomatic leiomyomas. In this procedure, both uterine arteries are selectively catheterized from a femoral artery approach and subsequently embolized with polyvinyl alcohol particles or coils. Uterine artery embolization may result in shrinkage of the uterus and leiomyomas, along with relief of menorrhagia and symptoms due to local mass effect (73). As a percutaneous interventional technique, this procedure may offer the advantages of avoidance of surgical risks, potential preservation of fertility, and shorter hospitalization (74,75).

• Role of MR Imaging in Treatment

Despite its relatively high cost, MR imaging is a noninvasive procedure that allows the diagnosis of leiomyomas to be established with a great degree of confidence and affects patient treatment by reducing the number of unnecessary surgeries. This reduction presumably may lead to a considerable reduction in health care expenditures (76).

MR imaging can assist in preoperative planning for myomectomy by enabling accurate detection and localization of individual tumors. Conditions that mimic leiomyomas at physical examination and US can be characterized with MR imaging (39), the results of which may change or obviate planned therapies. Preoperative classification of leiomyomas may be of clinical significance because submucosal and submucosal-intramural leiomyomas may be resected hysteroscopically, whereas laparoscopic or transabdominal myomectomy is considered for intramural

or subserosal leiomyomas. Inadvertent uterine incision and entry into the endometrial cavity can be minimized by preprocedural demonstration of the leiomyoma relative to the anterior or posterior wall of the uterus, thus resulting in decreased formation of postoperative adhesions and preservation of fertility. Direct visualization of leiomyomas with respect to the uterine zonal anatomy is important in determining whether sufficient myometrium will remain after myomectomy so that the childbearing function can be preserved (22). If hysteroscopic resection is being considered for large submucosal leiomyomas with intramural extension, the depth of extension into the myometrium may be precisely evaluated with MR imaging, thus minimizing the risk of uterine perforation. MR imaging can demonstrate postprocedural complications such as hematoma, abscess, fistula, uterine rupture, and peritoneal inclusion cyst (Fig 5).

MR imaging enables quantitative monitoring of GnRH analog therapy in patients with leiomyomas. Change in the size of individual leiomyomas, as well as of the uterus, can be assessed with MR imaging (77,78). GnRH analog therapy effectively reduces the volume of cellular leiomyomas but is less successful in shrinking myomas with hyaline or cystic degeneration. Contrast-enhanced MR imaging enables differentiation between these types of leiomyomas: Cellular leiomyomas show diffuse enhancement on early dynamic images, whereas degenerated leiomyomas show minimal or irregular delayed enhancement (26).

MR imaging may be helpful in patient selection for and guidance of uterine artery embolization. Three-dimensional contrast-enhanced MR arteriography can show the uterine arteries and provide a "road map" prior to embolization. One preliminary study has suggested that hemorrhagic leiomyomas (ie, those with very high signal intensity on T1-weighted images) do not shrink after embolization (79). MR imaging can be used to monitor the results of embolization by demonstrating the degree of shrinkage and loss of enhancement of the leiomyomas (80).

■ SUMMARY

This article summarizes the histopathologic features, MR imaging findings, differential diagnosis, and treatment of uterine leiomyomas. MR imaging allows detection, localization, and characterization of uterine leiomyomas and exclusion of other causes of uterine and adnexal masses in the female pelvis.

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