The interpretation of imaging findings in the premenopausal patient with acute pelvic pain is influenced by knowledge of the physiologic changes that occur in the pelvis as well as by the patient’s clinical history. Although ultrasonography (US) is the modality of choice for initial imaging, gynecologic disease is detected or suspected with increasing frequency at computed tomography (CT) because of the increasing availability and use of this modality. As a result, the recognition of common features of gynecologic entities on both US and CT images is essential for prompt diagnosis and expeditious management. Categorizing lesions according to their anatomic location, physiologic or pathologic origin, and internal characteristics (cystic, solid, or mixed) allows efficient and accurate diagnosis.
Introduction

Acute pain of pelvic origin is a common symptom necessitating emergent medical evaluation. The duration of acute pelvic pain may range from several hours to several days, and its possible causes span a gamut from functional ovarian cysts that require routine follow-up to adnexal torsion and ectopic pregnancy requiring urgent surgical management. All these events occur in premenopausal patients, and prompt diagnosis allows potentially ovary-sparing or life-saving surgery (1).

Clinical evaluation and laboratory testing are essential when a gynecologic condition is suspected to be the cause of acute pelvic pain. For the initial diagnostic imaging evaluation, ultrasonography (US) is the modality of choice. High-frequency endovaginal transducers allow excellent anatomic depiction and pathologic characterization. However, computed tomography (CT) also is often performed in patients with referred pain beyond the pelvis or in those who present after hours. The general after-hours availability of CT scanners contributes to the increasing frequency of the use of CT to evaluate patients with acute pelvic pain. As a result, knowledge of both the US and the CT features of acutely painful gynecologic conditions is beneficial.

Given the many possible causes of pelvic pain, a structured approach to image interpretation is necessary to narrow the differential diagnosis. First, the distinction between pregnant and non-pregnant patients, as determined by beta human chorionic gonadotropin (β-hCG) levels in correlation with menstrual history, is crucial. This clinical information portends the physiologic changes that may be expected and allows accurate image interpretation.

Pathologic gynecologic conditions may be grouped, first, according to their anatomic origin. Further, US and CT characterization of lesions as simple cysts, complex cysts, or mixed cystic or solid structures helps narrow the diagnostic possibilities. It is important also to remember the general difficulty of distinguishing between lower abdominal pain and pelvic pain. Pelvic pain may exist in the absence of a gynecologic cause, and US and CT images may depict nongynecologic disease if the initial imaging protocols are not tailored too narrowly within the pelvic region (2).

Ovaries

Ovarian cysts are a common source of acute pelvic pain. Many ovarian cysts are physiologic in origin. Normal physiology drives the monthly emergence of one or more dominant follicles. Pelvic pain may occur as the follicle matures and the ovarian capsule is stretched, at the time of ovulation (Mittelschmerz), or after cyst rupture or hemorrhage. Any mass ovarian lesion predisposes the ovary to torsion on its vascular pedicle, although torsion also occurs in the absence of an ovarian mass in prepubertal girls.

Follicular Cysts

Ovarian follicles are estrogen sensitive. Most remain nonovulatory, have a diameter of less than 10 mm, and are routinely depicted at US and CT (Fig 1). The persistent absence of nonovulatory follicles is suggestive of a peri- or postmenopausal state. During the first half of the menstrual cycle, follicle-stimulating hormone drives follicular enlargement at a rate of roughly 2 mm per day. Eventually, one or more dominant (Graafian) follicles with a diameter of 18–25 mm emerge. (Although these enlarged follicles are cystic in nature, it is appropriate to refer to them as follicles and reserve the term cyst for structures larger than 2.5–3.0 cm.) A surge in luteinizing hormone then triggers ovulation and the conversion of the dominant follicle into the corpus luteum (3).

When a dominant follicle fails to expel an oocyte, the follicle may further enlarge into a cyst. Follicular cysts often measure 3–8 cm in diameter and may remain hormonally sensitive. In pregnancy (with successful ovulation from another follicle), placental gonadotropin production causes luteinization of the follicular cyst, which may enlarge to as much as 25 cm. Most cysts are asymptomatic and incidentally discovered, if they are discovered at all. However, pain may develop because of rapid cystic enlargement, rupture, or hemorrhage, alone or in combination.

