Magnetic resonance (MR) imaging has extended the usefulness of imaging in evaluation of pelvic disorders associated with female infertility. The causes of female infertility include ovulatory disorders (ie, pituitary adenoma and polycystic ovarian syndrome), disorders of the fallopian tubes (ie, hydrosalpinx and pelvic inflammatory disease), uterine disorders (ie, müllerian duct anomaly, adenomyosis, and leiomyoma), and pelvic endometriosis. Although laparoscopy, hysteroscopy, hysterosalpingography, and transvaginal ultrasonography are the most effective techniques for evaluation of pelvic disorders related to female infertility, MR imaging is used in a variety of clinical settings in diagnosis, treatment, and management. The applications of MR imaging include evaluation of the functioning uterus and ovaries, visualization of pituitary adenomas, differentiation of müllerian duct anomalies, and accurate noninvasive diagnosis of adenomyosis, leiomyoma, and endometriosis. In addition, MR imaging helps predict the outcome of conservative treatment for adenomyosis, leiomyoma, and endometriosis and may lead to selection of better treatment plans and management. Finally, MR imaging may serve as an adjunct to diagnostic laparoscopy and hysterosalpingography in patients with hydrosalpinx, peritubal adhesions, or pelvic adhesions related to endometriosis.
Introduction
Infertility is defined as 1 year of unprotected intercourse that does not result in pregnancy (1,2). In recent years, demand for infertility services and treatment of infertility have increased. Laparoscopy, hysteroscopy, and hysterosalpingography are the most effective techniques currently used to evaluate female pelvic disorders related to infertility. Although transvaginal ultrasonography (US) has been the foremost imaging modality for assessing the female genital tract, magnetic resonance (MR) imaging has also been used for over 10 years to evaluate problems associated with female infertility (3). For example, MR imaging is well known to provide accurate information for differentiation of congenital uterine anomalies and detection and localization of uterine leiomyomas (3,4).

One of the advantages of MR imaging is the nonuse of ionizing radiation, which is an important consideration in women of reproductive age. Another advantage is that MR imaging is less invasive and less observer dependent than the classic imaging techniques. Furthermore, recent advances in MR imaging with the phased-array coil have created further imaging possibilities, resulting in excellent spatial and tissue contrast resolution, multiplanar capability, and fast techniques. The disadvantages of MR imaging are relatively high cost and long examination time; it is contraindicated in patients with pacemakers, cochlear implants, and certain metallic objects.

In this article, we provide an overview of the capabilities and potential of MR imaging for diagnosis, treatment, and management of female infertility. Of the various causes of female infertility, ovulatory disorders (ie, pituitary tumor and polycystic ovarian syndrome), disorders of the fallopian tubes (ie, hydrosalpinx and pelvic inflammatory disease), uterine disorders (ie, müllerian duct anomaly, adenomyosis, and leiomyoma), and pelvic endometriosis are specifically discussed.

MR Imaging Technique
It is recommended that an antiperistaltic (eg, 1 U.S. Pharmacopeia unit of glucagon or 20 mg of scopolamine butylbromide) be administered intramuscularly or intravenously before examination.

MR imaging was performed with a 1.5-T unit (Vision and Symphony, Siemens Medical Systems, Erlangen, Germany; Signa, GE Medical Systems, Milwaukee, Wis) with a phased-array coil. T2-weighted fast spin-echo images (repetition time msec/echo time [effective] msec = 3,000–5,000/80–120, echo train length of eight to 16, two signals acquired) were obtained in the sagittal and axial planes. T2-weighted images provide the most detailed information about the uterine zonal anatomy (see the Normal Anatomy section for details). Images obtained in the coronal or perpendicular planes relative to the long uterine axis may be useful adjuncts for assessment of the uterine cavity.

