CT and Sonographic Evaluation of Acute Right Lower Quadrant Abdominal Pain

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Acute right lower quadrant (RLQ) abdominal pain is a common chief complaint in clinical practice. The term "acute abdomen" may be applied if the onset of pain is sudden and unexpected and if the pain is present for less than 24 hr and associated with gastrointestinal symptoms. The differential diagnosis of acute RLQ pain includes a broad spectrum of clinical entities that range from benign self-limited disorders to illnesses associated with high morbidity. In up to 30% of cases, no pathologic diagnosis is ever made and symptoms resolve spontaneously without intervention [1]. It is often difficult on the basis of history and physical examination alone to separate these patients from those who require immediate surgery. The increased availability and use of CT and sonography have dramatically changed the clinical examination and treatment of patients who present with acute abdominal pain. These noninvasive imaging techniques have effectively replaced exploratory laparotomy as the primary means of examining patients who present with what was formerly known as a "surgical abdomen." This article will review the indications for, technique of, and imaging findings in CT and sonography of patients with acute RLQ pain.

Appendicitis

Appendicitis is the most common cause of acute RLQ pain. An accurate diagnosis can be established in most patients on the basis of history, physical examination, and simple laboratory tests. Because the surgical goal is to operate early before appendiceal perforation and perforitits develop, patients who present with typical findings undergo immediate laparotomy without radiologic examination. Unfortunately, the presenting features of appendicitis may be protean in nature. Diagnostic difficulty is greatest in the 20–33% of patients who present with atypical clinical findings [2, 3]. This difficulty has resulted in an average negative laparotomy rate of approximately 20% [2–5]. The diagnosis is most difficult to establish in preschool children, women from 20 to 40 years old, and the elderly. In fact, the surgical removal of a normal appendix increases to 35–45% in young women of reproductive age, in whom the distinction from pelvic inflammatory disease and acute gynecologic disorders may be extremely difficult [4].

Surgeons have traditionally accepted higher rates of unnecessary appendectomies to avoid the increased morbidity of appendiceal perforation. However, the medical and economic consequences of this approach are difficult to justify in the current cost-effective health care environment and have led to a resurgence of clinical investigation directed toward noninvasive imaging of patients with suspected appendicitis.

The result has been the performance of more than 100 studies during the past decade to evaluate the role of sonography and CT in patients with acute RLQ pain [6]. Sonography and CT have effectively replaced barium enema examination as the primary means of examining patients with suspected appendicitis. These cross-sectional imaging techniques enable direct visualization of the inflamed appendix, in contrast to barium enema examination, in which appendicitis is typically diagnosed on the basis of indirect evidence of inflammation (i.e., nonfilling of the appendix with extrinsic cecal mass effect). Barium enema examination has assumed a secondary, complementary role to that of sonography and CT, and may be helpful in evaluating complex colonic abnormalities detected with cross-sectional imaging (e.g., atypical presentation of cecal diverticulitis or perforated neoplasm).

Graded-Compression Sonography

Graded-compression sonography and CT have proven diagnostic value in clinically questionable cases of acute appendicitis [7–27]. The choice between sonography and CT depends largely on institutional preference and available expertise. Graded-compression sonography is a rapid, noninvasive, and inexpensive means of imaging the inflamed appendix [7]. The technique requires no patient preparation or contrast material administration and is not associated with ionizing radiation. Because the examination is interactive, scanning can be performed at the site where the patient is most tender, enabling correlation of imaging findings with patient symptoms [16]. Evaluation of the
bowel is facilitated by the ability to define mural anatomy and to show peristalsis in real time. If the bowel is unremarkable, the remainder of the abdomen and pelvis can be surveyed to establish an alternative diagnosis.