Follicular cysts are the most common well-defined adnexal masses. Arising from and compressing the adjacent ovarian parenchyma, they are easily recognized and localized at US and CT. At US, a lesion may be identified as intraovarian if it is surrounded by a rim of follicle-containing ovarian tissue. Follicular cysts are unilocular, contain anechoic fluid, and produce posterior through-transmission of sound waves (Fig 2a). Minimal low-level echoes related to proteina-
ceous fluid or cellular debris may be present and are always mobile. Cysts that are discovered incidentally typically involute and resolve in the course of one to two menstrual cycles. Follow-up US to verify their resolution is best performed on days 5–10 (follicular phase) of a subsequent menstrual cycle. Large follicular cysts may persist beyond a single menstrual cycle, and, less commonly, may endure through several cycles. There may be some overlap in appearance between follicular cysts and cystadenomas; however, the latter tend to be larger and more persistent, and they are more often found in older women.

At CT, a follicular cyst appears as a well-defined round simple fluid collection with thin nonenhancing walls (Fig 2b) and with internal attenuation.
that is generally less than 15 HU. When a follicular cyst is incidentally detected at CT, US need not be performed immediately for confirmation and may be deferred until the routine follow-up evaluation (4).

**Cystic Corpus Luteum**
When ovulation and implantation have occurred, luteinizing hormone drives the transformation of the remaining follicular bed into the corpus luteum. The granulosa cells of the follicle, previously avascular, undergo marked neoangiogenesis. The newly developed vasculature allows the delivery of progesterone produced by the corpus luteum into the maternal circulation but also predisposes the corpus luteum to hemorrhage. The corpus luteum is maintained by circulating β-hCG, which has an effect similar to that of luteinizing hormone. The corpus luteum normally regresses at the end of the first trimester, as the placenta becomes the dominant source of progesterone. Either the failure of the corpus luteum to involute or its hemorrhage may result in cystic enlargement. The distinction between a hemorrhagic corpus luteum and a corpus luteum cyst is largely arbitrary, with some authors using a size of 2 cm as the threshold differentiating a cyst (5).

The walls of luteal cysts are thicker than those of follicular cysts on both US and CT images and may be irregular because of a recent rupture or an adherent clot. The internal contents of the corpus luteum may be anechoic or isoechoic at US, depending on the degree and age of hemorrhage. Posterior through-transmission helps differentiate the corpus luteum from a solid mass, which may have echogenic components and a posterior shadow (6). Color Doppler US depicts increased peripheral vascularity of the corpus luteum (Fig 3).

Wall enhancement at CT is caused by the proliferation of blood vessels. Luteal cysts are often unilocular, with thick, crenulated walls (7). Attenuation of the luteal cyst is high because of the intracystic presence of blood products. When rupture has occurred, CT depicts fluid surrounding the adnexa (Fig 4).

**Hemorrhagic Ovarian Cysts**
Hemorrhage into a follicular cyst or corpus luteum generates pain and may lead to an emergent presentation. There is considerable overlap in the imaging appearance of hemorrhagic follicular and corpus luteum cysts, and their differentiation is dependent primarily on the clinical history. Temporal correlation of a symptomatic cyst with the luteal phase of the menstrual cycle or with a positive β-hCG level favors the diagnosis of hemorrhagic corpus luteum.

The US pattern varies according to the age of the hemorrhage and the degree of clot for-
based detection of endometriosis is not currently possible because the multiple diffuse implants are too small. As much as 80% of ectopic endometrial tissue is found in the ovaries. When larger focal deposits of endometrial tissue are present in the ovary, these endometriomas are detectable at imaging (9). Secondary rupture or infection of an endometrioma may lead to acute presentation, but such occurrences are uncommon.