T1-weighted spin-echo images (repetition time/echo time = 330–600/10–20, one to two signals acquired) were obtained in the axial or sagittal plane. T1-weighted images help characterize hemorrhage since extracellular methemoglobin causes T1 shortening. In addition, T1-weighted images obtained with a selective chemical fat-suppression technique are especially useful for detecting hemorrhagic adnexal masses (5–7) and should be obtained routinely in patients with infertility. There is no need to use intravenous contrast material (0.1 mmol/kg of gadolinium chelate) for routine infertility assessment. However, contrast material–enhanced studies are useful in selected cases, such as pelvic inflammatory disease, evaluation of vascularity in uterine leiomyoma, and detection of malignancy in an adnexal mass.

Other parameters included matrix size of 192–256 × 256–512, field of view appropriate to body habitus (22–26 cm), and 5–7-mm section thickness with an intersection gap of 20%.

Normal Anatomy
Reproductive-Age Women
Uterine zonal anatomy is exquisitely demonstrated on T2-weighted images (Fig 1). The endometrium has high signal intensity. The junctional zone, which corresponds to the innermost myometrium, appears as a band of low signal intensity. The peripheral myometrium has intermediate signal intensity that is higher than that of the striated muscle. The widths of the endometrium and junctional zone vary during the menstrual cycle; they are widest and most clearly visible in the late secretory phase. The uterine corpus is larger than the cervix throughout the reproductive-age period. In general, the corpus measures 6–8 cm in length by 5–6 cm in the transverse and anteroposterior dimensions (8).

The cervix also shows zonal architecture on T2-weighted images. The central area of high signal intensity represents epithelium and mucus, the middle area of low signal intensity represents fibrous stroma, and the outer area of medium sig-
Normal fallopian tubes are not routinely imaged because of their small diameter and tortuous course.

On T1-weighted images, the normal pelvic musculature and viscera demonstrate homogeneous low to medium signal intensity.

**Postmenopausal Women**

After menopause, the uterine corpus becomes smaller and approximately equal in size to the cervix. It measures 4–6 cm in length by 3–5 cm in the transverse and anteroposterior dimensions (8). The zonal anatomy is indistinct when women are not receiving exogenous hormones (Fig 2). Although the cervix does not atrophy significantly, the peripheral myometrium is usually unclear. Ovaries may be undetected at MR imaging since they seldom have follicles.

When a woman of reproductive age has a small uterus with indistinct zonal anatomy or undetectable ovaries, as seen in postmenopausal women, the possibility of a disorder related to insufficient hormone secretion should be considered (Fig 3).

**Ovulatory Dysfunction**

Disorders affecting ovulation account for 30%–40% of cases of female infertility (1). Measures of ovarian function include measurement of basal body temperature, endometrial biopsy, measurement of serum progesterone level, endocrine tests, and monitoring of follicle growth with US. Thus, the role of MR imaging is limited to assessment of whether a pituitary adenoma is present.
Pituitary Adenoma

Prolactin-producing hypophyseal adenoma (prolactinoma) is the most common functional pituitary adenoma. Its prevalence peaks in women between 20 and 30 years of age. Hyperprolactinemia can be a cause of infertility and is associated with diminished gonadotropin secretion, secondary amenorrhea, and galactorrhea. The patient should first be examined for drug-induced hyperprolactinemia before any infertility work-up is initiated. For example, antidepressants, cimetidine, dopamine antagonists, reserpine, sulpiride, verapamil, methyldopa, and estrogen therapy are known to interfere with prolactin secretion.

When a patient is suspected to have hyperprolactinemia not associated with drugs, MR imaging is the foremost and only imaging technique that can depict a pituitary microadenoma (<1 cm) (Fig 4). Most microadenomas have lower signal intensity than the normal pituitary gland on T1-weighted images. A convex outline of the pituitary gland or deviation of the pituitary stalk can also be detected. Dynamic study with intravenous bolus injection of contrast medium is the preferred technique for assessing microadenomas, as it allows excellent delineation between the tumor and the normal pituitary gland. In the dynamic study, the normal pituitary gland and stalk show strong enhancement in the early phase of dynamic imaging, whereas microadenomas show relatively weak enhancement (9,10).

