Female infertility accounts for two-thirds of all infertility problems, and it can be due to tubal, ovarian, and/or uterine factors. Tuboperitoneal disease is thought to be a contributing factor to infertility for up to 40% of infertile couples. Imaging-led evaluations of infertility focus primarily on the uterine cavity and fallopian tubes. Transvaginal ultrasound plays a vital role.

Hysterosalpingography provides information on the uterine cavity and fallopian tubes, including whether the fallopian tubes are patent. MRI is used as a problem-solving modality when ultrasound findings are inconclusive. Its excellent tissue contrast allows several conditions to be diagnosed precisely. Known disadvantages include the higher cost, longer scanning time, and restrictions on its use in women during the early stages of pregnancy. MRI is, however, noninvasive, and its findings can influence the treatment of infertile patients.

Practitioners seeking to evaluate the cause of infertility on MRI should be familiar with female genital development as well as normal uterine MRI findings. Female genital organs originate from the paired mullerian ducts. The lower portions of the ducts fuse to form the uterus and upper third of the vagina at around nine to 12 weeks of fetal development. The lowest portion of the upper vagina then fuses with the lower vagina, which develops from the vaginal plate of the urogenital sinus. The upper portions of the mullerian ducts remain separate and form the fallopian tubes. The wolffian ducts will have regressed during this period.

The normal uterus is seen as three zones on T2-weighted MRI. These are the endometrium (bright), the junctional zone (distinct low intensity), and the myometrium (higher intensity). The internal and external os, the cervical canal, and the anterior and posterior vaginal fornices all show clearly just behind the urinary bladder and the urethra.

ANATOMIC ANOMALIES

Most anomalies associated with female reproductive organs are due to the failure of the mullerian duct fusion process. The genotype and ovaries of patients with these so-called mullerian duct anomalies are normal. A prevalence rate of mullerian duct anomalies is approximately 3% among the general population. Presenting symptoms vary from incidental findings during infertility assessment to severe menstrual cramps. Approximately 25% of women with this type of anomaly will have infertility issues.

The American Fertility Society (AFS) categorizes mullerian duct anomalies into seven groups: class I (agenesis or hypoplasia of the uterus at any level), class II (unicornuate), class III (didelphic), class IV (bicornuate), class V (septate), class VI (arcuate uterus), and class VII (anomalies caused by in utero exposure to diethylstilbestrol). Classification according to this system can be achieved readily from MRI findings.2,3 In one comparative study, MRI diagnosed uterine anomalies with 100% accuracy, compared with 92% for ultrasound and less than 20% for hysterosalpingography.1

- **Class I.** Mullerian hypoplasia or agenesis can occur at any level of the mullerian ducts: vaginal, cervical, corporeal, or tubal-or at a combination of different levels. It can be either segmental or complete.2 Mayer-Rokitansky-Kuster-Hauser syndrome is the most common example, consisting of agenesis or hypoplasia of the upper third of the vagina and uterus with normal ovaries and fallopian tubes. Primary amenorrhea is a common complaint, and vaginal reconstruction surgery is all that is required.

Segmental agenesis, on the other hand, frequently causes cryptomenorrhea and should be treated...
differently. Hymenal atresia simply needs incision. Agenesis of the lower vagina can be treated easily by reconstruction surgery, reserving the possibility of future pregnancy. Cervical absence or hypoplasia, however, might necessitate hysterectomy.

- **Class II.** The unicorneuate uterus can present with or without a rudimentary horn. The horn-free unicorneuate uterus is lenticular in shape and deviated to one side (Figure 1). Evaluation of mullerian duct anomalies should include a careful search for the rudimentary horn and the presence of the endometrial cavity and the status of its communication with the main uterine cavity. Observation of an endometrial cavity in a rudimentary horn should prompt surgical resection, given the associated risk of spontaneous abortion in a communicating rudimentary horn or cryptomenorrhea in a noncommunicating rudimentary horn. The rudimentary horn can be fairly large and still have no cavity communication.