Endometriomas are complex cystic masses. A US finding of uniform low-level echogenicity or a ground-glass appearance is a result of repeated episodes of cyclic bleeding and corresponds to the finding of a "chocolate cyst" at gross examination. The typical appearance is that of a complex mass with internal echoes and some degree of posterior through-transmission. Although fresh blood may be anechoic initially, a hemorrhagic cyst is defined by low-level echogenicity in a fine, lacelike, reticular pattern for the first 24 hours, and this pattern is diagnostically specific (6,8) (Fig 5). As clot retraction occurs, US may depict triangular or curvilinear echogenic regions at the cyst wall. Fluid-debris levels develop as the clot liquefies.

Hemorrhagic ovarian cysts before rupture often appear unilocular on CT images, with an internal attenuation of 25–100 HU. Fluid-fluid levels and hemoperitoneum may be observed after cyst rupture. When hemorrhagic ovarian cysts are detected initially at CT, they need not be immediately evaluated with US unless there is substantial hemoperitoneum. Instead, follow-up US may be performed within one or two menstrual cycles to determine whether the cyst has resolved (7).

**Endometriomas**

Endometriosis affects an estimated 10% of premenopausal women. Ectopic endometrial tissue is estrogen sensitive, and it proliferates and bleeds synchronously with the endometrium. Without the normal drainage pathway of the vagina, bleeding from endometrial implants in the adnexa, uterosacral ligaments, or peritoneum often causes cyclic pelvic pain. The imaging-
episodes of bleeding (Fig 7). Both US and CT findings have low specificity for the diagnosis of endometriomas. Follow-up imaging is useful for differentiating endometriomas from pathologic entities such as hemorrhagic ovarian cysts, which resolve, and malignancies, which progress.

**Teratomas**

Another common complex mass arising from the ovary is the cystic teratoma or dermoid cyst. These lesions represent 96% of germ-cell tumors and 15% of all ovarian tumors (12). The vast majority of teratomas are mature and benign, with 99% demonstrating a cystic component. Teratomas are lined with squamous epithelium and contain elements from all three germ layers. They are bilateral in 15%–20% of cases, and they are associated with torsion in more than 15% of cases (13).

The US appearance is varied because of the presence of hyperechoic fat, teeth, and hair, as well as fluid in various amounts (Fig 8). Both predominantly cystic and predominantly solid masses have been described with approximately equal frequency. Echogenic shadowing mural nodules (Rokitansky nodules or dermoid plugs), which often contain hair or calcification, may be observed at US and are diagnostically specific (14). Complete posterior shadowing aids in the differentiation of mural nodules in teratomas from dependent thrombi in hemorrhagic cysts or endometriomas, which generally allow some posterior through-transmission (15).

On CT images, regions with fat attenuation are observed in more than 90% of cases. Mural nodules also are commonly seen on images that show the cyst wall in cross section, and they rarely enhance. Calcifications or teeth most often are found within mural nodules, but they also may be seen in cystic septa or walls. When cystic teratomas produce ovarian torsion, the resultant congestion and edema are manifested in thickening of the cyst wall, free pelvic fluid, or both (16).

**Cystadenomas**

Serous and mucinous subtypes of cystadenoma represent the most common ovarian tumors. The majority of mucinous tumors occur in postmenopausal women and therefore are unlikely to be confused with the other acute pathologic entities described in this article.

When a cystadenoma is present, both US and CT depict a complex cystic adnexal mass with internal attenuation that varies with the proteinaceous content of the lesion. Like any adnexal mass, a cystadenoma predisposes the ovary to torsion; however, because the lesion grows slowly, its first manifestation is often chronic pelvic pain or an abdominal mass.

**Torsion**

Adnexal torsion occurs when the ovary, with the surrounding tissues, becomes twisted on its vascular pedicle. Torsion generally occurs in
solid masses have been described. As the vascular pedicle twists, the low-pressure conduits of the venous and lymphatic system become occluded. US findings that result from this occlusion of outflow include engorgement of the ovary, with central hyperechogenicity indicative of edema and with enlarged (up to 25 mm in diameter) nonovulatory follicles at the periphery (Fig 9). Ischemia contributes to edematous ovarian enlargement (19). Alternatively, US images may depict the cyst (or, less commonly, the mass) that predisposed the ovary to torsion. As torsion progresses, hemorrhagic infarction occurs, and corresponding hypoechoic regions are observed on US images. Free fluid also is commonly detected, but this finding is nonspecific.