The graded-compression technique is performed with high-frequency probes (5- to 7.5-MHz linear array transducers). The study is initiated by asking the patient to point to the site of his or her maximum pain, which is often helpful in locating an aberrantly positioned appendix. Graded compression is used to displace normal gas-containing bowel loops to facilitate visualization of the inflamed appendix, which does not compress. Real-time scanning is initiated in the transverse plane and is directed toward imaging the cecal tip and the origin of the appendix. The normal appendix, when visualized, appears as a blind-ending tubular structure that generally measures 5 mm or less in anteroposterior dimension [28]. Though Rioux [14] was able to identify a normal appendix in 102 (82%) of 125 patients without appendicitis, most observers report that a normal appendix is seen in only a small minority of cases (0–4%) [7, 11, 24]. If the appendix is not seen, the landmarks of the cecal tip and iliac vessels must be clearly visualized to consider such cases negative.

A confident diagnosis of appendicitis based on sonography is made if a noncompressible appendix measuring 7 mm or greater in anteroposterior diameter is identified [11, 28] (Fig. 1). Appendices measuring between 5 and 7 mm are borderline in size. Appendicitis may be diagnosed in these indeterminate cases by showing increased appendiceal perfusion with color Doppler examination [15, 29]. A shadowing appendicolith generally indicates a positive study (Fig. 2). Gangrenous appendicitis may be suggested when loss of the echogenic submucosal layer occurs and color Doppler flow to that segment of the appendix is absent. Echogenic periappendiceal tissue indicates inflammation of adjacent mesenteric or omental fat. Periappendiceal abscesses typically appear as localized hypoechoic fluid collections with mass effect (Fig. 3A). Often increased flow on color Doppler sonography is noted surrounding the abscess (Fig. 3B).

Prospective studies of graded-compression sonography have demonstrated sensitivities of 75–90%, specificities of 86–100%, accuracies of 87–96%, positive predictive values of 91–

Fig. 1.—Typical sonographic appearance of appendicitis in 42-year-old man. Note dilated, noncompressible appendix (arrow) with echogenic intraluminal debris. Surgical exploration revealed nonperforated appendix. Numeric scale indicates depth (in sonometers) from transducer.

Fig. 2.—Acute appendicitis in 22-year-old woman with right lower quadrant pain. Sonogram shows multiple appendicoliths (arrows) within dilated appendix that were confirmed at surgery.

Fig. 3.—Surgically proven retrocecal appendiceal abscess in 64-year-old man. A, Sonogram reveals hypoechoic mass (arrow) posterior to cecum (C). B, Color Doppler sonogram shows marked hyperemia surrounding abscess (arrow).
94%, and negative predictive values of 89–97% for acute appendicitis [7–11, 13, 15]. In experienced hands, sonography can also show most entities requiring medical or surgical intervention that mimic acute appendicitis [30]. An important limitation of graded-compression sonography, however, is that it is an operator-dependent technique that requires considerable experience and expertise. Diagnostic specificity suffers in the presence of perforation, examination may be difficult with retrocecal appendicitis or in overweight patients, and nondiagnostic studies may result if abdominal pain and guarding prevent adequate RLQ compression [8, 28, 31]. Sonographic false-negative diagnoses may also result if a gas-filled or markedly dilated appendix is missed for small bowel, or in cases of early appendicitis in which inflammation is confined to the distal tip and the proximal appendix appears normal.

High-Resolution CT

CT is an accurate, easy, and rapid means of diagnosing and staging acute appendicitis. The emerging usefulness of CT in this clinical setting has paralleled advances in CT technology. Initial reports described the CT findings in advanced cases of perforated appendicitis [18–20]. Subsequent reports documented the ability of CT to show milder and more incipient forms of appendiceal inflammation [21–25]. These investigations confirmed that the sensitivity and specificity of CT diagnosis are maximized only when a deliberate effort is made to visualize the appendix.

