Female Infertility: A Systematic Approach to Radiologic Imaging and Diagnosis

Jill A. Steinkeler, MD • Courtney A. Woodfield, MD • Elizabeth Lazarus, MD
Mary M. Hillstrom, MD

Imaging plays a key role in the diagnostic evaluation of women for infertility. The pelvic causes of female infertility are varied and range from tubal and peritubal abnormalities to uterine, cervical, and ovarian disorders. In most cases, the imaging work-up begins with hysterosalpingography to evaluate fallopian tube patency. Uterine filling defects and contour abnormalities may be discovered at hysterosalpingography but typically require further characterization with hysterographic or pelvic ultrasonography (US) or pelvic magnetic resonance (MR) imaging. Hysterographic US helps differentiate among uterine synechiae, endometrial polyps, and submucosal leiomyomas. Pelvic US and MR imaging help further differentiate among uterine leiomyomas, adenomyosis, and the various müllerian duct anomalies, with MR imaging being the most sensitive modality for detecting endometriosis. The presence of cervical disease may be inferred initially on the basis of difficulty or failure of cervical cannulation at hysterosalpingography. Ovarian abnormalities are usually detected at US. The appropriate selection of imaging modalities and accurate characterization of the various pelvic causes of infertility are essential because the imaging findings help direct subsequent patient care.

©RSNA, 2009 • radiographics.rsna.org

LEARNING OBJECTIVES

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

- Recognize common tubal, uterine, cervical, and ovarian causes of infertility.
- Describe the importance of hysterosalpingography for evaluating infertility in women.
- Identify appropriate uses of pelvic MR imaging for evaluating infertility in women.

Abbreviation: DES = diethylstilbestrol

RadioGraphics 2009; 29:1353–1370 • Published online 10.1148/rg.295095047 • Content Codes: GU DB

©RSNA, 2009

See last page
Introduction

An estimated 7.4 million women, or 12% of the female population of reproductive age in the United States, were reported to be infertile in the 2002 National Survey of Family Growth (1). The demand for general infertility services showed rapid growth between 1996 and 2004, with a reported 92% increase in the number of assisted reproduction procedures (2). In association with that increase, there has been an increased demand for female infertility imaging services, including hysterosalpingography, hysterographic and pelvic ultrasonography (US), and pelvic magnetic resonance (MR) imaging. The potential causes of female infertility are numerous and may involve the fallopian tubes, peritoneum, endometrium, uterus, cervix, and ovaries. Therefore, imaging plays a crucial role in diagnostic work-up and treatment planning for female infertility.

An imaging evaluation for female infertility typically takes place after a clinical assessment. Because tubal occlusion is the most common cause of female infertility, the imaging evaluation begins with hysterosalpingography to determine whether the fallopian tubes are patent. Hysterosalpingography readily depicts the course, size, and contour as well as patency of the tubes. Peritubal abnormalities due to pelvic adhesions or endometriosis also may be detected; and endometrial and uterine abnormalities such as synechiae, polyps, leiomyomas, and müllerian duct anomalies may be depicted as filling defects and contour abnormalities, respectively. The findings at hysterosalpingography help the referring clinician and radiologist determine the next appropriate step in diagnosis and management.

Intratubal filling defects seen at hysterosalpingography are best evaluated with hysterographic US, which can help confirm the presence and characteristics of uterine synechiae, endometrial polyps, and submucosal leiomyomas. Uterine contour abnormalities detected at hysterosalpingography may be due to adenomyosis, leiomyomas, or müllerian duct anomalies. While pelvic US may be helpful for further evaluation of uterine contour abnormalities, MR imaging is especially useful for differentiating between adenomyosis uteri and uterine leiomyomas, which have a similar appearance at US. MR imaging provides optimal and accurate characterization of müllerian duct anomalies, crucial information for predicting pregnancy outcomes and choosing appropriate methods of intervention. Cervical causes of female infertility that can be evaluated with imaging include cervical stenosis, the presence of which may be indicated by an inability to cannulate the external cervical os or by narrowing of the endocervical canal seen at hysterosalpingography. When the cervical appearance at hysterosalpingography is normal, ovarian causes such as premature ovarian failure, gonadal dysgenesis, and polycystic ovary syndrome should be considered. The observation of characteristic features of polycystic ovary syndrome at US, in combination with clinical symptoms, may be indicative of the diagnosis.

The article describes the tubal, peritoneal, endometrial, uterine, cervical, and ovarian causes of infertility and illustrates their imaging appearances. A systematic multimodality imaging approach is advocated in which initial hysterosalpingography is followed by hysterographic US, pelvic US, pelvic MR imaging, or a combination thereof, with the selection of modalities depending on the findings at hysterosalpingography.