Macroadenomas (>1 cm) occupy the pituitary fossa and may cause visual abnormalities when they put pressure on the optic chiasm. Macroadenomas also tend to invade the cavernous sinus and erode the bony floor. The extent of the tumor can be determined by means of contrast-enhanced MR imaging (Fig 5).

Polycystic Ovarian Syndrome

The diagnosis of polycystic ovarian syndrome is based on hormone imbalance and laboratory findings. Patients with this syndrome often demonstrate an abnormal ratio of luteinizing hormone to follicle-stimulating hormone. The clinical manifestations include hirsutism, anovulation, and infertility. At gross pathologic analysis, the morphologic findings in the ovaries consist of multiple small follicular cysts surrounded by thickened and luteinized theca.

Monitoring of follicle growth is usually performed with US, and the usefulness of MR imaging is not proved. On T2-weighted images, polycystic ovarian syndrome appears as multiple tiny,
hyperintense peripheral cysts with hypointense central stroma (Fig 6) (11,12). However, MR imaging findings are nonspecific and serve only as supportive evidence of polycystic ovarian syndrome. Multiple tiny, hyperintense peripheral cysts have been seen in patients with anovulation, medication-stimulated ovulation, or vaginal agenesis (12).

**Disorders of the Fallopian Tubes**

Disorders of the fallopian tubes are a common cause of female infertility, accounting for 30%–40% of cases (1). Tubal disorders include damage to or obstruction of the fallopian tube and peritubal adhesions. Hysterosalpingography is the mainstay of evaluation of tubal patency, whereas laparoscopy is preferred for assessment of the peritubal environment. MR imaging aids in noninvasive assessment of tubal dilatation and peritubal disease. Dilated fallopian tubes manifest as fluid-filled ducts, which appear as retort-, sausage-, C-, or S-shaped cystic masses at MR imaging (Fig 7). Thin, longitudinally oriented folds along the interior of the tube represent incompletely effaced mucosal or submucosal plicae (13).
Pelvic inflammatory disease is one of the most common causes of tubal or peritubal damage. The diagnosis is usually based on clinical or transvaginal US findings. MR imaging can also be helpful in assessment of pelvic inflammatory disease by showing tubo-ovarian abscesses, dilated fluid-filled tubes, and free pelvic fluid (Fig 8) (14). On T1-weighted images, a high-signal-intensity rim in the innermost portion of a tubo-ovarian abscess has been reported. This rim shows marked enhancement on postcontrast images and is believed to correspond to granulation tissue admixed with hemorrhage (15).

Endometriosis also causes peritubal adhesions. As discussed later, transvaginal US is the preferred imaging technique for endometriosis and demonstrates high specificity, but MR imaging is more sensitive. Moreover, dilated fallopian tubes with high signal intensity on T1-weighted images, which correspond to hematosalpinx, reportedly correlate with one of the effects of endometriosis (Fig 9) (13). Nevertheless, MR imaging is as yet of little use in assessment of adhesions.

Uterine Disorders

Müllerian Duct Anomalies

If other causes of infertility are excluded, uterine anomalies may be suggested as a cause of infertility. On the other hand, unknown numbers of uterine anomalies may escape detection since reproductive ability is often unaffected or not noticeably affected (16).

Müllerian duct anomalies are classified according to the system established by the American Fertility Society (17) (Fig 10). MR imaging is useful for documenting uterine morphology. As mentioned earlier, coronal or perpendicular planes relative to the long uterine axis may provide useful information for assessment of the uterine cavity. The kidney should also be evaluated, since renal anomalies (ie, agenesis or ectopia) frequently accompany müllerian duct anomalies because of the close embryogenic relationship.

Class I: Hypoplasia or Agenesis.—Failure of normal development of the müllerian ducts causes uterine agenesis or hypoplasia. Patients present with primary amenorrhea in adolescence. In these cases, disorders of sexual differentiation should be excluded (18,19). It is necessary to document whether a functioning uterine corpus and cervix are present. For instance, a functioning uterine corpus and cervix could predict future fertility, but a functioning corpus without a cervix requires hysterectomy to prevent endometriosis.