Visualization of the appendix is determined by its size, the type and quality of the CT examination, the amount of mesenteric fat, and the degree of ileocecal bowel opacification. The normal appendix is identified in approximately 44–51% of routine abdominal CT studies in asymptomatic adults [32, 33]. It most commonly appears as a small tubular or ring-like pericecal structure within the RLQ. It is usually collapsed or slightly filled with fluid or air, has a pencil-thin wall, and is surrounded by the homogeneous fat density of the normal mesentry. The presence of a calcified appendicolith or appendiceal air has no clinical significance unless associated with appendiceal wall thickening or perappendiceal inflammation [34]. The ability of CT to show even small foci of calcification will occasionally result in detection of incidental nonobstructing appendicoliths. The appendix will appear otherwise normal in such cases. In contrast, findings of appendiceal inflammation are almost universally present in the setting of an obstructing appendicolith.

CT findings of acute appendicitis reflect the severity of inflammation. In mild appendicitis, the inflamed appendix appears as a slightly distended fluid-filled tubular structure that usually measures between 5 and 15 mm in diameter [21–23]. The appendiceal wall appears circumferentially and symmetrically thickened. The thickened wall is usually homogeneously dense on contrast-enhanced studies; however, a double-halo or target sign may be seen. Periappendiceal inflammation is usually present but may be absent in the most incipient cases [23] (Fig. 4). The inflammatory response ranges from subtle clouding of the mesoappendix in patients with mild appendicitis to frank phlegmon and abscess formation with associated ileocecal thickening in cases of perforation. A definitive CT diagnosis of appendicitis can be made if an abnormal appendix is identified or if a pericecal abscess or phlegmon is seen in association with an appendicolith [23, 24, 34] (Fig. 5). The simple presence of pericecal inflammation or an RLQ abscess is suggestive of but not specific for appendicitis. Another suggestive finding is the arrowhead sign, which results when focal symmetric thickening of the proximal cecum allows contrast media to funnel toward the origin of the occluded appendiceal orifice [35]. Identification of this sign may improve diagnostic confidence in cases of subtle appendicitis. Small regional lymph nodes occur in only a minority of adult patients with acute appendicitis. The reported incidence of these lymph nodes may be overstated on unenhanced CT examinations because unenhanced mesenteric vessels seen on end can mimic the appearance of adenopathy.

Optimized imaging of the appendix depends on the prospective acquisition of high-resolution (≤5-mm slice collimation) images of the RLQ. The benefits of improved z-axis resolution in this clinical setting were demonstrated by Balthazar et al. [23], who used conventional incremental dynamic CT and showed that 5-mm thin-section imaging enabled improved visualization of abnormal appendices (75% versus 18%), calcified appendicoliths (28% versus 23%), and findings typical of appendicitis (94% versus 79%) compared with prior investigations in which 10-mm slice collimation was used [21]. The use of thin-section helical CT has further enhanced appendiceal imaging by permitting acquisition of volumetric data sets unencumbered by respiratory misregistration. This technology has translated into improved detection of calcified appendicoliths, which were recently reported in 43–46% of patients with acute appendicitis [25, 27]. CT studies performed using high-resolution scanning techniques have shown sensitivities of 90–100%, specificities of 83–97%, accuracies of 93–98%, positive predictive values of 94–97%, and negative predictive values of 93–98% for acute appendicitis [23–25, 27].

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When compared with sonography, contrast-enhanced CT is more accurate in staging periappendiceal inflammation and abscesses, more likely to provide an alternative diagnosis in patients without appendicitis, and more sensitive for revealing the normal appendix [24]. This latter point is critical, because definitive exclusion of appendicitis requires visualization of the normal appendix in its entirety. Additional advantages of CT include the facts that this technique is operator-independent and that examination is not limited by patient body habitus.