Fallopian Tube Abnormalities

Fallopian tube abnormalities are the most common cause of female infertility, accounting for 30%–40% of cases (3). Hysterosalpingography provides optimal depiction of the fallopian tubes, allowing detection of tubal patency, tubal occlusion, tubal irregularity, and peritubal disease (4). If there is evidence of occlusion due to endometriosis, hysterosalpingography should be followed by MR imaging. A process diagram for diagnostic imaging of fallopian tube abnormalities is shown in Figure 1.

Tubal Occlusion

The fallopian tubes have three segments that are visible at hysterosalpingography: the interstitial portion, which traverses the myometrium; the isthmic portion, which courses within the broad
ligament; and the ampullary portion, which is adjacent to the ovary. Occlusion may occur at any site along the course of the tube. The differential diagnosis of tubal occlusion typically includes tubal spasm, infection, and prior surgery (4). Rare causes of tubal occlusion include granulomatous salpingitis due to tuberculosis, intraluminal endometriosis, parasitic infection, and congenital atresia of the fallopian tubes (5). When tubal occlusion in the proximal or interstitial portion of the fallopian tube is seen at hysterosalpingography, a tubal spasm should be considered as the possible cause. Delayed radiography may be performed to help differentiate tubal spasm from true tubal occlusion (6). A spasmolytic agent such as glucagon also may be administered to relax the uterine muscle and relieve a tubal spasm (4). In addition, it may be helpful to place the patient prone and reinject contrast material into the uterus (5). If a proximal tubal occlusion is confirmed at hysterosalpingography, fluoroscopically guided transcervical fallopian tube recanalization may be performed (6).

Hydrosalpinx results from occlusion at the ampullary end of the fallopian tube, a condition most commonly caused by pelvic inflammatory disease. At hysterosalpingography, the tube appears dilated, and there is an absence of intraperitoneal spillover of contrast material (Fig 2). If hydrosalpinx is seen at hysterosalpingography, it is important to prescribe postprocedural antibiotic prophylaxis, typically doxycycline, to prevent procedure-related infection due to stasis of contrast material within the obstructed fallopian tube (5). Treatment of distal tubal occlusion may include fluoroscopically guided transcervical fallopian tube recanalization; however, tubal microsurgery may be performed if recanalization is not successful (6).

**Tubal Irregularity**

Tubal irregularity at hysterosalpingography may be due to salpingitis isthmica nodosa, an inflammatory process within the fallopian tube. The exact cause of this process is unknown, but associations with pelvic inflammatory disease, infertility, and...
Figure 3. Tubal irregularity due to salpingitis isthmica nodosa. Spot (a) and magnified (b) views from hysterosalpingography depict multiple contrast material-filled luminal pouches (arrowheads) projecting 2–3 mm outward from the isthmic portion of both fallopian tubes.

Figure 4. Right peritubal pelvic adhesion due to previous pelvic inflammatory disease. Early (a) and late (b) hysterosalpingograms show normal contrast material filling of the right fallopian tube (arrow in a) and a rounded collection of leaked contrast material (arrowheads in b) adjacent to the ampullary portion of the right tube. The collection was due to peritubal adhesions. The left fallopian tube appears normal and patent.

Peritubal Abnormalities
Even when the fallopian tubes appear normal, an abnormal accumulation of contrast material may be seen adjacent to the ampullary ends of the tubes at hysterosalpingography. Peritubal pooling of contrast material is suggestive of peritubal adhesions (Fig 4). Both endometriosis and pelvic inflammatory disease may lead to peritubal adhesions with resultant infertility (6). When evidence
women have endometriosis, a condition defined by the presence of endometrial glands and stroma outside the uterus (7). This condition almost exclusively affects women during their reproductive years. It may be asymptomatic or may cause multiple symptoms, including pelvic pain and infertility (8,9). Imaging tests for endometriosis include pelvic US and MR imaging. Endometriosis may take the form of either small implants or cysts that change in size and appearance during the menstrual cycle and that may initiate an inflammatory response leading to fibrosis and adhesions. Endometriotic cysts, referred to as endometriomas, result from repeated hemorrhage within an implant.

