

Beyond Appendicitis: Common and Uncom- mon Gastrointestinal Causes of Right Lower Quadrant Abdominal Pain at Multidetector CT¹

CME FEATURE

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LEARNING OBJECTIVES FOR TEST 2

After completing this journal-based CME activity, participants will be able to:

- Discuss the importance of multidetector CT in evaluation of patients with acute RLQP.
- Describe the different CT protocols for evaluation of patients with RLQP.
- List the less common causes of RLQP and their key clinical and imaging findings.

*Andrei S. Purysko, MD • Erick M. Remer, MD • Hilton M. Leão Filho, MD
Leonardo K. Bittencourt, MD • Rodrigo V. Lima, MD • Douglas J. Racy, MD*

Right lower quadrant abdominal pain is one of the most common causes of a patient visit to the emergency department. Although appendicitis is the most common condition requiring surgery in patients with abdominal pain, right lower quadrant pain can be indicative of a vast list of differential diagnoses and is thus a challenge for clinicians. Other causes of right lower quadrant pain beyond appendicitis include inflammatory and infectious conditions involving the ileocecal region; diverticulitis; malignancies; conditions affecting the epiploic appendages, omentum, and mesentery; and miscellaneous conditions. Multidetector computed tomography (CT) has emerged as the modality of choice for evaluation of patients with several acute traumatic and nontraumatic conditions causing right lower quadrant pain. Multidetector CT is an extremely useful noninvasive method for diagnosis and management of not only the most common causes such as appendicitis but also less common conditions.

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TEACHING POINTS

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Abbreviation: RLQP = right lower quadrant pain

RadioGraphics 2011; 31:927–947 • Published online 10.1148/rg.314105065 • Content Codes: **CT** **GI**

¹From the Abdominal Imaging Section, Imaging Institute, Cleveland Clinic Foundation, 9500 Euclid Ave, Mail Code Hb6, Cleveland, OH 44195 (A.S.P., E.M.R.); Abdominal Imaging Section, Medimagem, Hospital Beneficência Portuguesa de São Paulo, São Paulo, Brazil (H.M.L.F., R.V.L., D.J.R.); and Clínica de Diagnóstico por Imagem (CDPI), Rio de Janeiro, Brazil (L.K.B.). Recipient of a Cum Laude award for an education exhibit at the 2009 RSNA Annual Meeting. Received March 17, 2010; revision requested April 28; final revision received October 26; accepted November 26. For this journal-based CME activity, the authors, editor, and reviewers have no relevant relationships to disclose. **Address correspondence to** A.S.P. (e-mail: purysko@gmail.com).

Introduction

From 1996 through 2006, the annual number of emergency department visits in the United States increased approximately 32% (from 90.3 million to 119.2 million) (1). Abdominal pain was the most common reason for an emergency department visit overall and the second most common reason after chest pain in patients 15 years old and older, accounting for over 8 million visits per year. At least one imaging study was ordered in almost one-half of the emergency department visits (1). Right lower quadrant pain (RLQP) is responsible for a large percentage of these cases and is one of the most challenging clinical presentations, with a vast list of differential diagnoses, including potentially life-threatening conditions that may require emergency surgery (2).

In this article, we review the importance of multidetector computed tomography (CT) in evaluation of patients with RLQP. We describe the typical imaging findings and key clinical elements of the most common entities involving the appendix, cecum, right colon, ileum, and adjacent mesentery and of some uncommon conditions that were underrecognized before common use of multidetector CT. Specific topics discussed are role of cross-sectional imaging; protocols; radiation dose; importance of conditions beyond appendicitis; inflammatory and infectious conditions involving the ileocecal region; diverticulitis; malignancies; conditions affecting the epiploic appendages, omentum, and mesentery; and miscellaneous conditions.

Role of Cross-sectional Imaging

Cross-sectional imaging with helical CT and more recently with multidetector CT has proved to be an extremely useful noninvasive method for evaluation of patients with acute abdominal pain, since the history and physical examination results are not always specific for distinct diseases and findings of plain radiography are often noncontributory (3).

Multidetector CT evaluation of appendicitis, the most common cause of acute abdominal pain requiring emergency surgery, has been extensively studied. Because it has high accuracy in diagnosis of not only appendicitis but also potential complications such as perforation and abscess formation, it is considered the imaging method of choice in patients with RLQP (4) (Fig 1a). The effect of multidetector CT includes reducing the rates of

negative appendectomies and related morbidity, the length of hospitalization, and subsequently the cost of patient care (5,6). Because of its success, the use of CT has skyrocketed: In a recent single-center series (7), a CT study preceded emergent appendectomy in 18.5% of patients in 1998 versus 93.2% of patients in 2007.

Because a normal or even a nonvisualized appendix at CT virtually allows exclusion of appendicitis, an alternative diagnosis should be sought (8).

Teaching Point

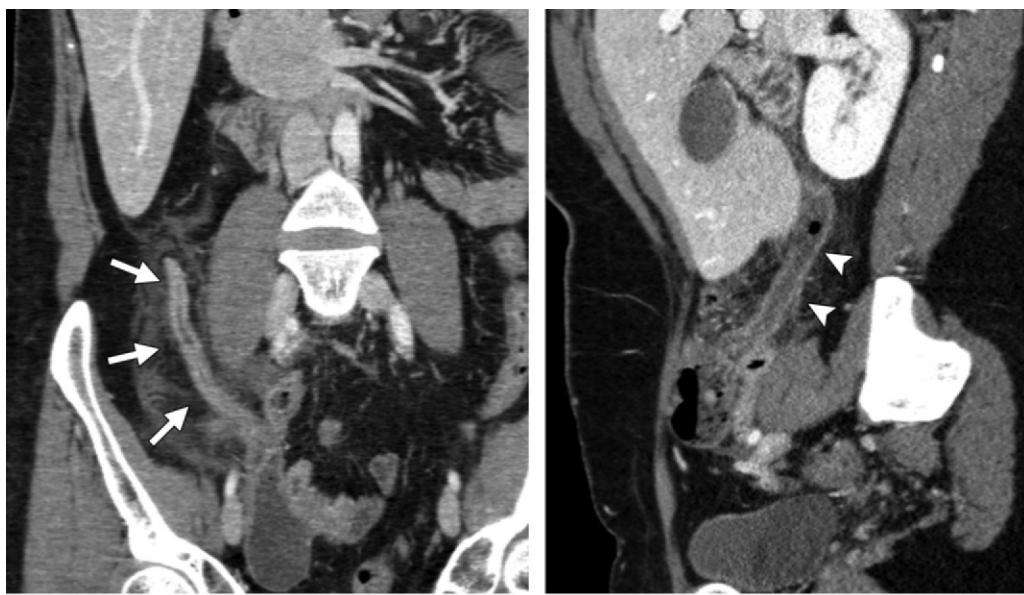
Protocols

Limited CT data acquisitions through the lower abdomen and upper pelvis to evaluate RLQP may result in incomplete or totally absent visualization of the appendix. Therefore, acquisition of thin sections covering the entire abdomen and pelvis from the domes of the diaphragm through the pubic symphysis in a single breath hold is recommended, as this will also potentially improve identification of alternative causes for the pain (9) (Fig 1b).

With multidetector CT, there is a significant decrease in acquisition time in comparison with that of earlier CT technology and consequently a reduction in motion artifacts. Moreover, the isotropic voxel datasets obtained with multidetector CT scanners allow performance of multiplanar reformation without loss of image resolution (10), a technique that has been shown to improve physician confidence in either confirming or excluding the diagnosis of appendicitis (11). In combination with additional postprocessing techniques, such as maximum intensity projection and volume rendering, multiplanar reformation may also improve identification and characterization of other pathologic conditions, sometimes with complex abnormal anatomy (12).

There is no consensus in the literature about use of intravenous, oral, and rectal contrast material in evaluation of patients with RLQP. Many dedicated protocols have been successfully tested, and the final decision may be made by considering the experience and work flow of each radiology department (9,13,14).

Use of intravenous contrast material has been shown to improve CT evaluation of alternative diagnoses and of patients with lack of intraabdominal and pelvic fat (13). Exceptions to routine use of intravenous contrast material in these patients are the presence of contraindications, such as abnormal renal function (translated as low glomerular filtration rate) or prior allergic reaction to iodinated contrast material.



a.

b.

Figure 1. (a) Appendicitis in a 22-year-old man with RLQP, nausea, and vomiting. Coronal CT image shows a retrocecal appendix (arrows) with a thick hyperenhancing wall and adjacent fat stranding. (b) Appendicitis in a 40-year-old man with RLQP radiating to the upper quadrant. Sagittal CT image shows a long, dilated retrocecal appendix (arrowheads) with similar inflammatory changes located in the subhepatic recess. The appendix in this case would be incompletely identified if only limited images of the right lower quadrant were obtained.

It is not necessary to withhold intravenous contrast material in patients in whom urinary calculus is among the differential diagnostic considerations. When multisector spiral scanners are used, the abdomen and pelvis are scanned before the administered contrast material is excreted, so stones are not obscured. The concern in this scenario is that one may be forced to repeat the acquisition with contrast material when no urinary calculus or other identifiable cause of the pain is detected, resulting in increased radiation exposure.