Mayer-Rokitansky-Küster-Hauser syndrome is a combined anomaly that belongs to this entity. The typical form of this syndrome is characterized by congenital absence of the uterus and upper vagina. The ovaries and fallopian tubes are usually normal. The atypical form of the syndrome includes associated abnormalities of the ovaries and fallopian tubes and renal anomalies (Fig 11) (20).
Figure 9. Hematosalpinx associated with endometriosis. Sagittal fat-suppressed T1-weighted (a) and T2-weighted (b) images show a dilated fallopian tube with a folded appearance (arrow). It has high signal intensity on both images and was diagnosed as a hematosalpinx. On the fat-suppressed T1-weighted image (a), a small endometrioma is seen as a tiny hyperintense lesion (arrowhead) on the surface of the hematosalpinx. B = bladder. (Reprinted, with permission, from reference 50.)

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<th>I. Hypoplasia/Agenesis</th>
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Figure 10. American Fertility Society classification of müllerian duct anomalies. DES = diethylstilbestrol, * = uterus may be normal or take a variety of abnormal forms, ** = may have two distinct cervixes. (Reprinted, with permission, from reference 17.)

<table>
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<th>V. Septate</th>
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**Class II: Unicornuate.**—Agenesis of a unilateral müllerian duct causes a single, so-called banana-shaped uterus with a single fallopian tube. On T2-weighted images, normal zonal anatomy is observed in a small uterus (Fig 12).

Some patients have a rudimentary horn on the contralateral side. When the rudimentary horn is noncommunicating, endometrial tissue expelled retrogradely through the fallopian tube during menstruation results in an increased frequency of endometriosis (21). This makes surgical resection of the horn necessary.

Spontaneous abortion and premature labor may occur in pregnancies with a unicornate uterus, and the poorest fetal survival among all uterine anomalies has been reported (16).

**Class III: Didelphys.**—Complete failure of fusion of the two müllerian ducts results in two complete uteri, each with its own cervix. T2-weighted images demonstrate two uterine horns or bodies with normal zonal anatomy (Fig 13). A longitudinal sagittal vaginal septum is usually, but not always, observed.

Among all uterine anomalies, uterus didelphys is associated with the highest possibility of successful pregnancy, except for arcuate uterus (16).

**Figure 11.** Mayer-Rokitansky-Küster-Hauser syndrome in a woman with primary amenorrhea. B = bladder. (a) Sagittal T2-weighted image shows uterine agenesis and absence of the vagina. (b) Coronal image obtained with true fast imaging with steady-state precession shows agenesis of the left kidney. Note the normal right ovary with follicles (arrow). Arrowheads = right kidney.

**Class IV: Bicornuate.**—Partial fusion of two müllerian ducts results in a bicornuate uterus with one cervix. The external uterine contour is concave or heart shaped, and the uterine horns are widely divergent. The MR imaging diagnostic criteria for bicornuate uterus are as follows: (a) divergent uterine horns with an intercornual distance exceeding 4 cm and (b) concavity of the fundal contour or an external fundal cleft more than 1 cm deep (Fig 14) (22).
Figure 12. Unicornuate uterus. Serial axial T2-weighted images (a obtained at a higher level than b) show a small uterus (arrow) with normal zonal anatomy. A rudimentary horn is not present. Arrowhead = right ovary.

Figure 13. Uterus didelphys with an obstructed hemivagina. (a) Axial T2-weighted image shows two separate uteri and two cervices (arrows), all of which have normal zonal anatomy. Arrowheads = ovaries. (b) Coronal T2-weighted image shows a hematocele (H) due to obstruction of the right hemivagina. (c) Contrast-enhanced computed tomographic (CT) scan shows agenesis of the right kidney. Uterus didelphys with an obstructed hemivagina is termed Wunderlich syndrome and is usually associated with ipsilateral renal agenesis. (Reprinted, with permission, from reference 50.)
Class V: Septate.—Septate uterus results from failure of resorption of a septum after complete fusion of the müllerian ducts. The septum may be a combination of both fibrous tissue and muscle. A fibrous septum is demonstrated as low signal intensity on T2-weighted images (Fig 15), whereas a septum composed of abundant muscular tissue shows intermediate signal intensity.