The US features of endometriosis are variable; US has low sensitivity for the detection of focal implants, but it may depict endometriomas (8,10). Endometriomas have a variable appearance, with the most specific US signs being an adnexal mass with faint internal echoes and highly echogenic mural foci (Fig 5) (9). They generally occur within the ovary, often bilaterally. The sensitivity and specificity of MR imaging for the identification of endometriosis are higher (71% and 82%, respectively) than those of US (11). MR imaging features of endometriosis include cystic masses with thickened walls and loss of the interface between the lesion and adjacent organs. The masses have internal high signal intensity on T1-weighted images and low signal intensity on T2-weighted images. Other high-signal-intensity features seen on T1-weighted images may include hydrosalpinx (the luminal contents of which may include blood products) and endometrial implants (Fig 6) (3,9,12). However, the sensitivity (13%) of MR imaging for the detection of endometrial implants is low (13). For this reason, MR imaging alone cannot take the place of laparoscopy for the definitive diagnosis of endometriosis (11,13).

**Intrauterine Filling Defects**

Intrauterine filling defects seen at hysterosalpingography may be caused by air bubbles in the contrast material injection, intrauterine adhesions, submucosal leiomyomas, endometrial polyps, or blood clots. Bilateral oblique views may help identify mobile, nondependent, round filling defects caused by air bubbles and to avoid mistaking these findings for intrauterine disease.
Figure 7. Diagram shows the appropriate steps in an imaging evaluation for intrauterine abnormalities.

Figure 8. Asherman syndrome in a patient with a history of dilation and curettage. (a) Hysterosalpingogram depicts several linear intrauterine filling defects (arrowheads). (b) Sagittal image from transvaginal hysterosalpingographic US shows multiple uterine synechiae (arrows).

Figure 9. Endocavitary leiomyoma (fibroid). Sagittal transvaginal gray-scale (a) and color Doppler (b) US images depict a solid mass (arrowheads) with internal echogenicity similar to that of the myometrium. The mass has a pedunculated attachment (arrow) to the uterus and extends into the cervical canal. The fibroid was excised at hysteroscopy.

More contrast material may be injected into the endometrial cavity to see whether the filling defects move; for example, the additional injection may cause air bubbles to be ejected via the fallopian tubes (14). Early views of the uterus should be obtained at hysterosalpingography because small filling defects may become obscured with more advanced opacification of the endometrial cavity (4). In general, hysterosalpingographic US is performed for a more detailed evaluation of the endometrial cavity if intrauterine filling defects are seen at hysterosalpingography (Fig 7).
Uterine Synechiae
Intrauterine adhesions, or synechiae, may be the result of previous pregnancy, dilation and curettage, surgery, or infection. Such adhesions appear as irregular linear filling defects at hysterosalpingography (Fig 8) (5). In addition, the endometrial cavity may appear distorted or may not expand as expected with the injection of contrast material.

Infertility secondary to uterine adhesions is known as Asherman syndrome. To accurately diagnose the condition, uterine adhesions must be differentiated from normal uterine folds, which also may appear as longitudinal filling defects when the endometrial cavity is not fully distended (4,14). Hysterographic US has greater sensitivity than hysterosalpingography for the identification of intrauterine adhesions, which appear as echogenic bands that traverse the endometrial cavity (15).

Endometrial Polyps and Submucosal Leiomyomas
Even subcentimetric endometrial polyps and submucosal leiomyomas may interfere with embryo transfer and implantation (5). Hysterographic US can depict endometrial lesions that are not visible with pelvic US and can help distinguish endometrial polyps from submucosal leiomyomas. It also allows a more accurate assessment of the number and location of endocavitary lesions, thus providing guidance for their subsequent management with hysteroscopic biopsy or excision.

Submucosal leiomyomas typically appear as hypoechoic masses that distort the normal-appearing endometrium on US images (15). They may have a peduncular attachment and thus mimic an endometrial polyp (Fig 9). A leiomyoma with more than 50% of its volume within the endometrial cavity may be treated effectively with hysteroscopic myomectomy (16). At hysterographic US, endometrial polyps typically appear as echogenic intracavitary masses (17). They occasionally contain cystic foci, and color Doppler US may help identify the characteristic central vascular stalk (4) (Fig 10).
Uterine Contour Irregularities

Uterine contour irregularities observed at hysterosalpingography may be due to a variety of entities, including adenomyosis, uterine leiomyomas, and müllerian duct anomalies. Pelvic US, pelvic MR imaging, or both are often required for further characterization of contour abnormalities found at hysterosalpingography (Fig 11).

Adenomyosis

Adenomyosis, a benign pathologic condition of the uterus, is characterized by the presence of ectopic endometrial glands within the myometrium, with surrounding smooth-muscle hyperplasia (18). Adenomyosis may affect the uterus diffusely or may occur as a focal lesion (adenomyoma). In women younger than 36 years, there is a strong association between adenomyosis and pelvic endometriosis, with adenomyosis being reported in approximately 90% of these patients (19). It has been postulated that adenomyosis is the cause of infertility in these women (19). Adenomyosis may be associated with infertility due to impaired uterine contractility, which is necessary for directed sperm transport through the uterus (19). Focal adenomyomas, especially in submucosal locations, also may impair fertility.