Oral and rectal contrast material have also been shown to improve evaluation of the appendix with helical CT. However, more recent data with multidetector CT have suggested eliminating both types of contrast material from protocols for evaluation of suspected appendicitis to achieve faster evaluation and better preparation for surgery, without necessarily decreasing the accuracy of the method (4,15,16).

Radiation Dose

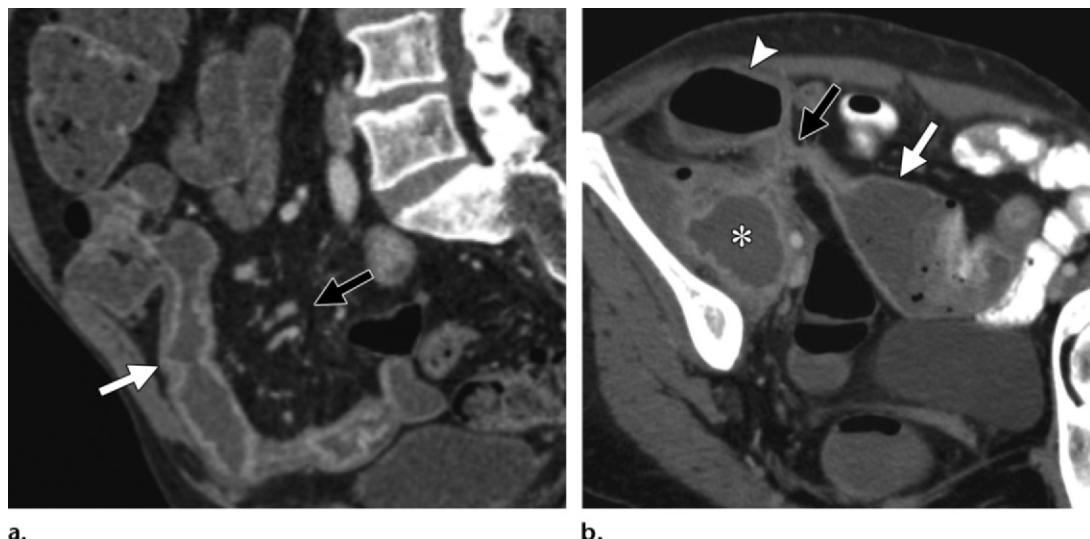
In accordance with the ALARA (as low as reasonably achievable) principle, examination protocols must take into account patient body habitus; in addition, dose reduction devices on imaging equipment should be active or manual

techniques should be used to moderate the exposure while ensuring the necessary diagnostic image quality (17). Efforts to reduce the radiation dose also include performance of a single contrast material-enhanced phase that coincides with the portal venous phase.

To avoid radiation exposure in patients less than 14 years of age and pregnant patients, the American College of Radiology appropriateness criteria recommend ultrasonography as the primary imaging modality for evaluation of RLQP suspicious for appendicitis (4). Nonenhanced magnetic resonance (MR) imaging has also gained favor in this setting and is recommended as an alternative in pregnant patients (4).

Importance of Conditions beyond Appendicitis

There is much less published data and awareness about less common causes of acute RLQP. The list of differential diagnoses is vast, and accurate assessment of CT features of these conditions is of major importance for appropriate selection of patient treatment, as it may prevent unnecessary hospital admission or surgery (2,18).



a.

b.

Figure 2. (a) Crohn disease in a 26-year-old man with RLQP and diarrhea. Coronal oblique CT image shows a thickened terminal ileum with strictures and mucosal hyperenhancement (white arrow). There is also proliferation of the mesenteric fat (black arrow). (b) Crohn disease in a 25-year-old woman with RLQP, fever, and leukocytosis. Axial oblique CT image shows a Y-shaped fistula (black arrow) between the distal ileum (white arrow) and cecum (arrowhead). The fistula is connected to an abscess in the right psoas muscle (*).

Inflammatory and Infectious Conditions Involving the Ileocecal Region

Crohn Disease

Inflammatory bowel disease affects approximately 1.4 million people in America, and its peak onset is at 15–30 years of age (19). Crohn disease can manifest anywhere in the gastrointestinal tract. Most patients experience chronic symptoms; however, acute exacerbations or complications may lead to acute abdominal pain. In fact, many cases of Crohn disease are diagnosed during work-up of acute RLQP, since the ileocecal region is most commonly affected by the disease, as opposed to ulcerative colitis, which predominates in the left colon (20).

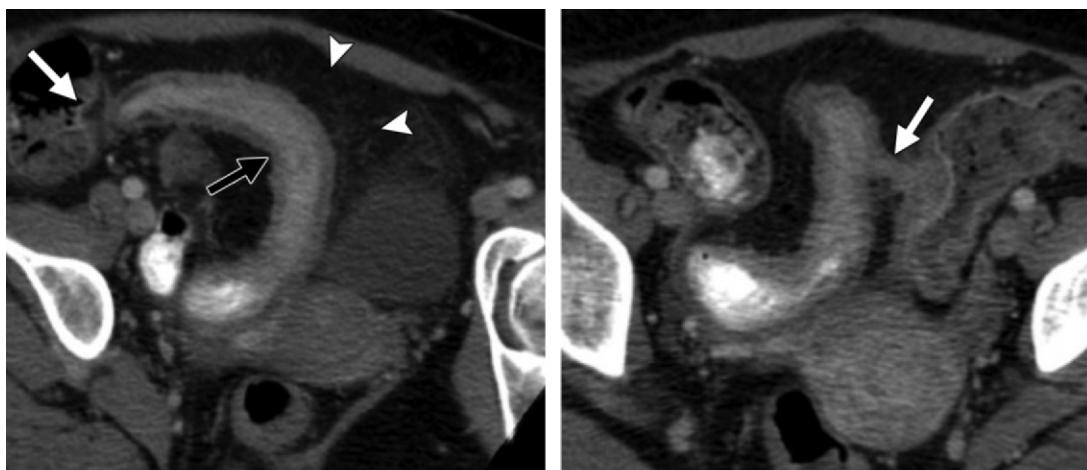
The diagnostic value of CT is based on excellent characterization of disease extension and severity, as well as estimation of inflammatory activity (21). The two most common CT findings of Crohn disease are eccentric wall thickening and mucosal hyperenhancement; the latter is an indicator of inflammatory activity (Fig 2).

Mural stratification due to intramural edema is also suggestive of active disease, as opposed

to a homogeneously enhancing wall. The presence of intramural fat usually indicates chronic changes (21,22). Segmental involvement with skipped normal regions may be seen and is one of the characteristics that help distinguish Crohn disease from ulcerative colitis, which affects the bowel in a more continuous fashion (21).

Engorgement of the vasa recta that penetrate the bowel wall (the comb sign) is an extraenteric finding that correlates with clinically advanced, active, and extensive Crohn disease (23). Fibrofatty proliferation along the mesenteric border of the affected bowel (the creeping fat sign) is another extraenteric finding; although not indicative of inflammatory activity, it is considered almost pathognomonic for Crohn disease (22). Reactive mesenteric lymph nodes may be present.

Small bowel strictures causing obstruction, fistulas, and abscesses are among the most common enteric complications associated with Crohn disease and are readily diagnosed with CT (Fig 2). An abscess can be confined to the bowel wall and pericolic fat or involve adjacent structures such as the bladder, psoas muscle, and pelvic sidewall. Multiplanar reformation is particularly helpful in characterizing fistulous tracts, which include enterovesical, enterocutaneous, perianal, and rectovaginal fistulas. Although positive oral



a.

b.

Figure 3. Crohn disease in a 23-year-old woman with RLQP and fever. **(a)** Axial oblique CT image shows a thick-walled terminal ileum (black arrow) proximal to the ileocecal valve (white arrow) with adjacent fibrofatty proliferation (arrowheads). Note that positive oral contrast material was administered, which limits the observation of the mucosal hyperenhancement. **(b)** Axial image shows a fistula (arrow) between the terminal ileum and sigmoid colon.

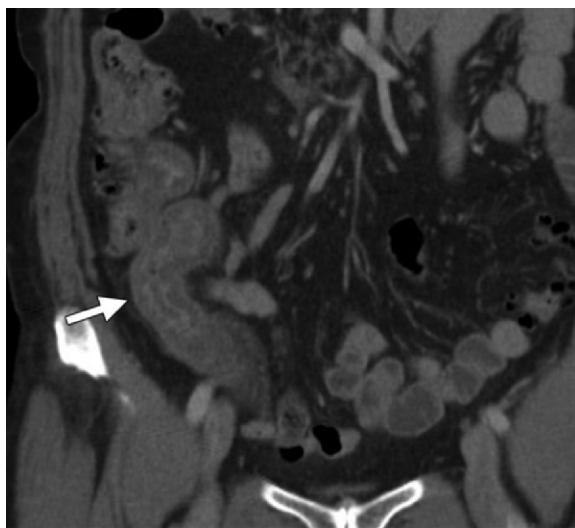


Figure 4. Infectious ileitis in a 32-year-old man with RLQP, fever, and bloody diarrhea. Culture of the stool demonstrated *Y enterocolitica* infection. Coronal CT image shows a markedly thickened terminal ileum with mural stratification (arrow).

contrast material may allow fistulous tracts to be better depicted, it may obscure mucosal hyperenhancement, which can be better depicted when the bowel lumen is distended by neutral contrast agents, such as those used for CT enterography and CT enteroclysis (24) (Fig 3).