The external uterine contour is normally convex, flat, or minimally indented by less than 1 cm (22), in contrast to that of a bicornuate uterus. T2-weighted images taken along a “true” coronal view of the uterine body and perpendicular to the long axis of the uterus provide exact images of the uterine contour and septum. This helps in differentiation of bicornuate from septate uterus.

Most patients evaluated for repeated abortions and found to have a uterine anomaly will have a septate uterus (16). Metroplasty is a surgical procedure used for treatment of this anomaly and may enhance fetal survival, with one report indicating that 95% of patients became pregnant, 73% carried to term, and 77% delivered a liveborn baby (23).

Class VI: Arcuate.—Arcuate uterus should be considered a normal variant, with a small indentation of the fundal endometrial canal and a normal external contour. It has no effect on fertility.

Class VII: Diethylstilbestrol Related.—Diethylstilbestrol is a synthetic estrogen that was used to prevent miscarriage in the 1940s to 1970s (24). Exposure of the female fetus to diethylstilbestrol results in uterine anomalies including T-shaped uterus, irregular constrictions, and hypoplasia. At the site of constriction, localized thickening of the junctional zone is seen on T2-weighted images (22).

Diethylstilbestrol-related anomalies are associated with an increased rate of spontaneous abortions, preterm deliveries, and ectopic pregnancies.

Adenomyosis
Adenomyosis is not a common cause of infertility. The frequency of symptomatic adenomyosis peaks between the ages of 35 and 50 years, and it...
is most often found in parous women (25). However, nulligravid women are sometimes affected and experience infertility. The exact reasons for infertility in patients with adenomyosis remain unclear, although an enlarged uterus may be associated with reduced uterine or endometrial receptivity.

Both transvaginal US and MR imaging allow accurate, noninvasive diagnosis of adenomyosis. The relevant diagnostic US findings are (a) thickening and asymmetry of the anterior or posterior uterine walls and (b) a poorly defined area of decreased or increased echogenicity, heterogeneous echotexture, or a myometrial cyst. The MR imaging criteria include (a) a myometrial mass of low signal intensity with indistinct margins on both T1- and T2-weighted images and (b) diffuse or focal widening of the junctional zone on T2-weighted images. A junctional zone thickness of 12 mm or more optimizes the accuracy of MR imaging for this diagnosis (26). Punctate high-signal-intensity foci, which correspond to ectopic endometrium, are often demonstrated on T2-weighted images (Fig 16). One study found that MR imaging has higher sensitivity than transvaginal US (88% vs 53%) (26), whereas another found that MR imaging is as accurate as transvaginal US with a sensitivity of 86% and specificity of 89% (27).

Traditionally, hysterectomy has been the mainstay of treatment for adenomyosis. Medical therapy including gonadotropin-releasing hormone (GnRH) analog can be a conservative treatment option, which may provide symptomatic relief and preserve fertility. In patients with adenomyosis undergoing GnRH analog therapy, monitoring with MR imaging has demonstrated a significant decrease in junctional zone width and number of high-signal-intensity foci (28). The interface between adenomyosis and myometrium became more discrete with a concomitant reduction of the junctional zone in some cases (Fig 17).

Figure 17. Adenomyosis treated with GnRH analog. (a) Sagittal T2-weighted image obtained before treatment shows adenomyosis in the posterior myometrium (arrows) with punctate hyperintense foci. (b) Sagittal T2-weighted image obtained after GnRH analog therapy shows that the lesion (arrows) is significantly smaller. The interface between the lesion and the myometrium is more discrete. (c) Sagittal T2-weighted image obtained 1 year after the end of treatment shows that the lesion (arrows) has returned to its pretherapy appearance.
Diffuse adenomyosis with asymmetric widening of the junctional zone and punctate hyperintense foci tended to show this change, indicating the possibility of enucleating “shrunken adenomyosis” (28).