Adenomyosis may be detected with various imaging modalities, including hysterosalpingography, US, and MR imaging. At hysterosalpingography, adenomyosis is identifiable with a finding of multiple linear or saccular contrast material collections that protrude beyond the normal contour of the endometrial cavity (Fig 12). The endometrial cavity may appear enlarged or distorted. US and MR imaging may be performed if the findings at hysterosalpingography are suggestive but inconclusive. US features of adenomyosis include globular uterine enlargement, heterogeneous myometrial echotex-
Figure 14. Adenomyosis. Sagittal T2-weighted MR image shows high-signal-intensity foci (arrow) indicative of ectopic endometrial glandular implants with associated thickening of the junctional zone (> 12 mm) (arrowheads) due to smooth-muscle hypertrophy in a patient with focal anterior body adenomyosis. Retroversion of the uterus also is seen.

Figure 15. Adenomyosis and leiomyoma. Coronal T2-weighted fat-saturated MR image depicts focal thickening of the junctional zone (arrowheads), which is a characteristic finding of focal adenomyosis, and an adjacent well-defined intramural leiomyoma (arrow) that produces a greater mass effect on the outer uterine contour.

Leiomyomas
Uterine leiomyomas are the most common benign pelvic mass lesions and the most common cause of uterine enlargement in nonpregnant women (23). Leiomyomas may be found in any part of the uterus, in submucosal, intramural, and subserosal locations. They most often occur in multiples but also may occur singly. Infertility may result when leiomyomas are numerous or have submucosal or intracavitary locations that interfere with embryo transfer and implantation. In addition, patients with multiple leiomyomas are at an increased risk for early spontaneous fetal loss (24).

A finding of uterine enlargement, distortion, or mass effect on the endometrial cavity on hysterosalpingograms is suggestive of uterine leiomyoma (Figs 16, 17). If the lesion is located near the uterine cornua, it may obstruct the ipsilateral fallopian tube and thus cause a lack of tubal opacification.
Leiomyomas have a variable appearance at pelvic US. The uterus may be enlarged or lobulated and may have a heterogeneous echotexture. Discrete leiomyomas may appear uniformly hypoechoic or have heterogeneous echogenicity with hyperechoic calcifications, and they may be accompanied by an acoustic shadow. They may be largely submucosal and distort the endometrium, or they may occur as discrete intracavitary mass lesions (Fig 18).

With its excellent soft-tissue contrast resolution, pelvic MR imaging is the most accurate imaging modality for evaluating the size, location, and number of uterine leiomyomas. At MR imaging, the myomatous uterus often appears enlarged and lobulated. Leiomyomas most commonly are depicted as focal masses with signal that is hypointense to that of the myometrium on T2-weighted images. The exact location of a leiomyoma and its relationship to the endometrial cavity can easily be determined with pelvic MR imaging (Fig 19).

**Müllerian Duct Anomalies**

Müllerian duct anomalies are another potential cause of alteration in the normal uterine contour and, thus, of female infertility. It is estimated that approximately 1% of all women and 3% of women with recurrent pregnancy losses have a uterovaginal anomaly. As many as 25% of women with müllerian duct anomalies (compared with only 10% of the general population) have reproductive problems, including increased risk for spontaneous abortion, prematurity, intrauterine growth retardation, abnormal fetal lie, and dystocia at delivery (25–28).
Accurate characterization of müllerian duct anomalies is essential because pregnancy outcomes and treatment options vary between the different classes of anomalies. Therefore, in many cases when an anomaly is suspected or incompletely characterized at hysterosalpingography, further evaluation is performed with pelvic US, MR imaging, or both. Hysterosalpingography does not allow reliable differentiation between septate and bicornuate anomalies because the outer uterine contour is not visible; by contrast, US has a reported accuracy of 90%–92% for the characterization of anomalies, particularly with the use of three-dimensional techniques (29). However, US may not fully demonstrate the extent of septal and vaginal anomalies or uterine remnants. MR imaging has the highest reported accuracy (nearly 100%) for the characterization of müllerian duct anomalies, because of its excellent soft-tissue resolution and multiplanar imaging capabilities (29,30). Key features that should be evaluated with US and MR imaging are the presence, size, and shape of the uterus, in particular the external fundal contour. The presence, location, and appearance of the kidneys also should be routinely evaluated because of the high frequency of associated renal anomalies in patients with müllerian duct anomalies (3,25,31). Image acquisition in true coronal and true axial planes of the uterus allows accurate evaluation of the uterine contour and cavity.