MR enterography has a similar capability for detection of the mentioned bowel changes. In the typically young patient population that is affected by Crohn disease, MR imaging is a first-line option to avoid radiation exposure, especially since repeat imaging is often necessary (24).

Infectious Enterocolitis

Infectious ileocolitis is a relatively common clinical condition that often manifests with mild symptoms resembling those of viral gastroenteritis. However, it may lead patients to seek medical attention for acute abdominal pain indistinguishable from that of appendicitis, particularly when the cause is infection of the ileocecal area by *Yersinia enterocolitica*, *Campylobacter jejuni*, and *Salmonella enteritidis* (25).

Although most cases do not require imaging owing to the self-limited nature of the symptoms, CT may be necessary in patients with severe or persistent pain for differentiation from alternative diagnoses (26). Nonspecific findings, such as circumferential mural thickening of the terminal ileum and cecum with homogeneous enhancement and adjacent adenopathy, may be seen at CT (Fig 4). Stranding of the pericolic and mesenteric fat, a small amount of ascites, and air-fluid levels may or may not be associated (25,26).

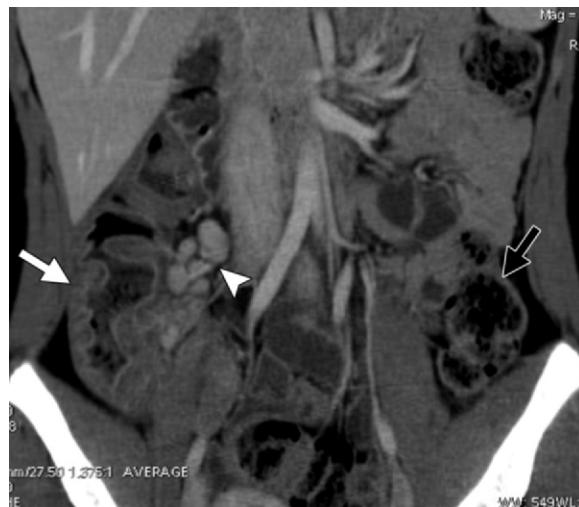


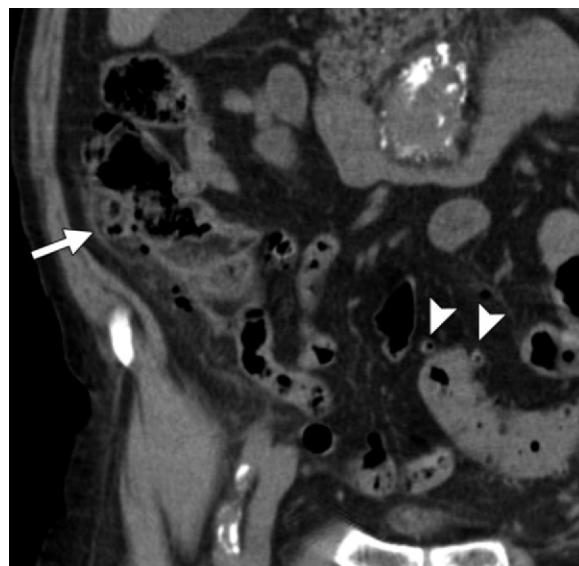
Figure 5. Neutropenic colitis (typhlitis) in a 14-year-old girl with leukemia who presented with RLQP, diarrhea, and fever during the course of chemotherapy. Coronal volume-rendered image shows cecal mural thickening (white arrow) in comparison with the contralateral normal segment of the left colon (black arrow). Multiple pericecal enlarged lymph nodes are seen (arrowhead).

Figure 6. Right colonic diverticulitis in a 78-year-old man with a 3-day history of RLQP and anorexia. Coronal CT image shows multiple right colonic diverticula and adjacent fat stranding (arrow). Diverticula are also present in the sigmoid colon (arrowheads), but no inflammation is seen in the surrounding fat.

Neutropenic Colitis (Typhlitis)

The typical clinical presentation of neutropenic colitis is a neutropenic patient undergoing chemotherapy for malignancy, such as acute leukemia, who presents with RLQP, fever, diarrhea, and sometimes evidence of peritonitis. Neutropenic colitis has also been associated with other immunosuppressive conditions and posttransplantation states (27). The mechanism of this disease is not completely clear, but it involves intestinal mucosal damage that can rapidly progress to perforation due to a combination of infection, ischemia, hemorrhage, and even neoplastic infiltration (21).

CT is the study of choice for diagnosis of typhlitis owing to the risk of bowel perforation with colonoscopy or contrast enema examination (21). Typhlitis classically involves the right colon, but the ileum and transverse colon may also be involved. CT features include cecal distention, circumferential wall thickening with areas of low



attenuation secondary to edema or necrosis, and inflammatory stranding of the adjacent mesenteric fat (28,29) (Fig 5).

The presence of pneumatosis, pneumoperitoneum, and pericolic fluid collections must be recognized, as they may indicate complications such as necrosis and perforation that require urgent surgical care (28). **Typhlitis must be suggested in immunocompromised patients with circumferential and symmetric wall thickening of the cecum and ascending colon to allow prompt medical or surgical intervention (30).**

Teaching Point



Figure 7. Ileal diverticulitis in a 58-year-old man with RLQP, nausea, and low-grade fever. Coronal oblique CT image shows a normal cecum (arrow) and small diverticula in the terminal ileum with adjacent fat stranding (arrowhead).

In comparison with the secondary inflammatory changes of the cecum seen in appendicitis, the length of mural thickening of the cecum and right colon involved by typhlitis is generally much greater and the bowel thickening is more circumferential and symmetric.

Diverticulitis

Right Colonic and Cecal Diverticulitis

Diverticulitis of the colon is one of the most common causes of acute abdominal pain in elderly patients. It typically manifests as left-sided lower abdominal pain, as the left and sigmoid colon are predominantly affected. Less often, the right colon and cecum may be involved, clinically mimicking appendicitis (31).

CT findings of acute diverticulitis consist of asymmetric or circumferential colonic wall thickening associated with focal pericolic fat stranding (32). When the cecum or right colon is affected, demonstration of inflamed diverticula, usually located at the level of maximum pericolic inflammation, along with a normal appendix are key elements in differentiation from appendicitis (32) (Fig 6).

Teaching Point

Differentiation from malignancy involving the right colon and cecum may be difficult or in some cases impossible on the basis of CT findings (33). Although nonspecific, the findings of a preserved enhancing pattern of the thickened colon wall (inner high-attenuation layer, thickened low-attenuation middle layer, and outer high-attenuation layer), fluid in the mesentery, and engorgement of adjacent mesenteric vasculature favor the diagnosis of diverticulitis (21,33). Conversely, the presence of pericolic lymph nodes suggests the diagnosis of malignancy rather than diverticulitis (34).

CT also allows detection of and surgical planning for frequently associated complications such as fistula, obstruction, free perforation, and abscess (21).

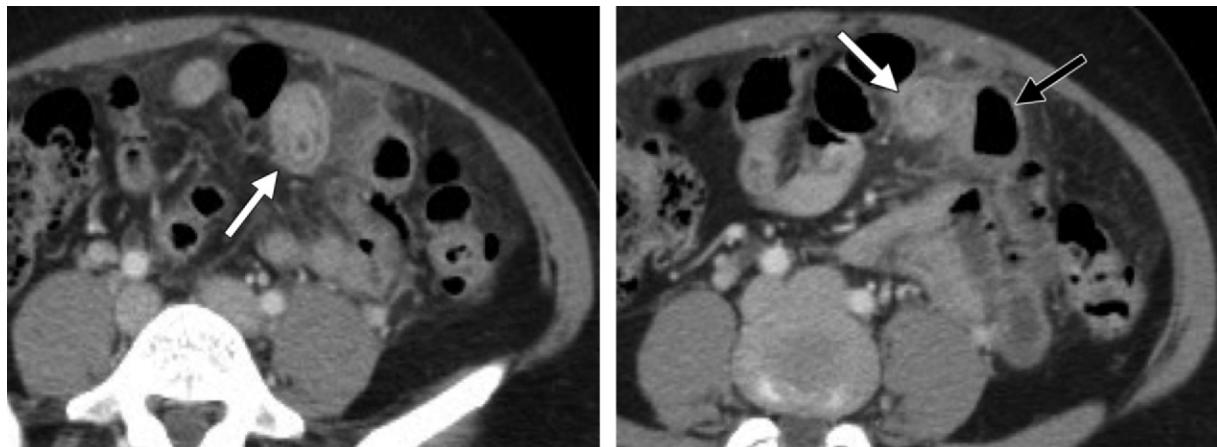
Ileal and Meckel Diverticulitis

Acquired small bowel diverticula, particularly in the terminal ileum, are much less frequent than colonic diverticula and represent an uncommon site of inflammation (35). They may be solitary but more often are multiple. These diverticula result from mucosal herniation of the bowel at sites of vascular entry and are therefore located on the mesenteric border of the terminal ileum, less than 7.5 cm from the ileocecal valve (Fig 7).

Ileal diverticula are usually asymptomatic and are encountered more often in men over the age of 40 years (36). When ileal diverticula become inflamed, the clinical presentation may be indistinguishable from that of acute appendicitis. Morbidity and mortality rates are higher than those of appendicitis. Associated complications include perforation, bleeding, and small bowel obstruction (37).