Ovarian viability in the presence of torsion is difficult to determine. Since the ovary receives a dual arterial supply (from the aorta via the ovarian artery and from the adnexal, or ovarian, branch of the uterine artery), high-grade torsion is necessary to produce inflow occlusion. Color Doppler images that show an absence of arterial waveforms or high resistance to arterial flow with absent venous flow are highly suggestive of ovarian torsion, particularly when those findings are accompanied by ovarian enlargement. However, the converse does not hold true (ie, normal arterial waveforms do not rule out torsion). In a series of girls younger than 16 years, arterial flow was demonstrated in 40% of ovaries with proved torsion at laparoscopy (17). The absence
of arterial waveforms should be interpreted with consideration of the clinical manifestations and technical factors (eg, body habitus and distance of the ovary from the transducer).

Gray-scale US may directly depict the twisted vascular pedicle. As the transducer scans longitudinally along the vascular pedicle, real-time US reveals swirling of the vasculature. This so-called whirlpool sign is reported to be specific for adnexal torsion. In addition, color Doppler evaluation of the pedicle in the presence of torsion is thought to allow determination of ovarian viability (20). However, the reliability of such an evaluation is limited by the operator’s skill, and, to our knowledge, there is no US sign that is widely acknowledged to be indicative of ovarian viability.

At CT, the finding of an adnexal mass or enlarged ovary with a diameter of more than 5 cm may be suggestive of torsion. Smooth wall thickening to more than 3 mm in cystic adnexal masses also has been reported in the presence of torsion (21). Because of the thickened wall, the fallopian tube often has the appearance of a targetlike mass between the adnexa and uterus (Fig 10). Additional findings may include ascites and uterine deviation toward the affected side, which are present in more than 40% of cases (22). Lack of contrast enhancement, or hematoma due to hemorrhagic infarction, also may be depicted. However, the overall accuracy of CT is inferior to that of US in the preoperative diagnosis of adnexal torsion (23).

Nonovarian Adnexa

Paraovarian Cysts

Although paraovarian cysts are not of ovarian origin, they are categorized with other simple cysts that may cause pain due to rupture or torsion. Paraovarian cysts, which represent 10%–20% of all adnexal masses, arise from the pelvic mesothelium and paramesonephric tissue, although there are rare reports of paraovarian cysts with mesonephric (Wolffian) duct origin. The US and CT appearance of these cysts is similar to that of simple cysts found in other anatomic sites: well defined, unilocular, and containing homogeneously anechoic fluid (24). A diagnosis of paraovarian cyst is favored when the ovary is depicted as separate from the cyst; however, clear depiction of its separateness is often prevented by adnexal distortion (Fig 11). Large paraovarian cysts have been described in locations superior to the bladder, possibly having migrated there during their enlargement (25). Because paraovarian cysts are not hormonally responsive, their imaging appearance does not change over time. Stability at follow-up examinations during different
monly result in a predisposition to the formation of such adhesions. US depicts a normal-appearing ovary that is surrounded by loculated fluid, in a pattern resembling a spider web (26). Diagnosis at CT may be more difficult. The fluid collections are often irregular, conforming to the borders of adjacent organs or the peritoneal wall. The wall of the collection itself is generally thicker than that of a paraovarian cyst (27) (Fig 12).

Hydrosalpinx

The fallopian tubes shuttle the ovum to the uterus for implantation. Typically 1–4 mm in diameter (28), the fallopian tubes are not regularly seen on US or CT images. At US, the depiction of normal fallopian tubes is possible only when they are outlined by ascites. Direct depiction otherwise is a marker of a pathologic process. When adhesions obstruct the fimbriated end of the fallopian tube, hydrosalpinx results because of the accumulation of intraluminal secretions.