- **Class III.** Uterine didelphys is characterized by complete duplication of the uterine body and cervix. The patient can be asymptomatic or may have associated cryptomenorrhea if a vaginal septum is present. Possible fertility problems include preterm spontaneous abortions, premature labor, and fetal growth retardation. The uterine corpus can be repaired successfully with surgery, but surgical union of the cervix will result in incompetent cervix, also called cervicla insufficiency.

Unilateral renal agenesis is common in patients with uterine didelphys but not in women with a bicorneuate uterus. Practitioners performing an MRI evaluation of the cervix in young women should check for the possible presence of a plica palmatae (low intensity). This may be mistaken for a septum or duplication of the cervix.

- **Class IV.** The bicorneuate uterus has two uterine cornua. Widely separated cornua and concaved fundal configuration distinguish this condition from the septate uterus, another type of mullerian duct anomaly. Signal intensity of tissue between the two horns of the bicorneuate uterus is usually similar to that of the myometrium. This is not always a reliable guide, however, because intervening tissue can be partially fibrous.3 Distinguishing the bicorneuate uterus from the septate uterus is extremely important because surgical strategies for the two anomalies are quite different.3 A septate uterus can be treated by hysteroscopic resection of the septum, but a bicorneuate uterus is treated only by the transabdominal metroplasty, which is more invasive.

- **Class V.** The septate uterus has a flat fundal configuration and normal intercornual distance. While the bicorneuate uterus is usually symptom-free, the septate uterus is the lesion that is most commonly associated with infertility. Implantation in the poorly vascularized fibromuscular tissue of the septum can lead to spontaneous abortion. MRI is probably the most reliable method of distinguishing the septate uterus from the bicorneuate uterus, particularly in cases where the septum consists of muscle superiorly and fibrous tissue inferiorly.

### GENETIC DISORDERS

Intersex problems associated with ambiguous genitalia are not rare occurrences. Women may present with a complaint of primary amenorrhea or infertility. MRI will display internal genital organs clearly. True hermaphroditism has a mosaic genotype, leading to the presence of both the ovary and the testis. Pseudohermaphroditism refers to a condition in which secondary sexual characteristics are different from the sex determined by genes and gonads.

Female pseudohermaphroditism refers to women who are genetically female and have ovaries but show the male phenotype. The most common cause is androgen overproduction, such as in adrenogenital syndrome. Normal female internal organs will be identifiable owing to the absence of both testes and mullerian inhibiting factor. Male pseudohermaphroditism covers incomplete masculinization of the external genitalia in a 46XY male karyotype with female phenotype. Presentation may range from hypospadias to testicular feminization. The most severe form, testicular feminization, is caused by androgen insensitivity. The patient may be raised as female and present with a complaint of primary amenorrhea or even infertility. MRI will reveal whether the prostate is absent and show the rudimentary or absent uterus and vagina. It will also reveal the presence of the lower two-thirds of the vagina, which is not mullerian in origin. Resection of undescended testes, usually found in the inguinal canal, is
Static and cine imaging offers clues to female infertility

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Typically, patients with Turner's syndrome have a 45XO karyotype, streak gonads, poorly developed sexual characters, and infertility. Mosaic karyotype is common, though, and in some cases, even pregnancy is possible with an appropriate treatment. Accurate evaluation of internal organs will help determine treatment options.