Meckel diverticulum, the most common congenital anomaly of the gastrointestinal tract, occurs due to nonobliteration of the omphalomesenteric duct (an embryologic structure that normally becomes obliterated during gestation). In contradistinction to acquired ileal diverticula, Meckel diverticulum is located on the antimesenteric border, approximately 100 cm from the ileocecal valve (36,38).

Figure 8. Meckel diverticulitis in a 35-year-old man with nausea, vomiting, and periumbilical pain. **(a)** Axial CT image shows a blind-ended tubular structure with a thickened wall (arrow) and adjacent fat stranding, findings that correspond to an inflamed Meckel diverticulum. **(b)** Axial CT image shows the diverticulum (black arrow) entering the antimesenteric border of the distal ileum (white arrow).

**a.****b.**

Related complications include mucosal ulceration and gastrointestinal bleeding from ectopic gastric mucosa, intussusception, perforation, and inflammation. Inflammation accounts for approximately 30% of complications and can result from a number of different mechanisms, the most important of which is luminal obstruction by an enterolith or foreign body in a manner similar to that of appendicitis (38).

The CT appearance of Meckel diverticulitis is a blind-ending pouch of variable size, generally containing fluid and air or particulate material, with mural thickening, hyperenhancement, and surrounding mesenteric inflammation located at or near the midline (39) (Fig 8).

Appendiceal Diverticulitis

Appendiceal diverticula are uncommon. Like most other gastrointestinal tract diverticula, they are far more often acquired than congenital. Although the exact pathogenesis is unknown, increased intraluminal pressure from proximal obstruction appears to be responsible for formation of the diverticula, according to current theories (40). This is particularly important given the well-established high association between appendiceal diverticula and appendiceal neoplasms, including mucinous tumors, which may play an important role in the development of pseudomyxoma peritonei (40).

Most appendiceal diverticula are pseudodiverticula, with herniation of the mucosa through the muscularis. They may be single or multiple, usually measure less than 0.5 cm, and are more often located along the mesenteric border of the distal third of the appendix (41).

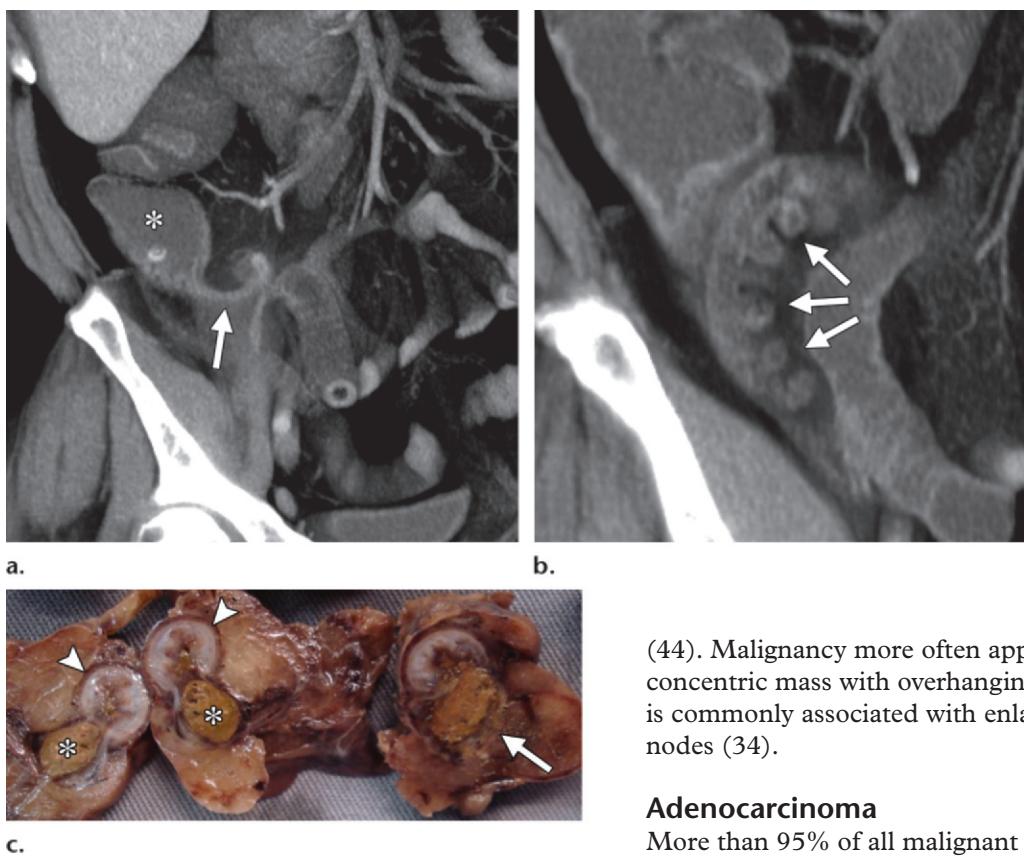
Clinically, appendiceal diverticulitis is distinct from acute appendicitis and much rarer. It affects older patients (usually >30 years of age), has a more insidious onset, and lacks the characteristic migratory pain location and the gastrointestinal symptoms seen in classic appendicitis. These features may lead to delayed diagnosis, resulting in higher rates of perforation and mortality owing to a thinner diverticulum wall (41).

At CT, an appendiceal diverticulum appears as a round outpouching beyond the margin of the appendix that can contain fluid, air, or enhancing soft tissue. Diverticular inflammation is seen as prominent enhancement of the diverticulum wall with surrounding fat stranding (42) (Fig 9). Features of reactive inflammatory changes in the appendix, such as increased diameter, wall thickening, and hyperenhancement, can lead to a misdiagnosis of appendicitis at CT (42).

Malignancies

Acute RLQP may be the initial presentation of a malignancy involving the ileocecal region, such as adenocarcinoma, lymphoma, gastroin-

Figure 9. Appendiceal diverticulitis in a 45-year-old man with a 5-day history of RLQP, nausea, and vomiting. **(a)** Coronal oblique volume-rendered image shows a normal cecum (*) and proximal one-third of the appendix (arrow). **(b)** Coronal oblique CT image shows multiple round outpouchings along the distal two-thirds of the appendix with increased mural enhancement (arrows). **(c)** Photograph of the sectioned appendix (arrowheads) shows multiple diverticula (*), some of which have a discontinuous wall and inflammatory changes in the surrounding fat (arrow).



intestinal stromal tumor, or metastasis, especially in the event of a complication, such as perforation or abscess (43). Differentiation between an acute inflammatory condition and malignancy at CT is not always an easy task, since findings may overlap, as discussed in the section on diverticulitis.

A stratified enhancement pattern in a thickened segment of bowel wall (up to 2 cm thick), producing a double halo or target configuration, is usually associated with a benign process. Long segments of involvement (10 cm or longer) and fat stranding adjacent to a thickened bowel segment, especially if disproportionately more severe than the degree of wall thickening, are also findings that favor an acute inflammatory process

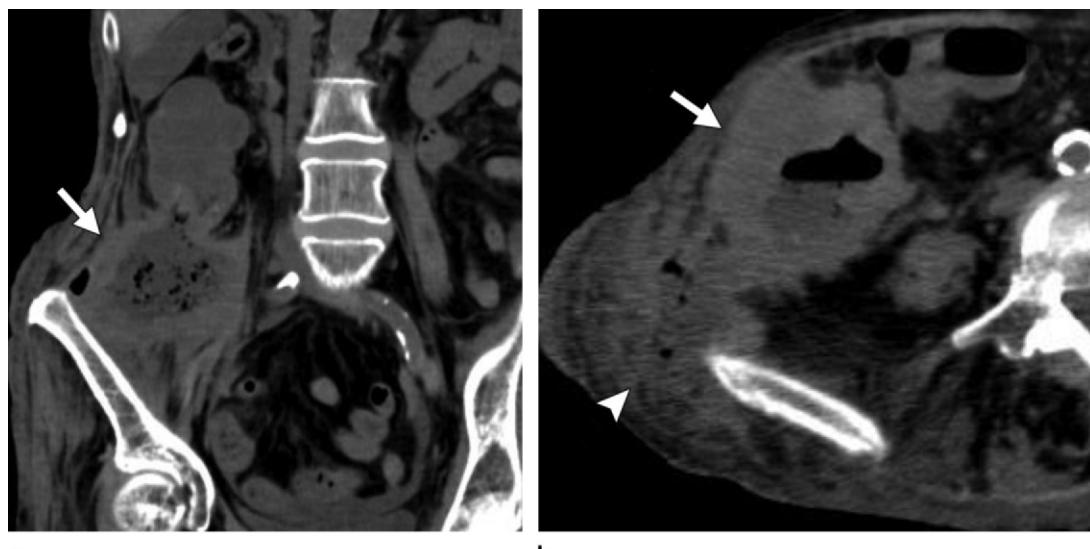
(44). Malignancy more often appears as a focal concentric mass with overhanging shoulders and is commonly associated with enlarged pericolic nodes (34).

Adenocarcinoma

More than 95% of all malignant cecal masses are adenocarcinomas. They typically occur in elderly patients, who may present with rectal bleeding, anemia, low-grade fever, or a palpable mass.

Perforation in colon cancer occurs in up to 10% of cases and is more often a subacute process due to slow gradual infiltration of the bowel wall, disguising inflammatory signs (45). It may occur proximal to a tumor owing to necrosis of stercoral ulcers or increased pressure proximal to an obstructing lesion (43).