US depicts the fallopian tube as a fusiform tubular structure extending between the uterus and adnexa. Tapering of the proximal fallopian tube as it enters the uterus is a useful sign for anatomic localization. The internal fluid is anechoic, and dynamic imaging reveals multiple folds in the tube (28) (Fig 13). Real-time US has the added advantage of documenting the absence phases of the menstrual cycle, in particular, is suggestive of the diagnosis.

Peritoneal Inclusion Cysts

Pelvic adhesions that surround the ovary and create complex cystic masses must be differentiated from paraovarian cysts and hydrosalpinx. Previous surgery and pelvic inflammatory disease common result in a predisposition to the formation of such adhesions. US depicts a normal-appearing ovary that is surrounded by loculated fluid, in a pattern resembling a spider web (26). Diagnosis at CT may be more difficult. The fluid collections are often irregular, conforming to the borders of adjacent organs or the peritoneal wall. The wall of the collection itself is generally thicker than that of a paraovarian cyst (27) (Fig 12).
of peristalsis within the fallopian tube, a finding that helps differentiate hydrosalpinx from a fluid-filled loop of small bowel. Isolated torsion of the fallopian tubes without an adnexal abnormality is possible but rare, with an estimated incidence of one in 1.5 million women (29). The occurrence of isolated torsion after tubal ligation is signaled by fusiform tubal dilatation and surrounding pelvic inflammation. Hydrosalpinx has a similar appearance at CT, which generally shows paired tubular juxtauterine structures filled with simple fluid.

**Ectopic Pregnancy**
Ectopic pregnancy is always a consideration in women of reproductive age with acute pelvic pain and with a positive \( \beta \)-hCG level. Imaging features of ectopic pregnancy are described in another article in this issue (30) and therefore are not discussed here.

**Pelvic Inflammatory Disease**
Pelvic inflammatory disease refers to a gamut of infectious conditions of the upper reproductive tract, including endometritis, salpingitis, and tuboovarian abscess. The source of disease is typically an ascending lower tract infection, although hematogenous spread and direct extension of an infection (eg, from an adjacent abscess) also are possible. *Neisseria gonorrhoeae* or *Chlamydia trachomatis* is believed to be the offending agent in two-thirds of cases, but polymicrobial infection also has been reported (31). As many as 24% of visits to the emergency department for gynecologic pain are attributable to pelvic inflammatory disease. Presentation with a report of dull and aching pain usually occurs 7–10 days after menstruation (1).

Early in the course of such an infection, US and CT findings may be normal. As the infection progresses, US demonstrates a loss of normal tissue planes and an ill-defined uterus. Uterine enlargement may be present and is most noticeable at transabdominal US. Thickening of the endometrium may be present but is nonspecific. Because fluid within the endometrial canal may mimic a gestational sac, this finding should be correlated with the \( \beta \)-hCG level.

Salpingitis may progress to hydrosalpinx or pyosalpinx if left untreated. In pyosalpinx, US images show complex fluid with echogenic debris distending the fallopian tubes. Other imaging clues include folding of the tubular structure, tapering of the ends, and short linear echogenic foci projecting into the lumen (32). At later stages, tuboovarian abscesses may form. This continuum involves the production of increasing amounts of inflammatory exudates, pus, and
The uterosacral ligaments may appear thickened. When a tuboovarian abscess is present, CT images show complex fluid-attenuation collections with thickened and irregularly enhancing walls (Fig 14b). Anterior displacement of the broad ligament because of the posterior position of the mesovarium may allow differentiation of a tuboovarian abscess from a pelvic abscess of other origin (33). Unlike tuboovarian abscesses, which result from an ascending pelvic infection, general pelvic abscesses result from an adjacent infection in the appendix, colon, or (uncommonly) bladder. These abscesses may have a thicker wall and may be located at a distance from the adnexa (Fig 15).