Although most investigators stress the importance of administering IV and oral contrast media to patients with suspected appendicitis, this topic is now somewhat controversial. Supporters of contrast-enhanced CT maintain that IV contrast material is essential for diagnosing mild appendicitis in patients with a paucity of mesenteric fat; differentiating appendicitis with perforation from nonspecific pericecal phlegmon; distinguishing enhanced vessels from lymph nodes; evaluating the mural enhancement pattern as a means of differentiating benign from malignant causes of bowel thickening; and ensuring optimized characterization of the many gastrointestinal, genitourinary, and gynecologic disorders with which patients can present with acute lower abdominal pain [6, 21–24, 34, 36] (Fig. 6). These investigators also advocate the use of oral water-soluble iodinated contrast material (diatrizoate meglumine) to improve recognition of the normal or abnormal appendix and specifically to avoid misdiagnosing collapsed nonopacified ileal loops as the appendix. This scanning methodology is not universally agreed upon, however, because recent studies have shown excellent diagnostic results with unenhanced CT [26, 27]. Proponents of unenhanced CT contend that this technique allows patients to be scanned immediately because oral contrast material is not administered, that patients benefit from not being exposed to the potential risk of a contrast agent reaction, and that the lower cost of the unenhanced examination makes it a cost-effective imaging alternative to sonography [27]. Adequate opacification of RLQ bowel loops typically requires 45–60 min. As an alternative, Rao et al. [25] have promoted a focused appendiceal CT technique in which a limited helical CT study of the RLQ is performed after rapid administration of oral and colonic contrast material but without IV contrast media. These investigators achieved excellent diagnostic sensitivity (100%) and specificity (95%) with this technique and showed partial or complete opacification of the normal appendix in 29 (71%) of 41 patients without appendicitis. These results warrant further investigation, given the importance of identifying a normal appendix in patients with...
suspected appendicitis. To date, no prospective studies have been performed comparing the accuracy of enhanced and unenhanced CT in patients with acute RLQ pain. This type of investigation is needed because it may expose a potential reduction in diagnostic accuracy of unenhanced CT for establishing alternative diagnoses (e.g., pyelonephritis, bowel ischemia) in patients without appendicitis.

In addition to its high diagnostic accuracy, CT also serves as an accurate “road map” for determining the proper approach for surgical or percutaneous abscess drainage [37]. CT is especially useful in cases of perforation because it can reliably differentiate phlegmon from abscess. This distinction has important clinical significance because surgeons may treat patients with periappendiceal phlegmon or small abscesses with an initial nonsurgical trial of antibiotic therapy. Patients with liquefied abscesses may undergo percutaneous drainage if these appear well localized or immediate surgical exploration with drainage and appendectomy if abscess formation appears extensive and poorly defined [38].

Cecal Diverticulitis

Cecal diverticulitis is a relatively uncommon disorder that is usually misdiagnosed preoperatively as appendicitis. Cecal diverticulitis results from inflammation and perforation of acquired right-sided colonic diverticula, which occur in approximately 5% of patients with diverticular disease in developed Western countries. The frequency of cecal diverticulitis may be higher in Japan, where a greater incidence of right-sided diverticulosis exists [27, 39]. The sonographic findings consist of segmental hypoechoic mural thickening and adjacent inflammation of the fat, resulting in an echogenic mass [40, 41]. The inflamed diverticulum can often be identified as an echogenic outpouching within an area of asymmetric mural thickening. The diverticulum may cast an acoustic shadow and may contain a falciform or gas. The CT findings usually consist of mild asymmetric thickening of the cecal wall, focal pericolic inflammation, and the presence of diverticula [42] (Fig. 7). Marked asymmetric wall thickening and pericolic phlegmon or abscess may be noted in severe cases. Differentiation from appendicitis or perforated carcinoma may be difficult if the normal appendix is not seen or if a prominent soft-tissue mass component is present, respectively.

Perforated cecal carcinoma should be included in the differential diagnosis in patients more than 50 years old. Neoplasms generally appear as hypoechoic masses that cause asymmetric mural thickening and have less internal vascularity than inflammatory lesions. A confident CT diagnosis of perforated carcinoma can be made in the presence of contiguous organ invasion, malignant peritoneal implants, and distant metastases (Fig. 8). Strategically located tumors may also occlude the appendiceal orifice, causing mucinous dilatation or secondary appendicitis.