Most abscesses from perforating colon carcinomas are intraperitoneal. They may remain localized in the paracolic area or extend to the flank, tracking along tissue planes, and appear as an abscess at another site, such as the thigh or subcutaneously on the trunk (43) (Fig 10).



a.

b.

Figure 10. Perforating adenocarcinoma of the cecum in a 72-year-old man with fever, subacute RLQP, and a palpable mass. (a) Coronal CT image shows marked asymmetric mural thickening of the cecum (arrow). (b) Axial CT image shows the perforated cecum (arrow) with fecal content extending into the abdominal wall (arrowhead).

Lymphoma

About 80% of lymphomas of the ileum or colon occur primarily in the ileocecal region, because Peyer patches (a lymphoid tissue) develop in the terminal ileum (46). Lymphomas predominantly affect men in the 6th and 7th decades and often manifest as abdominal pain and weight loss. Owing to the nonspecific nature of these symptoms, patients frequently present late with advanced locoregional disease. Long-standing celiac disease, Crohn disease, and immunosuppression have been reported as risk factors (47).

Lymphoma of the ileocecal region may occur in four forms: circumferential or constrictive, polypoid, ulcerative, and aneurysmal (46). Most commonly, it manifests as single or multiple segmental areas of circumferential thickening, with homogeneous attenuation and poor enhancement (44). In this form it may mimic adenocarcinoma, particularly when asymmetric, but the segment of bowel involved is usually longer and the transition from tumor to normal bowel is more gradual (47). Lack of signs of obstruction, even when a large mass is present, also raises suspicion of lymphoma (Fig 11).

Lymphoma of the ileocecal area may appear as a polypoid lesion of variable size, which may act as the lead point of an intussusception (46). In the ulcerative form, fistulous tracts develop

between adjacent bowel loops from an ulcerated mass (44). Finally, the aneurysmal form involves dilatation of the lumen or cavity of the mass, which is significantly larger than the proximal and distal bowel segments (44).

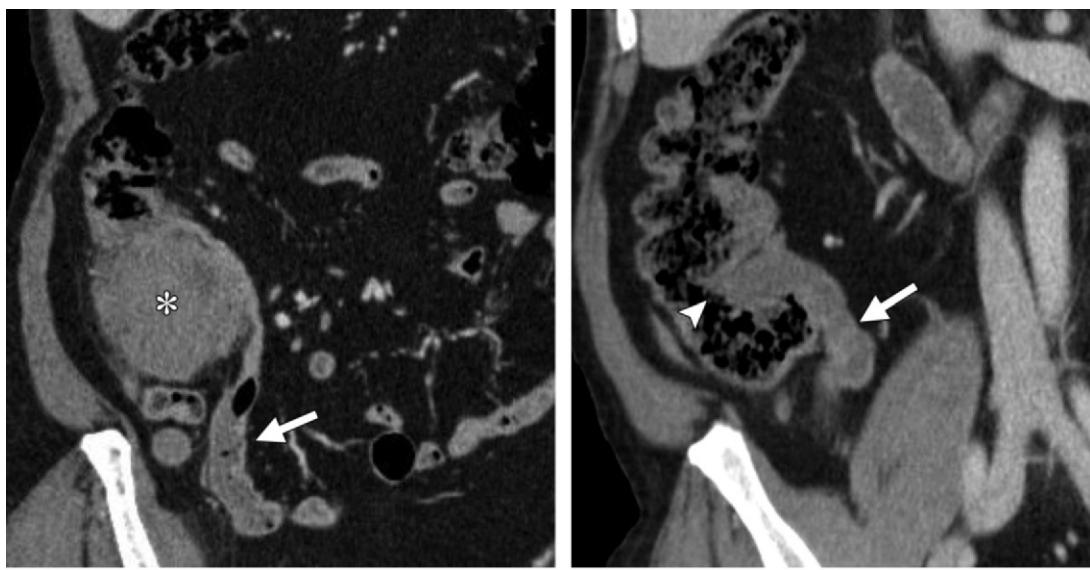
Bulky mesenteric and retroperitoneal lymph nodes are commonly associated and may help in differentiation from adenocarcinoma (47).

Conditions Affecting the Epiploic Appendages, Omentum, and Mesentery

Epiploic Appendagitis

Epiploic appendages are round, fat-containing peritoneal pouches arising from the serosal surface of the colon that measure 0.5–5 cm in length. Epiploic appendagitis is an uncommon and self-limited condition, most often affecting middle-aged men, that is caused by inflammatory and ischemic changes related to torsion or venous thrombosis of the epiploic appendages. Epiploic appendages are not normally visualized at CT unless surrounded by fluid (ie, ascites) or inflamed (18).

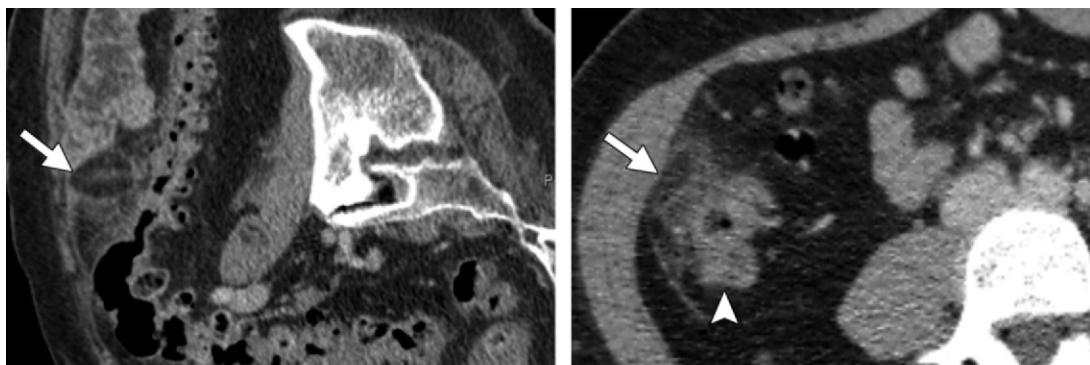
There are two recognized forms of this condition. Spontaneous torsion of epiploic appendages, with resultant vascular occlusion and ischemia, has been implicated as the cause of primary epiploic appendagitis. Inflammation of adjacent organs, including the colon, gallbladder, and appendix, leads to the secondary form (48).



a.

b.

Figure 11. Lymphoma of the ileocecal valve in a 35-year-old man with RLQP, low-grade fever, and weight loss. Arrow = terminal ileum. **(a)** Coronal CT image shows a homogeneous mass of soft-tissue attenuation arising from the ileocecal valve and filling the cecal lumen (*), with no small bowel obstruction proximally. **(b)** Follow-up CT image obtained after chemotherapy shows significant reduction in the size of the mass, with a normal ileocecal valve (arrowhead).



a.

b.

Figure 12. **(a)** Epiploic appendagitis in a 45-year-old man with left lower quadrant pain. Curved reformatted CT image shows an inflamed epiploic appendage (arrow) in the most common location along the sigmoid colon. The typical appearance is a pericolic oval lesion of fat attenuation with a hyperattenuating rim and a central dot of high attenuation. **(b)** Epiploic appendagitis in a 32-year-old man with acute onset of RLQP. Axial CT image shows an inflamed epiploic appendage of the ascending colon (arrow). The ascending colon is nearly collapsed but demonstrates mild reactive thickening (arrowhead).

Since epiploic appendages are larger and more numerous in the sigmoid and descending colon, appendagitis typically manifests as left lower quadrant pain, mimicking acute diverticulitis. Less frequently, it may also involve the right colon and cecum, clinically mimicking appendicitis (18).

The typical CT appearance of epiploic appendagitis is a pericolic oval lesion of fat attenu-

ation with a hyperattenuating rim. A central dot of high attenuation or an irregular or linear focus may also be present and corresponds to engorged or thrombosed central vessels or central areas of hemorrhage or fibrosis (Fig 12). Wall thickening of the adjacent colon may be seen but is most often normal in thickness (18).

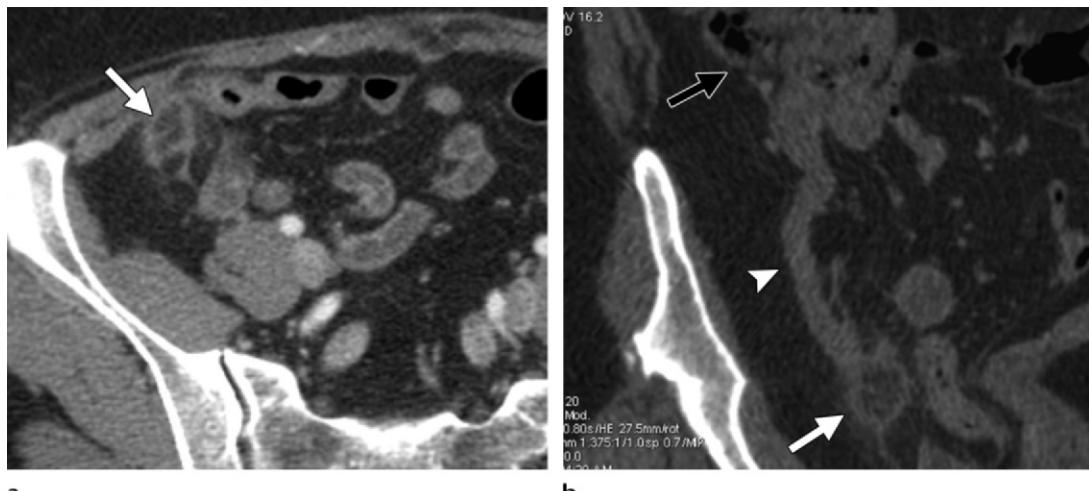


Figure 13. Epiploic appendagitis of the veriform appendix in a 38-year-old man with a 2-day history of RLQP. **(a)** Axial CT image shows an inflamed epiploic appendage (arrow). **(b)** Curved reformatted CT image shows the relationship of the inflamed epiploic appendage (white arrow) to the veriform appendix (arrowhead). Black arrow = normal cecum.