**UTERINE AND PELVIC DISEASES**

MRI is also able to differentiate between uterine myometrial lesions. Accurate preoperative diagnosis is important for infertile patient management, given the number of possible treatment options. Identification of the number and precise location of myometrial lesions on MRI should help minimize intervention and provide sufficient information for the use of newly developed nonsurgical therapies. The emergence of treatments for leiomyomas, such as focused ultrasound and uterine arterial embolization, makes it increasingly important to distinguish benign lesions from malignancies. Leiomyomas are by far the most common uterine tumor. The sharply marginated, rounded tumors are easily distinguished from ill-defined adenomyosis on MRI. Leiomyomas typically display a distinct low signal intensity with a speckled appearance on T2-weighted images. Cystic degeneration or edema, however, can cause the lesions to exhibit mainly high signal intensity. Accurate differentiation of leiomyomas from leiomyosarcomas on imaging is not possible at present. Endometrial distortion by a submucosal lesion is clearly identifiable on MRI. Imaging findings can help when choosing between treatment options, such as uterine arterial embolization, hysteroscopic resection, laparoscopic resection, or laparotomy followed by leiomyoma enucleation or hysterectomy. MRI is also useful for postprocedural follow-up.

Endometriosis causes occlusive tubal disease. It also has adverse effects on immunity, fertilization, and ova growth, though its exact mechanism of infertility has yet to be determined. Approximately 10% of all women, and 30% to 50% of infertile women, will have endometriosis. The severity of endometriosis is staged according to the revised AFS classification, ideally using laparoscopy. MRI is unable to identify adhesions and small implants easily, so it is unlikely to replace laparoscopy as the staging tool of choice. MRI can, however, diagnose endometriosis accurately when it is hidden by dense adhesions and inaccessible to laparoscopy. Using fat-suppressed images improves the diagnostic accuracy of MRI by up to 77%. Small implants may be identifiable even within the normal-sized ovary. MRI can diagnose solid endometriosis, which is frequently mistaken for a malignant mass. Solid endometriosis is observed as a low-signal mass on T2-weighted images. Tiny foci of high signal intensity may frequently be seen on T1-weighted images. Severe adhesions, such as pouch of Douglas obliteration, may be identifiable on MRI. Findings that indicate adhesions include a retroflexed uterus, a low-intensity fibrous plaque covering the posterior uterine surface, a pinpoint convergence of bowel to the plaque, and a posterior vaginal fornix elevated toward the fibrotic plaque.

The most important finding, when considering conservative treatment for infertile patients with endometriosis, is malignancy arising in an endometrial cyst. Malignant tumors originate in 0.3% to 0.8% of all endometrial cases. The lesions enlarge and display mural nodules, appearing as low signal on T1-weighted images and high signal on T2-weighted images and enhancing strongly after administration of contrast.

**PSEUDOLESIONS, UTERINE FUNCTIONS**

Another important consideration in the assessment of infertile patients on MRI is the presence of pseudolesions that mimic leiomyomas or adenomyosis. An area of low signal intensity in the uterus that bulges into the endometrial cavity is normally considered to be a leiomyoma. But such low-intensity regions may actually represent uterine contractions, if sequential images in an MRI study show different findings. This phenomenon serves as a reminder that the uterus is an organ consisting of smooth muscle and has an inherent contractility. Static uterine MRI findings represent the average or sum of all uterine motion during image acquisition. Uterine kinematics can be evaluated directly using cine MRI. These findings can then be used to assess uterine function. Uterine peristalsis, for instance, refers to rhythmic contractions of the inner...
myometrium, represented as surging waves at the endometrial-myometrial junction, and is supposed to be closely related to important uterine functions, such as fertility and menstruation.13,14 We have succeeded in displaying uterine peristaltic waves on cine MRI.15 Waves surge frequently from the cervix to the fundus at midcycle. This direction is in accordance with upward sperm transport. The absence of identifiable uterine peristalsis during the luteal phase could facilitate implantation. Infrequent but relatively thick waves surge from the fundus to the cervix during menstruation, aiding discharge.

Further cine MRI studies may elucidate the mechanisms of contraception, infertility, and endometriosis. Evaluation of peristalsis may be of benefit to women whose cause of infertility is unknown.

MRI provides a noninvasive and unique evaluation of the causes of female infertility. Static MRI visualizes organic lesions and mullerian duct anomalies clearly, while cine MRI techniques are emerging as a new tool for evaluating uterine function and contractility.

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References


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