Typhlitis

Typhlitis, also known as neutropenic enterocolitis, is an acute inflammatory and necrotizing process of multifactorial origin that characteristically affects the cecum or the terminal ileum and appendix. Initially described in terminally ill leukemic children, typhlitis is also seen in adult patients with agranulocytosis after chemotherapy for hematologic malignancy and as a complication of immunosuppression for organ transplantation and with AIDS [43]. Infection by bacterial, viral, or fungal agents plays a dominant role; however, focal ischemia and neoplastic infiltration may coexist. Patients typically present with known risk factors, RLQ pain, fever, and diarrhea. Early diagnosis and aggressive treatment with broad-spectrum antibiotics are essential to avoid transmural necrosis and perforation. Sonography characteristically reveals circumferential mural thickening of the right colon [44]. CT findings include segmental bowel wall thickening, low-attenuation intramural regions indicative of edema or necrosis, pneumatosis coli, pericolic fluid, and perienteric stranding [45–47] (Fig. 9).

The differential diagnosis of acute right-sided colonic inflammation includes pseudomembranous colitis, which may occur in immunosuppressed individuals or in patients who have had prolonged antibiotic therapy complicated by Clostridium difficile enterotoxin overgrowth [48]. The inflammation is pancolonic in most cases; however, isolated involvement of the CT and Sonography of Acute Abdominal Pain

Fig. 8.—Perforated cecal carcinoma in 63-year-old woman with acute right lower quadrant pain and palpable mass. Contrast-enhanced CT scan shows heterogeneously enhancing, asymmetrically thickened cecum (C). Note direct extension of tumor toward abdominal wall (arrow) and inflammatory stranding of omentum (arrowhead). Perforated adenocarcinoma of cecum and proximal ascending colon was identified at surgery.

Fig. 9.—Typhlitis in 42-year-old female neutropenic patient who experienced acute right lower quadrant pain after undergoing bone marrow transplantation for multiple myeloma. Contrast-enhanced CT scan shows circumferential cecal wall thickening, heterogeneous bowel wall enhancement, and pneumatosis coli (arrow). Diagnosis was established on basis of characteristic imaging features and typical clinical presentation.
cecum and the ascending colon is not rare. The colon may appear near-normal with mild involvement. In severe cases, marked low-attenuation mural thickening is seen on CT, with intraluminal contrast agent trapped between swollen haustral folds. The CT appearance of pseudomembranous colitis is nonspecific. Colonic biopsies, stool cultures, and enzyme immunoassay of stool samples for toxin A or B may be needed to differentiate this entity from other infectious or inflammatory colitides [48].

Mesenteric Adenitis and Acute Terminal Ileitis
Mesenteric adenitis is an appendicitis-mimicking disorder whose self-limited symptoms relate to benign inflammation of lymph nodes within the ileal mesentery. Coexistent inflammation of the terminal ileum and cecum usually occurs. The disease commonly affects children and young adults and is most frequently caused by Yersinia enterocolitica, Y. pseudotuberculosis, and Campylobacter jejuni. The noninvasive diagnosis of mesenteric adenitis is suggested when graded-compression sonography or CT reveals moderately enlarged mesenteric lymph nodes with or without associated ileal or ileocecal wall thickening [49–51]. The appendix is usually not visualized by sonography in these cases [50, 51]. Because CT can show a normal appendix and definitively exclude appendicitis, it has greater diagnostic specificity in this clinical setting [49]. Patients with AIDS may develop mesenteric lymphadenitis resulting from Mycobacterium avium-intracellulare infection. This diagnosis should always be considered in HIV positive patients who have RLQ pain and cavitary adenopathy.