Epiploic appendages may also be present in the veriform appendix and are usually smaller than those on the serosal surface of the colon. However, epiploic appendagitis of the veriform appendix is rare (49) (Fig 13).

Omental Infarction

A rare cause of abdominal pain, omental infarction is caused by interruption of blood supply to the omentum due to torsion or venous thrombosis. Primary (idiopathic) infarction is usually precipitated by coughing, straining, or overeating. Secondary infarction occurs from vascular damage (thrombosis or torsion) related to trauma, surgery, hernia, or adhesion (50).

The CT features of acute omental infarction include a solitary, well-circumscribed, triangular or oval, heterogeneous fatty mass, sometimes with a whorled pattern of concentric linear fat stranding. It is characteristically situated between the anterior abdominal wall and the transverse or ascending colon, corresponding in location to the greater omentum (18,51,52) (Fig 14). Thickening of the adjacent bowel wall is either absent or disproportionately milder in comparison with the inflammatory changes in the omentum (52).

The CT features of epiploic appendagitis and omental infarction may overlap, and differentiation may not be possible in some cases. However, since treatment for both conditions is supportive with the same prognosis, it is questionable if such differentiation has practical relevance (50,52).

Mesenteric Adenitis

Primary mesenteric adenitis is defined as the presence of clustered (more than three) right-sided lymph nodes in the small bowel mesentery or anterior to the psoas muscle, usually larger than 5 mm, without an identifiable acute inflammatory condition (53,54). Most cases are believed to be related to an underlying infection of the terminal ileum (53). Patients usually present with acute RLQP, fever, and leukocytosis.

The disorder is more frequent in children. In adults, secondary mesenteric adenitis is far more frequent and may be seen in many local inflammatory conditions such as appendicitis, diverticulitis, and Crohn disease or as part of a systemic inflammatory condition such as systemic lupus erythematosus and human immunodeficiency virus infection (55).

Primary mesenteric adenitis is a diagnosis of exclusion. At CT, it is characterized by the presence of right-sided mesenteric lymphadenopathy without an identifiable inflammatory condition

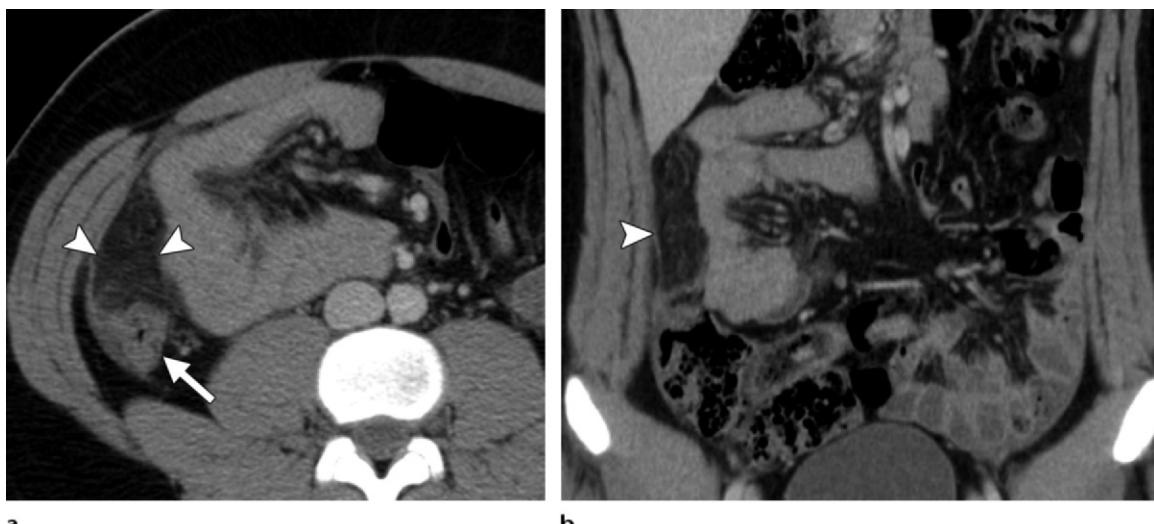


Figure 14. Acute omental infarction in a 40-year-old man with acute onset of RLQP after exercising. Axial (a) and coronal (b) CT images show a triangular heterogeneous fatty mass (arrowheads) anterior to the ascending colon (arrow in a).



Figure 15. Mesenteric adenitis in a 19-year-old man with RLQP and low-grade fever. Coronal volume-rendered image shows multiple enlarged mesenteric lymph nodes (arrowheads) without abnormalities in the ileocecal region.

(Fig 15). For this reason, careful evaluation should be performed to determine whether an underlying cause is present (53).

Miscellaneous Conditions

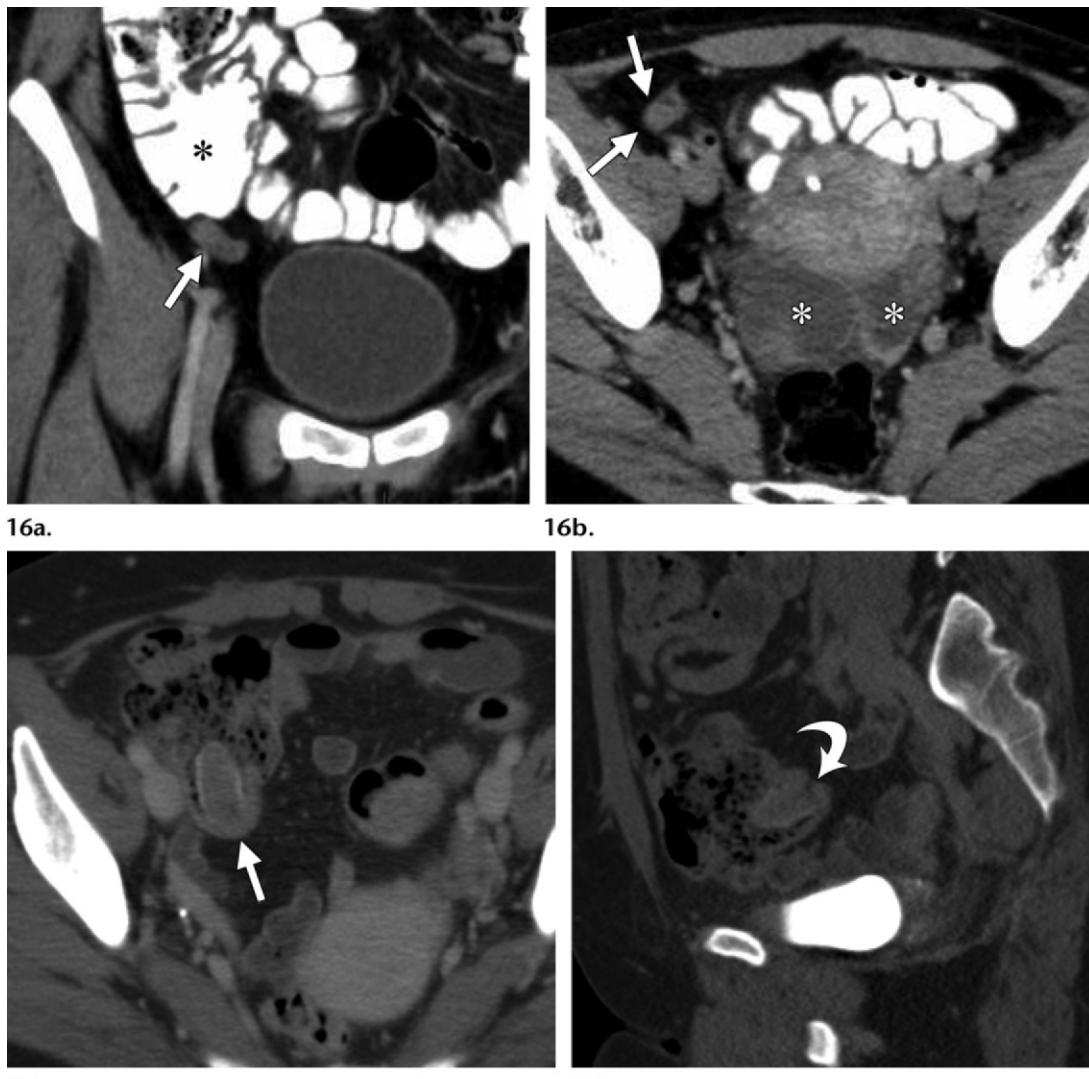
Endometriosis

Endometriosis, defined as the presence of endometrial tissue outside the uterine cavity and musculature, is a common disorder in women

of childbearing age and is often associated with chronic pelvic pain and infertility. Although it most often affects the genital organs or pelvic peritoneum, it occurs at a rate of 3%–37% in various parts of the gastrointestinal tract, including the rectosigmoid colon, followed by the ileum (usually within 10 cm of the ileocecal valve) (44), jejunum, and cecum (56,57).