However, as with much of the treatment for uterine leiomyoma, the effect of medical therapy is not permanent because the disease course is reversed when treatment is discontinued. MR imaging clearly demonstrates the recurrent disease (Fig 17) (29).

**Leiomyoma**

Uterine leiomyoma, especially submucous leiomyoma, may be associated with pregnancy loss rather than infertility. Although leiomyoma is an infrequent cause of infertility, there may be some interference with sperm transport or implantation as a result of distortion, an increased surface area within the uterine cavity, or impingement by the leiomyoma on the endocervical canal or interstitial portion of the fallopian tube (30).

For identification of leiomyomas, transvaginal US can be a reliable method. A recent report states that transvaginal US is as effective as MR imaging for detection but that MR imaging outperforms transvaginal US in preoperative evaluation of location, number, and size of leiomyomas (31). Sonohysterography also clearly demonstrates the relationship between the endometrium and submucosal leiomyomas and thus serves as an important adjunct to transvaginal US (32). The diagnostic MR imaging finding for leiomyoma is a sharply marginated mass that typically has lower signal intensity than the myometrium on T2-weighted images (Fig 18). In addition, MR imaging is a highly accurate modality for differentiating leiomyomas from adenomyosis in cases of enlarged uterus, with a reported accuracy of 99% (33). Treatment options for leiomyoma include hysterectomy, myomectomy, medical hormonal therapy, and uterine artery embolization (UAE), whereas adenomyosis is usually treated with hysterectomy or medical hormonal therapy. For this reason, exact differentiation between leiomyoma and adenomyosis is important for patients who wish to preserve the uterus.

At MR imaging, leiomyomas can demonstrate various signal intensities depending on the type of degeneration. Hyalinization is the most common type and is seen as low signal intensity on T2-weighted images. Edema is also a common histopathologic finding and shows high signal intensity on T2-weighted images with marked enhancement. Cystic degeneration appears as distinct, round areas of low signal intensity on T1-weighted images and high signal intensity on T2-weighted images and lacks enhancement (34,35). Myxoid degeneration appears as a cystic mass filled with gelatinous material and has high signal intensity on T2-weighted images. Myxoid stroma contributes to delayed enhancement. Red
degeneration is a kind of hemorrhagic infarction; it appears as a peripheral rim of high signal intensity on T1-weighted images and of low signal intensity on T2-weighted images and completely lacks enhancement (35).

Myomectomy is a surgical procedure for patients who hope to preserve fertility. The reported rate of successful conception after myomectomy was 59.5% for patients with leiomyoma-associated infertility when there was no other apparent cause of infertility (36). A US study of uterine remodeling after myomectomy revealed a gradual decrease in uterine volume in the 6 months after the procedure, with the most remarkable change occurring in the initial 2–3 months (37). In an MR imaging study, the most remarkable uterine change occurred 1 month after myomectomy and consisted of a reduction in uterine volume and a proportionally normal zonal anatomy (38). Changes continued to be observed 6 months after the procedure. MR imaging also clearly demonstrated a postmyomectomy uterine scar, intramural hematoma, and disease recurrence (Fig 19) (38).

UAE is gaining attention as a possible treatment for symptomatic leiomyoma. It is a relatively new method, and patients who wished to maintain fertility were usually excluded from the initial studies. It appears to be effective for improving menorrhagia, pelvic pain, and pelvic pressure in 96%–100% of patients (39,40). The average reduction in volume of the uterus and leiomyomas was 34%–55% after 3–4 months of UAE (40,41).