**Teaching Point**
The uterosacral ligaments may appear thickened. When a tuboovarian abscess is present, CT images show complex fluid-attenuation collections with thickened and irregularly enhancing walls (Fig 14b). Anterior displacement of the broad ligament because of the posterior position of the mesovarium may allow differentiation of a tuboovarian abscess from a pelvic abscess of other origin (33). Unlike tuboovarian abscesses, which result from an ascending pelvic infection, general pelvic abscesses result from an adjacent infection in the appendix, colon, or (uncommonly) bladder. These abscesses may have a thicker wall and may be located at a distance from the adnexa (Fig 15).

**Free Pelvis Fluid**
Free intraperitoneal fluid is demonstrable at US and CT. A small simple fluid collection (3–5 mL) that is anechoic at US and has attenuation of less than 20 HU at CT is often physiologic. A collection of more than 10 mL should arouse concern about the possibility of a pathologic process (2). Although free intraperitoneal fluid usually is found in the most dependent region of the pelvis, the rectouterine pouch of Douglas, fluid also may be depicted immediately adjacent to a ruptured ovarian cyst (Fig 16). When the presence of a pathologic fluid collection is suspected but not
trial fluid in the nongravid uterus is nonspecific, it has been described in association with cystic teratomas and ruptured corpus luteum cysts (36).

Fibroids
Benign smooth-muscle tumors (leiomyomas and fibroids) are the most common tumors of the uterus; they are found in more than one-fifth of women over the age of 30 years (9). These estrogen-dependent tumors are found, in order of decreasing frequency, in an intramural, subse-
during the period of greatest increase in myometrial volume, generally before 10 weeks of gestation (37). Pedunculated fibroids are predisposed to torsion (38) (Fig 19).

US shows a solid uterine mass, typically with minimal echotexture (Fig 20a), although heterogeneity may result from necrotic degeneration. Calcifications within the fibroid, which are more common in older patients, appear as hyperechoic foci with posterior shadowing, but that finding is of little clinical relevance. CT is helpful for confirming US findings of a solid soft-tissue uterine mass. The uterus may be enlarged. A lobulated uterine contour has been reported in the presence of fibroids that extend beyond the mucosal or serosal layer. A central region of low attenuation within a fibroid is suggestive of internal degeneration, and heterogeneous contrast enhancement may be present (Fig 20b). Pedunculated subserosal fibroids have been described as juxtauterine masses with peripheral enhancement and necrotic centers at CT (9,38).

Figure 20. Degenerating fibroid. (a) Longitudinal transvaginal color Doppler US image of the inferior part of the uterus demonstrates a complex cystic mass with internal echogenicity and no internal vascularity. (b) Axial contrast-enhanced CT image shows an isoattenuating uterine mass with a well-defined complex cystic center (arrow) containing fluid and debris layering, a feature indicative of hemorrhagic degeneration.

Figure 21. Intrauterine contraceptive device. Axial CT image shows a T-shaped device in the appropriate position.

Intrauterine Contraceptive Devices
Intrauterine device placement is commonly performed for the purpose of contraception. The US and CT appearances vary according to the type of device, but a T-shaped device is the most commonly seen within the uterus (Fig 21). The
device appears well defined, hyperechoic at US, and hyperattenuating at CT. Rarely (in approximately 0.1% of cases), perforation into or through the myometrium may occur as a complication of intrauterine device placement (39). When perforation occurs, hemorrhage and free pelvic fluid are possible, with associated pelvic pain. The finding of an intrauterine device within the myometrium is highly suggestive of perforation. A device also may migrate by tracking into a surgical scar. Linear coils designed to occlude the fallopian tubes may migrate into the endometrial canal or enter the myometrium by perforation (Fig 22).

Summary
Multiple entities, including normal physiologic changes, may cause acute pelvic pain in premenopausal patients. Correlation of the individual clinical history with imaging features (especially the anatomic location and morphologic characteristics) is beneficial for narrowing the diagnostic possibilities. Knowledge of the common US and CT appearances of various normal and abnormal gynecologic conditions allows their accurate diagnosis and expeditious management.

References

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US and CT Evaluation of Acute Pelvic Pain of Gynecologic Origin in Nonpregnant Premenopausal Patients

Andrew W. Potter, MD, and Chitra A. Chandrasekhar, MBBS

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Please direct all inquiries to:

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