Appendiceal endometriosis accounts for less than 1% of all pelvic lesions. It is almost always seen with ovarian endometriosis and occurs in approximately 3% of patients with endometriosis (58). As with endometriosis elsewhere in the intestinal tract, appendiceal endometriosis tends to be asymptomatic and may be found primarily or incidentally at appendectomy. Symptomatic patients may present with RLQP similar to that of acute appendicitis; the pain most often occurs cyclically during menstruation (56). Endometriosis in the ileocecal region and appendix has also been associated with intussusception, mucocele, bleeding, and perforation, especially during pregnancy (56).

At CT, appendiceal endometriosis often manifests as a nonspecific focal mass, usually in the distal third of the appendix, or as a distended but nonopacified appendix (when oral or rectal contrast material is used) without evidence of inflammation (59) (Figs 16, 17).



16a.

16b.

17a.

17b.

Figures 16, 17. (16) Appendiceal endometriosis in a 32-year-old woman with known endometriosis and episodes of RLQP. (a) Coronal CT image shows the opacified cecum (*) and a soft-tissue mass filling the appendix (arrow). (b) Axial CT image shows the appendiceal soft-tissue mass (arrows) and bilateral ovarian endometriomas (*). (17) Appendiceal endometriosis in a 35-year-old woman with RLQP. (a) Axial CT image shows a tubular soft-tissue mass in the cecum (arrow). (b) Sagittal oblique CT image shows an appendiceal mucocele invaginated within the cecum (arrow). Surgical exploration demonstrated an invaginated appendiceal mucocele containing endometriotic tissue.

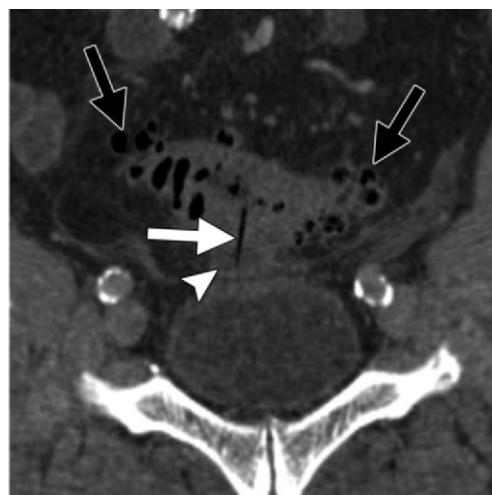
Ingestion of a Foreign Body

Although foreign-body ingestion is common, complications such as intestinal perforation occur in less than 1% of cases (60). Most cases occur accidentally in patients with altered mental status

or patients with dentures. The foreign body is usually a nondigestible component of food, such as a fish or chicken bone or a toothpick (61). Clinical diagnosis of perforation on the basis of the history and physical examination results is difficult, since patients rarely report prior foreign-body ingestion and the symptoms are nonspecific.



18.



19a.



19b.

Figures 18, 19. (18) Foreign-body ingestion in a 38-year-old man with colicky abdominal pain. Coronal CT image shows a long linear hyperattenuating structure (arrow) in the mesentery. Pneumoperitoneum was not identified. At laparotomy, a fish bone was recovered and a sealed perforation of the terminal ileum was identified. (19) Foreign-body ingestion in a 76-year-old man with lower abdominal pain, low-grade fever, and dysuria. (a) Coronal CT image shows a linear structure of air attenuation (white arrow), which traverses the wall of the sigmoid colon in a region of diverticulosis (black arrows). There is a small abscess (arrowhead) in the area of perforation, above the dome of the bladder. (b) CT image of two wooden toothpicks shows that their attenuation is similar to that of air. A similar toothpick was recovered at surgery.

The ileocecal region is the most common site of intestinal perforation by a foreign body, along with the rectosigmoid. Perforation also occurs in areas of narrowing, angled or pouching zones, zones with adhesions or surgical anastomoses, and areas containing diverticula (60). Multiplanar reformation allows identification of the perforation site, the nature of the object, and complications such as abscess or obstruction. Whatever their orientation in space, thin calcified structures within the abdominal cavity can be identified (61) (Fig 18).

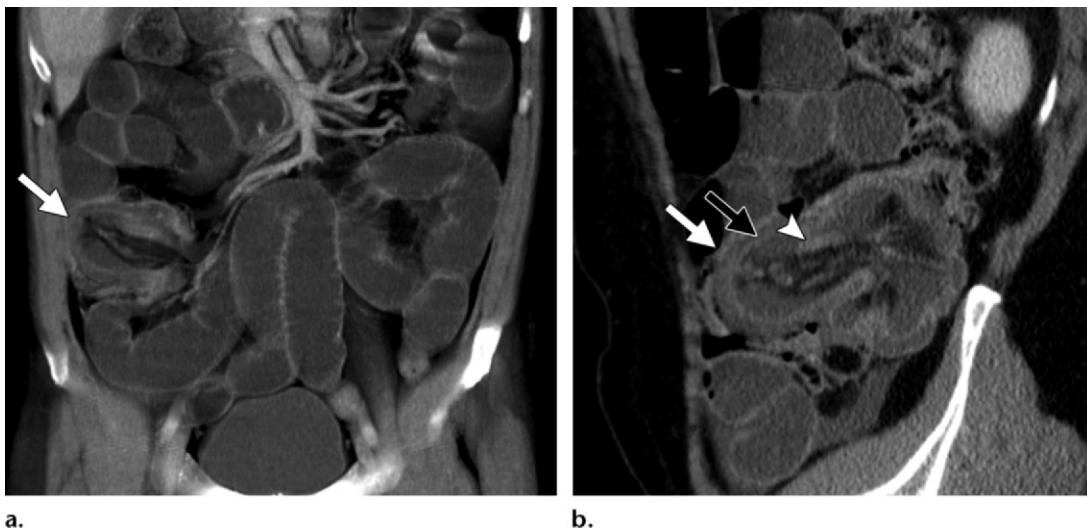
Wooden foreign bodies such as toothpicks are not always easily recognized, especially in the acute phase, when wood may have air attenuation, thus mimicking bubbles of gas (Fig 19). In the subacute phase, the attenuation tends to increase, becoming progressively isoattenuating to the surrounding soft-tissue structures and finally becoming hyperattenuating due to granulomatous reaction and calcification. Pneumoperitoneum may not be seen due to progressive impaction of the foreign body in the intestinal wall, with the site being covered by fibrin, omentum, or bowel loops, which prevent leakage of gas or fluid.

Intussusception

Intussusception is rare in adults, accounting for 5% of reported cases. In children, most cases are idiopathic; in adults, however, a considerable percentage of cases, particularly colocolic and ileocolic intussusceptions, are secondary to an underlying pathologic condition such as a benign or malignant neoplasm (eg, lipoma, leiomyoma, adenomatous polyp, lymphoma, and metastasis), which serves as a lead point (62). Clinically, intussusception manifests as intermittent colicky pain, nausea, and vomiting, which are related to bowel obstruction.

Multidetector CT is the modality with the highest diagnostic accuracy. The typical characteristics are a complex soft-tissue mass composed of an outer intussuscipiens and inner intussusceptum and an eccentric area of fat attenuation representing mesentery with mesenteric vessels (Fig 20). A target-shaped bowel-within-bowel appearance is the classic appearance on axial scans and is pathognomonic (63).

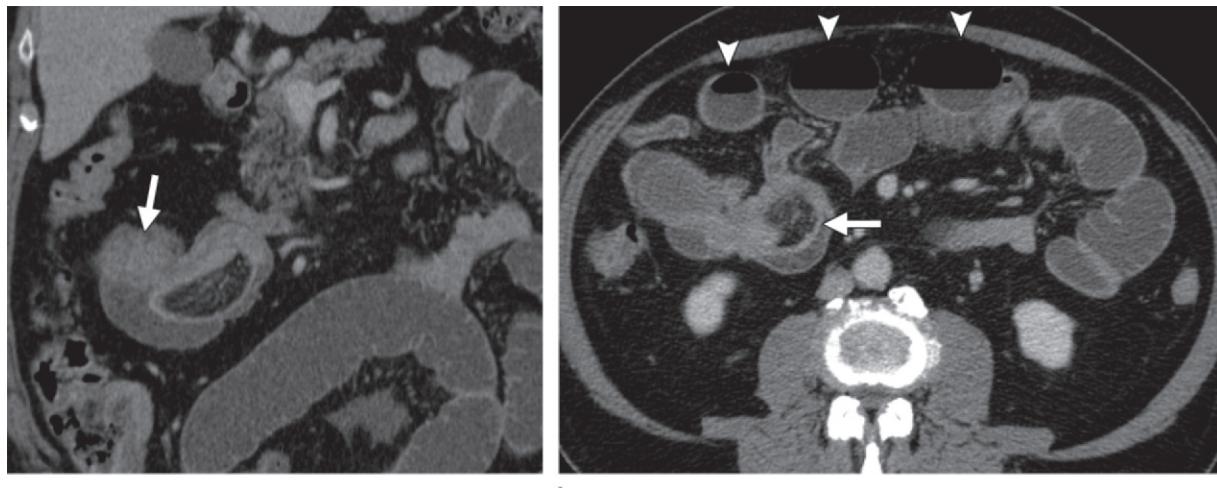
Teaching Point



a.

b.