The MR imaging findings of leiomyomas after UAE are high signal intensity on T1-weighted images and homogeneous low signal intensity on T2-weighted images. It is thought that leiomyomas become infarcted shortly after UAE and that hemorrhagic necrosis and blood breakdown products are responsible for these signal intensity changes (42,43). At contrast-enhanced imaging, the vascularity of leiomyomas is seen to significantly diminish after UAE (41,43), although...
myometrial perfusion is maintained (Fig 20). In studies of UAE, 150–250-μm-diameter polyvinyl alcohol particles became lodged in arteries with a diameter of 1–2 mm, whereas arterioles were not blocked by the injected particles. Thus, the arterioles spared from the direct effect of the particles may supply the myometrium (41,44).

Furthermore, MR imaging may be valuable for predicting the outcome of UAE. High signal intensity in a leiomyoma on T1-weighted images is a negative predictor of volume reduction (41,42). It is hypothesized that such leiomyomas have already undergone hemorrhagic degeneration and loss of vascular supply, so that they show a poor response to UAE (42). On the other hand, submucosal location of a leiomyoma is a positive predictor of volume reduction after UAE (Fig 21) (41).

GnRH analog produces medical menopause and may be a conservative treatment option. The average volume reduction in the uterus and leiomyoma is 40%–50% after 6 months of this medical therapy (30), but its effect is not permanent and reversal will occur when treatment is discontinued. Thus, medical therapies may be used as adjuncts or as temporary substitutes for surgical treatment or for treatment of patients who are approaching menopause. MR imaging with contrast media may help predict treatment outcome. Enhancement of leiomyomas on post-contrast T1-weighted images is a positive predictor of volume reduction with an average reduction rate of 44.7%, whereas that of unenhanced leiomyomas is 17.8% (Fig 22) (45).

As a result, the role of MR imaging in patients with uterine leiomyoma includes the following uses: (a) exact differentiation between leiomyoma and adenomyosis; (b) localization of leiomyomas (subserosal, myometrial, submucosal, and cervical); (c) prediction of outcome of treatments such as UAE and GnRH analog therapy; and (d) monitoring for posttreatment changes and recurrences in patients treated with uterus-conserving methods.
Figure 22. Uterine leiomyomas treated with GnRH analog. B = bladder, * in a and c = ovary. Sagittal T2-weighted (a) and contrast-enhanced fat-suppressed T1-weighted (b) images obtained before treatment and T2-weighted image obtained after GnRH analog therapy (c) show multiple uterine leiomyomas. The largest leiomyoma is in the uterine fundus (short arrows). Before treatment, this lesion demonstrates high signal intensity on the T2-weighted image (a) and marked enhancement on the contrast-enhanced image (b). The volume of this lesion is reduced after treatment (c). In contrast, the small leiomyomas in the posterior myometrium (arrowheads) are unchanged after treatment (c). Before treatment, these lesions demonstrate low signal intensity on the T2-weighted image (a) and weak enhancement on the contrast-enhanced image (b). The large leiomyoma in the posterior myometrium (long arrow) is also unchanged after treatment (b), even though it demonstrates enhancement before treatment (b).
Endometriosis is found in 25%–50% of infertile women, and 30%–50% of women with endometriosis are infertile (46). Laparoscopy is the mainstay for diagnosis, staging, and treatment of the disease. Transvaginal US is the preferred imaging technique to identify ovarian endometriosis. A recent study on the diagnostic performance of transvaginal US found a sensitivity of 45% and a specificity of 99% (47). The authors of that study concluded that an adnexal mass with diffuse low-level internal echoes and absence of particular neoplastic features is highly likely to be an endometrioma if multilocularity or hyperechoic wall foci are present (47). However, transvaginal US has limited usefulness in identifying peritoneal implants.

MR imaging has also proved to be a useful modality for establishing an accurate diagnosis of endometriosis. The diagnostic MR imaging findings for ovarian endometriomas are (a) adnexal cysts of high signal intensity on both T1- and T2-weighted images (Fig 23) or (b) high signal intensity on T1-weighted images and low signal intensity on T2-weighted images (shading) (Fig 24). The dense concentration of cyclic hemorrhage and the high viscosity of the contents in the endometrioma cause T2 shortening and produce shading. These adnexal lesions are often multiple (multiplicity) (Fig 24). With these criteria, MR
imaging provides a sensitivity of 82%–90% and a specificity of 91%–98% (6,48) in diagnosis of ovarian endometriomas.