The American Society of Reproductive Medicine system is most commonly used to classify müllerian duct anomalies (32). This system, which is based on embryology, comprises seven classes: I, uterine hypoplasia and agenesis; II, unicoricate uterus; III, uterus didelphys; IV, bicornuate uterus; V, septate uterus; VI, arcuate uterus; VII, diethylstilbestrol (DES)-related anomalies.

**Class I: Uterine Hypoplasia and Agenesis.**—Hypoplasia and agenesis of the uterus and proximal vagina, which result from failed or incomplete development of both müllerian ducts, account for 5%–10% of müllerian duct anomalies (25). Patients may present with primary amenorrhea and often are initially evaluated with pelvic US or MR imaging, which reveals a small or absent uterus and proximal vagina. Mayer-Rokitansky-Küster-Hauser syndrome, the most common variant in this class of anomalies, is manifested by complete vaginal agenesis and, in most cases, uterine agenesis (25) (Fig 20). The reproductive potential of patients with uterine hypoplasia is limited, and that of patients with uterine agenesis is absent.
75% of cases, a longitudinal vaginal septum is present, with or without a unilateral horizontal vaginal septum and resultant unilateral hematometrocolpos (34) (Fig 23). Metroplasty may be performed in patients who have experienced recurrent spontaneous abortions or preterm deliveries, but the benefit of such surgery remains unclear (35).

Class IV: Bicornuate Uterus.—Incomplete fusion of the müllerian ducts results in a bicornuate uterus, a condition that accounts for approximately 10% of uterine anomalies (25). In patients with this condition, hysterosalpingography shows two symmetric but divergent uterine horns. US and MR imaging may help confirm the presence of a bicornuate uterus by depicting a deep (> 1 cm) fundal cleft in the outer uterine contour and an intercornual distance of more than 4 cm (Fig 24) (29). In some patients, US and MR imaging show two separate cervical canals; in such a case,
Figure 23. Uterus didelphys. (a, b) Transverse transabdominal pelvic US image (a) and oblique axial T2-weighted MR image (b) demonstrate two divergent uterine horns (arrows) with distention of the right endometrial cavity (arrowheads in b). (c) Sagittal T1-weighted fat-suppressed MR image depicts high-signal-intensity material distending the right endometrial cavity and cervix (arrowheads), a finding indicative of right hematometrocolpos. An obstructive horizontal right vaginal septum was subsequently resected. (d) Coronal T2-weighted MR image demonstrates associated right renal agenesis.

Figure 24. Bicornuate uterus. Oblique coronal T2-weighted MR image shows two symmetric uterine horns (arrowheads) with a deep fundal cleft (arrow). The low-signal-intensity change in the right endometrial cavity is due to biopsy-proved endometrial carcinoma.
Class V: Septate Uterus. — Partial or incomplete septal resorption after müllerian duct fusion results in a septate uterus, which is the most common uterine anomaly, accounting for approximately 55% of müllerian duct anomalies (25). Similar to a bicornuate uterus, a septate uterus has two cavities that are visible at hysterosalpingography. US and MR imaging may help differentiate a septate from a bicornuate uterus by depicting a normal convex, flat, or minimally concave (< 1-cm-deep) external fundal contour with a septate uterus (29,36). MR imaging also readily demonstrates the composition and extent of the septum: A fibrous septum is typically thin, with low signal intensity on T2-weighted images, whereas a muscular septum tends to be thicker, with intermediate signal intensity on T2-weighted images (Fig 25). Patients with a septate uterus have the poorest reproductive and obstetric outcomes, with spontaneous abortion rates ranging from 26% to 94% (25). A septectomy may be performed in those who have experienced recurrent spontaneous abortions. A fibrous septum can be resected hysteroscopically, whereas a muscular septum may require metroplasty (29).

Class VI: Arcuate Uterus. — An arcuate uterus is the mildest anomaly and may be considered a normal variant. Near complete septal resorption results in a shallow, smooth, broad-based impression on the uterine cavity, which may be depicted at hysterosalpingography, US, and MR imaging (29). Observation of a normal outer uterine contour at US and MR imaging helps confirm the diagnosis (Figs 26, 27). An arcuate uterus usually has no effect on fertility or obstetric outcomes (37).