Crohn’s disease can present with mesenteric adenopathy; however, marked mural thickening of the terminal ileum is the most striking sonographic feature (Fig. 10), which may be associated with hyperemia of mural vessels on color Doppler imaging. A combination of thickened ileum, cecum, and appendix can occasionally be seen sonographically in both Crohn’s disease and appendiceal phlegmon [52]. These entities are distinguished by identifying the epicenter of the inflammatory process, which in Crohn’s disease manifests as severe ileocecal thickening with only minimal periappendiceal inflammation. The CT features of Crohn’s disease are well established and usually pose no diagnostic difficulty [53]. Characteristic findings include terminal ileal thickening with or without a target sign enhancement pattern on contrast-enhanced CT, fibrofatty proliferation of the ileal mesentery, reactive adenopathy, and perienteric sinus tracts and mesenteric abscesses in cases of severe extramural inflammation.

Small-Bowel Diverticulitis
The differential diagnosis of ileal inflammation includes ileal diverticulitis, a rare condition that arises as a result of inflammation of either an acquired ileal pseudodiverticulum or a true congenital Meckel’s diverticulum. The CT findings are usually nonspecific and consist of mural thickening with periienteric inflammation [54] (Fig. 11). A “target” appearance may be noted on contrast-enhanced examinations, indicative of nonneoplastic bowel wall thickening. The diagnosis can be suggested preoperatively if CT evidence exists of air-filled diverticula within the inflammatory process. This finding is unusual in our experience, however, and the diagnosis is usually confirmed by barium studies that show the presence of ileal diverticula with serosal inflammatory changes. A specific CT diagnosis of Meckel’s diverticulitis can be made if an obstructing enterolith is identified within the inflamed diverticulum.

Epiploic Appendagitis
Epiploic appendagitis is an unusual clinical entity that is thought to occur as a result of spontaneous torsion, ischemia, or inflammation of an epiploic appendage of the large bowel [55–57]. The condition presents with acute abdominal pain that can mimic appendicitis if the cecum or ascending colon is affected. The cause is uncertain; however, torsion has been reported after strenuous exercise and excessive stretching. Symptoms are self-limited and spontaneously regress. Sonographic findings include a small, echogenic, noncompressible ovoid mass that is usually located directly under the abdominal wall at the site of maximum tenderness [57]. The inflamed mass is often delineated by a hypoechoic line or ring. The corresponding CT features consist of a small pedunculated fat-
Acute Renal Obstruction

Patients with acute renal obstruction may present with RLQ pain when obstruction is caused by a distal ureteral calculus. Unenhanced helical CT is a rapid and effective means of detecting ureteral calculi, and this technique has replaced excretory urography as the screening method of choice in many centers. Smith et al. [60] have shown unenhanced helical CT can detect ureteral stone disease with a sensitivity of 97%, a specificity of 96%, and an accuracy of 97%. Associated secondary findings include ureteral dilatation, perinephric stranding, collecting system dilatation, asymmetric renal enlargement, and periureteral edema [61, 62] (Fig. 14). Periureteral edema typically presents as a circumferential rim of soft-tissue attenuation that surrounds the obstructing stone. This tissue-rim sign has proved useful in distinguishing obstructing ureteral calculi from meddlesome phleboliths [61]. If an unenhanced helical CT study is nondiagnostic, contrast-enhanced CT can follow, which may reveal renal infarction, renal vein thrombosis, or pyelonephritis in patients with acute flank pain and unenhanced CT studies with negative findings.

A confident sonographic diagnosis of acute urinary obstruction is made when hydronephrosis is present proximal to a shadowing stone. With distal calculi, the dilated ureter may be seen as it courses over the pelvic brim adjacent to the iliac vessels. Diagnostic efficacy is limited, however, in cases in which a ureteral calculus is not seen and hydronephrosis is minimal or nonexistent [63]. Color flow assessment of ureteric jets may help establish the diagnosis if the jet is completely absent or continuous low-level jets are present on the symptomatic side [64]. Transvaginal scanning is particularly useful in detecting distal ureteral calculi that are not seen transabdominally [65].