However, multilocularity and wall foci or nodules are neoplastic features associated with malignancy (clear cell carcinoma and endometrioid carcinoma are the most common malignancies associated with endometriosis), which is difficult to distinguish from endometriosis. T1-weighted images obtained with the selective fat-suppression technique improve the diagnostic accuracy for peritoneal implants to a sensitivity of 47%–61% and a specificity of 87%–97%. These are significantly higher values than those for T1- and T2-weighted images only, which have a sensitivity of 11%–27% (Fig 25) (7,8).

The treatment options are medical therapy and surgical therapy. Medical therapy includes danazol and GnRH analog, which aim to induce a pseudomenopause state. In this setting, MR imaging makes it possible to monitor hormonal therapy noninvasively. Furthermore, one study found that shading on T2-weighted images is the most important negative predictor of volume reduction (49). The reasons for failure to respond in an endometrioma with shading include the following: (a) The epithelial lining of an endometrioma becomes attenuated by the pressure of retained blood in the cyst and (b) the contents in the cyst are too dense to be absorbed (49). This seems to suggest that hormonal therapy should be discontinued when shading is observed in endometriomas after initial medication, and the lesions henceforth should be treated with surgical therapy (Fig 26) (49). Laparoscopy or laparotomy is the preferred technique for conservative surgery. It effectively ablates ovarian endometriomas, peritoneal implants, and adhesions and may enhance fertility.

For preoperative assessment, MR imaging allows identification of the location, size, and number of endometriomas or implants. Although MR imaging has limited usefulness for making an accurate diagnosis of adhesions, the low-signal-intensity stranding that obscures organ interfaces is an important finding for identification of adhesions. Posterior displacement of the uterus, “kiss-
ing” ovaries (Fig 23), angulated bowel loops (Fig 23), an elevated posterior vaginal fornix (Fig 25), loculated fluid collections, and hydrosalpinx (particularly hematosalpinx) (Fig 9) are the other findings that indicate adhesions (50–52). A recent study found that multiphase and multisec-
tion MR imaging with kinetic display may allow prediction of pelvic adhesions. In that study, organ movement was analyzed with a half-Fourier acquisition single-shot fast spin-echo sequence. It provided a sensitivity of 72.5% and a specificity of 87.4% for diagnosis of adhesions (53).

Figure 26. Ovarian endometrioma treated with GnRH analog. Arrowheads = right ovary. (a, b) Axial T1-weighted (a) and T2-weighted (b) images obtained before treatment show a hyperintense cyst (arrows), which represents a left ovarian endometrioma. (c, d) Axial T1-weighted (c) and T2-weighted (d) images obtained after GnRH analog therapy show that the lesion is smaller (arrows) and has low signal intensity on the T2-weighted image (d). Hormonal therapy should be discontinued in such a case because shading is a negative predictor of disease reduction.

Conclusions

MR imaging is a useful modality as an adjunct for routine infertility work-ups. It is valuable for detection of pituitary adenoma when patients are suspected of having a disorder of the hypothalamic-pituitary-ovarian axis. The role of MR imaging in assessing the pelvic cavity in patients with infertility includes evaluation of the functioning uterus and ovaries, differentiation of müllerian
duct anomalies, and accurate noninvasive diagnosis of adenomyosis, leiomyoma, and endometriosis. MR imaging also helps predict the outcome of conservative treatment for adenomyosis, leiomyoma, and endometriosis and may help patients select better treatment plans and management. MR imaging may also serve as an adjunct to diagnostic laparoscopy and hysterosalpingography for patients with hydrosalpinx, peritubal adhesions, or pelvic adhesions related to endometriosis.

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