Class VII: DES-related Uterine Anomalies. — Between 1945 and 1970, DES was used for prevention of spontaneous abortions and treatment of hyperemesis gravidarum. Female fetuses exposed to DES in utero are at risk for developing a hypoplastic, irregular, T-shaped uterus and hypoplastic and strictured fallopian tubes, and they have an increased incidence of vaginal clear cell carcinoma later in life (38,39). In pregnant women who underwent in utero exposure to DES, the hypoplastic...
Figures 26, 27. Arcuate uterus. Three-dimensional coronal US image (26) and coronal oblique T2-weighted MR image (27), obtained in different patients, show a smooth, broad-based, shallow endometrial impression (arrow) with a normal external contour of the uterine fundus (arrowhead).

Figure 28. DES-related uterine anomaly. Hysterosalpingogram demonstrates a hypoplastic T-shaped uterus. The patient had been exposed to DES while in utero.

The uterus incurs a higher risk of spontaneous abortion, preterm delivery, and ectopic pregnancy. The classic features of DES-related uterine anomalies, unlike other classes of müllerian duct anomalies, are best depicted by hysterosalpingography (Fig 28). Hysteroscopic dilation of the uterine cavity may improve reproductive outcomes (40).

Cervical Abnormalities

Cervical Factor Infertility

The phrase cervical factor infertility connotes an inadequate quality or volume of cervical mucus, a condition that accounts for approximately 10% of cases of female infertility. Patients in whom the presence of this condition is suspected may be assessed with a postcoital test that does not involve imaging.

Cervical Stenosis

The term cervical stenosis is clinically defined as cervical narrowing that prevents the insertion of a 2.5-mm-wide dilator (41). This condition may be congenital or secondary to infection or trauma. Risk factors include previous cone biopsy, cryotherapy, laser treatment, and biopsy for cervical dysplasia (42,43). The more severe the stenosis, the more likely it is to be symptomatic (43). Consequences of cervical stenosis include obstruction of menstrual flow with resulting amenorrhea, dysmenorrhea, and potential infertility due to inability of sperm to enter the upper genital tract (41). Cervical stenosis also may be a serious impediment to assisted fertility techniques including embryo transfer and intrauterine insemination (42).

At hysterosalpingography, cervical stenosis may appear as narrowing of the endocervical canal (normal diameter, 0.5–3.0 cm), or it may manifest as complete obliteration of the cervical os, preventing insertion of the hysterosalpingographic catheter (44). Observations of narrowing of the endocervical canal on hysterosalpingograms should be correlated with clinical findings, because the diameter of the normal endocervical canal and internal os may vary (45). Masses such as cervical polyps, fibroids, and neoplasms also may cause narrowing of the cervical lumen (45).
Morphologic alterations of the ovary may be found in more than 80% of women with a clinical diagnosis of polycystic ovary syndrome (46). Morphologic alterations that may be detected at pelvic US include enlarged ovaries, increased echogenicity of the ovarian stroma, and an increased number of small follicular-type cysts (a finding of at least 12 cysts was proved diagnostically specific but not sensitive) (48). A finding of polycystic ovaries at US is not diagnostic for the syndrome, because 20%–30% of the normal population, particularly young women, may have ovaries with this appearance. Polycystic ovary syndrome is a functional disorder: Polycystic ovaries need not be present for the diagnosis to be made; and conversely, in the absence of other signs and symptoms, their presence is not sufficient to establish the diagnosis (46,48).

In some patients with polycystic ovary syndrome the ovaries are enlarged, but the range of sizes of diseased ovaries overlaps widely with that of normal ovaries. Increased echogenicity of the ovarian stroma is the most sensitive and specific US sign of the syndrome, but the finding is subjective (48). At MR imaging, the ovaries in patients with polycystic ovary syndrome classically demonstrate a low-signal-intensity central stroma surrounded by small peripheral cysts on T2-weighted images (Fig 29) (49).

Conclusions
The pelvic causes of female infertility include tubal, peritoneal, uterine, endometrial, cervical, and ovarian abnormalities. A multimodality imaging approach may be useful for determining the cause of infertility and guiding clinical management in specific cases (Fig 30). An imaging evaluation for female infertility typically begins with an assessment of the ovaries.

Figure 29. Polycystic ovary syndrome. (a) Transvaginal US image of the right ovary depicts multiple peripheral subcentimetric follicles (arrow). (b) Coronal T2-weighted MR image from the same patient shows bilateral ovarian enlargement with multiple peripheral follicles (arrows).
of tubal patency at hysterosalpingography, which may be followed by pelvic US, pelvic MR imaging, or both to further characterize any additional findings (eg, intrauterine filling defects or uterine contour abnormalities). Failure to cannulate the cervix at hysterosalpingography is suggestive of a cervical abnormality, whereas a normal hysterosalphingographic examination may point toward the possibility of an ovarian cause of infertility.