Acute Gynecologic Conditions

The most common gynecologic disorders that present with acute pelvic pain are ovarian cysts, pelvic inflammatory disease, adnexal torsion, and ectopic pregnancy. Because of the broad overlap between the clinical presentations of these diseases and acute appendicitis...

Fig. 11.—Meckel’s diverticulitis in 53-year-old man. Contrast-enhanced CT scan shows inflammatory mass medial to ileocecal valve (arrow). Note mild perienteric inflammatory stranding and asymmetric thickening of adjacent ileal small-bowel loop. Histologic review of surgical specimen revealed inflamed Meckel’s diverticulum lined by intestinal and gastric epithelium. (Courtesy of Bauman JS, Norwalk, CT)

Fig. 12.—Epiploic appendagitis in 40-year-old woman. Contrast-enhanced CT scan shows fat-attenuation mass with surrounding hyperattenuating rim arising from serosal surface of ascending colon (arrow). Note presence of mild inflammatory stranding of adjacent pericolic fat. Diagnosis was established on basis of characteristic CT features and clinical presentation. (Courtesy of Rao PM, Boston, MA)

Fig. 13.—Right-sided omental infarction in 70-year-old man with acute right lower quadrant pain. Contrast-enhanced CT scan reveals well-circumscribed, ovoid, fat-attenuation lesion with hyperattenuating streaks interposed between ascending colon and right anterolateral abdominal wall (arrow). Underlying colon appears normal. Diagnosis was made on basis of characteristic CT features and clinical presentation.
and the proven efficacy of sonography in pelvic imaging, many investigators consider sonography to be the screening technique of choice in young adult women with acute RLQ pain. The use of high-frequency transvaginal probes with color Doppler sonography affords unparalleled imaging of the female pelvis and should be used routinely in this clinical setting.

Functional cysts with or without hemorrhage are common in women of childbearing age. One should not assume that an adnexal cyst is the cause of the patient’s symptoms unless other disorders have been excluded. The sonographic appearance of hemorrhagic corpus luteum cysts varies with the temporal relationship between clot formation and clot lysis [66]. Clot is typically echogenic and may reveal a convex border if it is in the process of retraction (Fig. 15). Lyzed blood within a cyst often contains thin echogenic linear strands that assume a cobweb appearance. Areas of hemorrhage or clot appear avascular with color Doppler sonography. Occasionally, hemorrhagic cysts produce low-resistance waveforms and may mimic the appearance of ovarian tumors and other disorders.

Pelvic inflammatory disease produces a spectrum of sonographic findings. Transvaginal scanning may show normal findings in patients with early salpingitis. The diagnosis of pyosalpinx is suggested if sonography shows a dilated fallopian tube containing echogenic debris or a fluid–debris level; however, one must exclude hematosalpinx from an ectopic pregnancy [67] (Fig. 16). With progressive inflammation, transvaginal scanning may reveal ovarian enlargement, indistinct ovarian contours, and periovary fluid consistent with periophoritis. Tuboovarian abscesses result in complex pelvic fluid collections that often contain internal septations, mural irregularity, scattered low-level internal echoes, and fluid–debris levels. Because these abscesses rarely contain gas, identification of a gas-containing pelvic abscess should suggest a gastrointestinal source such as appendicitis, diverticulitis, or Crohn’s disease.

Ovarian torsion results from partial or complete rotation of the ovarian pedicle and is most commonly associated with underlying cysts or tumors. Typical sonographic features include an enlarged echogenic ovary containing prominent peripheral follicles that may be located in an extrapelvic location [68, 69]. Usually absent or diminished central venous flow is noted on color Doppler sonography; however, low-velocity (<5 cm/sec) arterial flow may be preserved at the periphery of the ovary as a result of its dual blood supply. Transvaginal color Doppler sonography characteristically shows complete absence of venous flow if the ovary is nonviable [70]. The differential diagnosis includes degeneration of

**Fig. 14.**—Obstructing ureteral calculus in 52-year-old man.
A, Unenhanced helical CT scan shows mild right-sided hydronephrosis and perinephric stranding (arrow).
B, Unenhanced helical CT scan at level of ureterovesical junction shows obstructing 3-mm calculus in distal right ureter (arrow). Calcified pelvic phlebolith lies posterolateral to left ureterovesical junction (arrowhead).

**Fig. 15.**—Hemorrhagic follicular cyst of right ovary in 19-year-old woman with right lower quadrant pain. Transvaginal sonogram shows echogenic clot (arrow) within right ovarian cyst. Follow-up scan 3 weeks later showed complete resolution.

**Fig. 16.**—Pelvic inflammatory disease in 26-year-old woman. Transvaginal sonogram shows enlarged fallopian tube (T) adjacent to normal right ovary (O). Echogenic fluid in cul-de-sac (arrow) is caused by pus in peritoneal cavity.
a uterine myoma. This diagnosis is suggested if color Doppler sonography reveals an avascular myoma where the patient is most tender (Fig. 17).

The diagnosis of ectopic pregnancy must be considered in all sexually active women who present with pelvic pain during their reproductive years. A negative pregnancy test effectively excludes this diagnostic possibility. If the test is positive, quantitative beta-hCG (human chorionic gonadotropin) levels may be correlated with transvaginal sonographic findings to differentiate a normal intrauterine pregnancy from either an abnormal intrauterine pregnancy or an ectopic pregnancy [71]. Ectopic pregnancy may be accurately diagnosed by identifying an extratubal yolk sac or living embryo. Visualization of an echogenic adnexal or tubal ring separate from the ovary that has prominent peripheral color Doppler sonography flow is strongly suggestive of the diagnosis [72] (Fig. 18).

The CT findings of most acute gynecologic disorders are nonspecific. Hemorrhagic ovarian cysts typically appear as high-attenuation (>25 H) adnexal masses. Follicular cysts may present with extensive hemoperitoneum if cyst rupture occurs with continued bleeding (Fig. 19). A diagnosis of tuboovarian abscess is made if a tubular, septate, cystic pelvic mass is identified in a patient with characteristic history (Fig. 20). Supportive findings include indistinctness of the pelvic floor fascial planes, increased density of the pelvic fat, and anterior displacement of the mesosalpinx [73]. The CT findings of ovarian torsion relate to the appearance of both the fallopian tube and the ovary. The involved fallopian tube often appears as a thickened and hemorrhagic tubular or comma-shaped structure that extends from the uterine cornua to the abnormal-appearing adnexa [74].

The ovary may appear hemorrhagic with complete absence of enhancement. Additional findings include hemoperitoneum, a peculiar protrusion that is continuous with the uterus, and prominently engorged blood vessels that seem to drape around the affected ovary [75].

**Conclusion**

A broad spectrum of clinical entities may cause acute RLQ pain. Because the clinical differentiation of appendicitis from many gynecologic disorders may be difficult, sonography should be performed routinely in young adult women with RLQ pain. Sonography is also favored in pregnant women and pediatric patients because of its lack of ionizing radiation. When clinically indicated, an optimized CT examination, used either as the initial imaging technique or after an indeterminate sonogram, will facilitate a rapid and correct diagnosis in most cases.
Fig. 20.—Bilateral tuboovarian abscesses in 33-year-old woman with pelvic inflammatory disease. Contrast-enhanced CT scan shows bilateral complex cystic tubular adnexal masses (arrows). Diagnosis of bilateral pyosalpinx and tuboovarian abscess was made on basis of typical clinical presentation and characteristic CT features. Follow-up sonograms showed gradual resolution during 2-year period.

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