References

This article meets the criteria for 1.0 credit hour in category 1 of the AMA Physician’s Recognition Award. To obtain credit, see accompanying test at http://www.rsna.org/education/rg_cme.html.
Female Infertility: A Systematic Approach to Radiologic Imaging and Diagnosis

Jill A. Steinkeler, MD, et al

Hysterosalpingography provides optimal depiction of the fallopian tubes, allowing detection of tubal patency, tubal occlusion, tubal irregularity, and peritubal disease.

In general, hysterographic US is performed for a more detailed evaluation of the endometrial cavity if intrauterine filling defects are seen at hysterosalpingography.

Uterine contour irregularities observed at hysterosalpingography may be due to a variety of entities, including adenomyosis, uterine leiomyomas, and müllerian duct anomalies.

With its excellent soft-tissue contrast resolution, pelvic MR imaging is the most accurate imaging modality for evaluating the size, location, and number of uterine leiomyomas.

Accurate characterization of müllerian duct anomalies is essential because pregnancy outcomes and treatment options vary between the different classes of anomalies.
RadioGraphics 2009

This is your reprint order form or pro forma invoice
(Please keep a copy of this document for your records.)

Reprint order forms and purchase orders or prepayments must be received 72 hours after receipt of form either by mail or by fax at 410-820-9765. It is the policy of Cadmus Reprints to issue one invoice per order. Please print clearly.

Author Name _______________________________________________________________________________________________
Title of Article _______________________________________________________________________________________________
Issue of Journal_______________________________           Reprint #  _____________    Publication Date  ________________
Number of Pages_______________________ ________                KB # _____________                Symbol  RadioGraphics
Color in Article?    Yes   /   No       (Please Circle)

Please include the journal name and reprint number or manuscript number on your purchase order or other correspondence.

Order and Shipping Information

Reprint Costs (Please see page 2 of 2 for reprint costs/fees.)

_______ Number of reprints ordered $________

_______ Number of color reprints ordered $________

_______ Number of covers ordered $________

Subtotal $________

Shipping Address (cannot ship to a P.O. Box) Please Print Clearly
Name ____________________________
Institution _________________________
Street _____________________________
City ____________________ State _____ Zip __________
Country __________________________
Quantity __________________________ Fax __________________
Phone: Day ___________ Evening __________
E-mail Address _____________________

Additional Shipping Address* (cannot ship to a P.O. Box)
Name ____________________________
Institution _________________________
Street _____________________________
City ____________________ State _____ Zip __________
Country __________________________
Quantity __________________________ Fax __________________
Phone: Day ___________ Evening __________
E-mail Address _____________________

* Add $32 for each additional shipping address

Payment and Credit Card Details
Enclosed: Personal Check ___________
Credit Card Payment Details ___________
 Checks must be paid in U.S. dollars and drawn on a U.S. Bank.
Credit Card: __ VISA  __ Am. Exp.  __ MasterCard
Card Number _________________________
Expiration Date ______________________
Signature: ___________________________

Please send your order form and prepayment made payable to:
Cadmus Reprints
P.O. Box 751903
Charlotte, NC  28275-1903
Note: Do not send express packages to this location, PO Box.
FEIN #:541274108

Invoice or Credit Card Information
Invoice Address Please Print Clearly
Please complete Invoice address as it appears on credit card statement
Name ____________________________
Institution _________________________
Department _________________________
Street _____________________________
City ____________________ State _____ Zip __________
Country __________________________
Phone ___________________________ Fax __________________
E-mail Address _____________________

Cadmus will process credit cards and Cadmus Journal Services will appear on the credit card statement.
If you don’t mail your order form, you may fax it to 410-820-9765 with your credit card information.

Signature __________________________ Date ______________________
Signature is required. By signing this form, the author agrees to accept the responsibility for the payment of reprints and/or all charges described in this document.

Page 1 of 2

RB-1/01/09
## Black and White Reprint Prices

<table>
<thead>
<tr>
<th># of Pages</th>
<th>Domestic (USA only)</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>$239</td>
<td>$260</td>
<td>$285</td>
<td>$303</td>
<td>$323</td>
<td>$340</td>
<td></td>
</tr>
<tr>
<td>5-8</td>
<td>$379</td>
<td>$420</td>
<td>$455</td>
<td>$491</td>
<td>$534</td>
<td>$572</td>
<td></td>
</tr>
<tr>
<td>9-12</td>
<td>$507</td>
<td>$560</td>
<td>$651</td>
<td>$684</td>
<td>$748</td>
<td>$814</td>
<td></td>
</tr>
<tr>
<td>13-16</td>
<td>$627</td>
<td>$698</td>
<td>$874</td>
<td>$954</td>
<td>$1,038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-20</td>
<td>$755</td>
<td>$845</td>
<td>$974</td>
<td>$1,064</td>
<td>$1,166</td>
<td>$1,272</td>
<td></td>
</tr>
<tr>
<td>21-24</td>
<td>$878</td>
<td>$985</td>
<td>$1,115</td>
<td>$1,250</td>
<td>$1,377</td>
<td>$1,518</td>
<td></td>
</tr>
<tr>
<td>25-28</td>
<td>$1,003</td>
<td>$1,136</td>
<td>$1,294</td>
<td>$1,446</td>
<td>$1,607</td>
<td>$1,757</td>
<td></td>
</tr>
<tr>
<td>29-32</td>
<td>$1,128</td>
<td>$1,281</td>
<td>$1,459</td>
<td>$1,632</td>
<td>$1,819</td>
<td>$2,002</td>
<td></td>
</tr>
<tr>
<td>Covers</td>
<td>$149</td>
<td>$164</td>
<td>$219</td>
<td>$275</td>
<td>$335</td>
<td>$393</td>
<td></td>
</tr>
</tbody>
</table>

Minimum order is 50 copies. For orders larger than 500 copies, please consult Cadmus Reprints at 800-407-9190.

### Reprint Cover

Cover prices are listed above. The cover will include the publication title, article title, and author name in black.

### Shipping

Shipping costs are included in the reprint prices. Domestic orders are shipped via FedEx Ground service. Foreign orders are shipped via a proof of delivery air service.

### Multiple Shipments

Orders can be shipped to more than one location. Please be aware that it will cost $32 for each additional location.

### Delivery

Your order will be shipped within 2 weeks of the journal print date. Allow extra time for delivery.

## Color Reprint Prices

<table>
<thead>
<tr>
<th># of Pages</th>
<th>Domestic (USA only)</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>$247</td>
<td>$267</td>
<td>$385</td>
<td>$515</td>
<td>$650</td>
<td>$780</td>
<td></td>
</tr>
<tr>
<td>5-8</td>
<td>$297</td>
<td>$343</td>
<td>$655</td>
<td>$923</td>
<td>$1,194</td>
<td>$1,467</td>
<td></td>
</tr>
<tr>
<td>9-12</td>
<td>$445</td>
<td>$563</td>
<td>$926</td>
<td>$1,339</td>
<td>$1,748</td>
<td>$2,162</td>
<td></td>
</tr>
<tr>
<td>13-16</td>
<td>$587</td>
<td>$710</td>
<td>$1,201</td>
<td>$1,748</td>
<td>$2,297</td>
<td>$2,843</td>
<td></td>
</tr>
<tr>
<td>17-20</td>
<td>$738</td>
<td>$858</td>
<td>$1,474</td>
<td>$2,167</td>
<td>$2,846</td>
<td>$3,532</td>
<td></td>
</tr>
<tr>
<td>21-24</td>
<td>$888</td>
<td>$1,005</td>
<td>$1,750</td>
<td>$2,575</td>
<td>$3,400</td>
<td>$4,230</td>
<td></td>
</tr>
<tr>
<td>25-28</td>
<td>$1,035</td>
<td>$1,164</td>
<td>$2,034</td>
<td>$2,986</td>
<td>$3,957</td>
<td>$4,912</td>
<td></td>
</tr>
<tr>
<td>29-32</td>
<td>$1,186</td>
<td>$1,311</td>
<td>$2,302</td>
<td>$3,402</td>
<td>$4,509</td>
<td>$5,612</td>
<td></td>
</tr>
<tr>
<td>Covers</td>
<td>$149</td>
<td>$164</td>
<td>$219</td>
<td>$275</td>
<td>$335</td>
<td>$393</td>
<td></td>
</tr>
</tbody>
</table>

Tax Due

Residents of Virginia, Maryland, Pennsylvania, and the District of Columbia are required to add the appropriate sales tax to each reprint order. For orders shipped to Canada, please add 7% Canadian GST unless exemption is claimed.

### Ordering

Reprint order forms and purchase order or prepayment is required to process your order. Please reference journal name and reprint number or manuscript number on any correspondence. You may use the reverse side of this form as a proforma invoice. Please return your order form and prepayment to:

**Cadmus Reprints**
P.O. Box 751903  
Charlotte, NC  28275-1903

**Note:** Do not send express packages to this location, PO Box.  
FEIN #:541274108

Please direct all inquiries to:

**Rose A. Baynard**  
800-407-9190 (toll free number)  
410-819-3966 (direct number)  
410-820-9765 (FAX number)  
baynardr@cadmus.com (e-mail)

Reprint Order Forms and purchase order or prepayments must be received 72 hours after receipt of form.