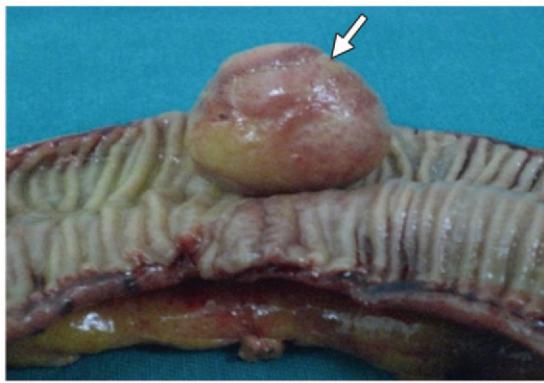
Figure 20. Intussusception in a 63-year-old man with RLQP, a palpable mass, nausea, and vomiting. (a) Coronal volume-rendered image shows diffuse dilatation of fluid-filled small bowel loops and an ileocecal intussusception (arrow). (b) Sagittal oblique CT image shows the inner intussusceptum (black arrow), the outer intussuscipiens (white arrow), and intraluminal mesenteric fat (arrowhead).



a.

b.

Figure 21. Intussusception in a 50-year-old man with nausea, vomiting, and periumbilical pain. (a) Coronal oblique CT image shows an ileal polypoid mass (arrow), which serves as the lead point for an ileoileal intussusception in the right lower quadrant. (b) Axial CT image shows dilated small bowel loops with air-fluid levels (arrowheads), a finding indicative of small bowel obstruction. The area of fat attenuation (arrow) within a bowel loop corresponds to the pulled-in mesentery. (c) Photograph of the pathologic specimen shows the polypoid small bowel mass (arrow), which was a gastrointestinal stromal tumor.



c.

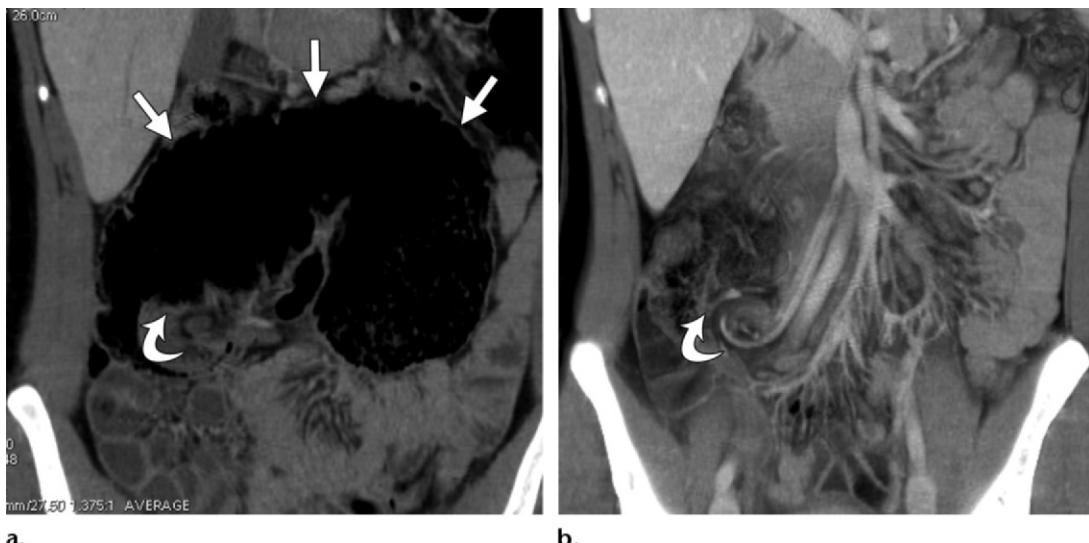


Figure 22. Cecal volvulus in a 65-year-old man with RLQP and constipation. **(a)** Coronal CT image shows a dilated cecum (straight arrows) that is twisted along its axis (curved arrow). The cecum and ascending colon are folded and occupy the left upper quadrant. **(b)** Coronal volume-rendered image shows the swirl of the vessels (arrow).

Multiplanar reformation is particularly important for both identification and characterization of the intussusception, making it possible to confidently confirm the diagnosis. This technique allows better measurement of the length of the intussusception by helping one fully appreciate its course. It also allows identification of an underlying lead point and detection of obstruction or ischemia (63) (Fig 21).

With the widespread use of CT, cases of transient intussusception have been increasingly detected and reported in the literature (62,63). They usually occur in the small bowel, especially the jejunum, are less than 3.5 cm long, do not cause obstruction, and are not associated with a lead point. These intussusceptions have no clinical significance. This phenomenon occurs in young patients and patients with a history of enteric disease, such as celiac disease or Crohn disease.

Cecal Volvulus

Cecal volvulus is a rare condition seen in patients who have an abnormally mobile cecum owing to a congenital or acquired abnormal fixation to the posterior parietal peritoneum. This allows the cecum to twist along its long axis, resulting in a closed-loop obstruction (64). Cecal volvu-

lus has a high rate of morbidity and mortality if not treated in a timely fashion, primarily due to vascular compromise of the bowel.

Previous laparotomy, distal obstruction, neoplasm, constipation, and pregnancy have been suggested as predisposing or triggering factors (64,65). Clinically, patients present with acute constant or cramping RLQP. Abdominal distention, constipation, nausea, and vomiting are also frequently present and are associated with the resultant bowel obstruction (65).

Three types of cecal volvulus have been described, according to the pathophysiologic mechanism. In type I (the axial torsion type), the cecum twists in the axial plane, rotating along its long axis. In type II (the loop type), the distended cecum twists and inverts. In type III (cecal bascule), the distended cecum folds anteriorly without any torsion (64).

Diagnosis of cecal volvulus is made with plain radiography in less than 50% of cases (66). With multidetector CT, it is possible to recognize cecal volvulus and its complications (ie, ischemia and obstruction) more easily (64) (Fig 22). It is also possible to recognize the subtypes.



a.

b.

Figure 23. Ischemic colitis in a 72-year-old man with RLQP after an episode of severe hypotension. **(a)** Axial nonenhanced CT image shows an increased amount of gas in the cecum and right colon (arrowheads). **(b)** Coronal CT image (lung window) shows extensive pneumatosis coli involving the cecum and right colon (arrow) and a small amount of pneumoperitoneum (arrowheads).

Teaching Point

The combination of a distended ectopic cecum and the swirl of the mesenteric vessels is seen in type I and II cecal volvulus. In type II volvulus (the loop type), the cecum usually occupies the left upper quadrant. In the bascule type, the swirl of the vessels is not present (64).

Circumferential wall thickening, increased attenuation in the mesenteric fat, pneumatosis intestinalis, and pneumoperitoneum are ominous signs related to complications.

Ischemic Colitis

Ischemic colitis is the most common manifestation of ischemic injury to the gastrointestinal tract. As in the other forms of intestinal ischemia, it can be divided into two forms: occlusive or thromboembolic (about 80% of cases) and nonocclusive (about 20%) (67).

Isolated involvement of the right colon or cecum is uncommon in comparison with left colon ischemia but has been reported with increased frequency, particularly in elderly patients, in association with nonocclusive forms, which include low systemic flow states (eg, hypovole-

mic shock, severe heart failure and arrhythmias, renal insufficiency, and sepsis) as well as vasoconstriction secondary to drugs (eg, cardiotonics, nonsteroidal anti-inflammatory drugs, and amphetamines) (68,69). In younger patients, cocaine, an illicit vasoconstrictor drug, has also been associated with bowel ischemia, hours or even days after its use (70).

Patients with right colon ischemia usually present with mild to moderate RLQP that may be preceded by constipation. Unlike in patients with left-sided ischemia, rectal bleeding is uncommon. Right colon ischemia is associated with an increased risk of severe disease requiring surgery or leading to death, whereas most patients with left-sided or transverse colon ischemia recover uneventfully (68).

Although the CT changes seen in the colon during the course of ischemia are nonspecific, they appear to correlate with the pathologic damage (67). In the early stages, ischemia can appear at CT as a hyperattenuating or hyperenhancing mucosa secondary to hyperemia and hemorrhagic phenomena, followed by circumferential bowel wall thickening due to submucosal edema (71,72).

If the ischemic insult persists, reduced and eventually absent enhancement, secondary to intense vasospasm, is accompanied by bowel dilatation. In advanced stages, intramural gas (pneumatosis coli) as well as gas in the portal or mesenteric vessels are associated with development of an infarction (72) (Fig 23). However, the only pathognomonic sign of transmural necrosis is perforation, which manifests as pneumoperitoneum or pneumoretroperitoneum (67).

Although pneumatosis coli can be seen in a variety of conditions (eg, lung disease, collagen disturbances, and steroid treatment), its presence should be considered suggestive of bowel infarction, especially if associated with decreased or absent parietal enhancement; clinical correlation is vital (71,72). In addition to helping detect changes in the bowel wall, multidetector CT with three-dimensional reformation can help evaluate the mesenteric vessels in patients with acute mesenteric ischemia. In occlusive or thromboembolic forms, vascular obstruction appears at CT as an area of absent opacification in the lumen of an artery or vein (73).

Conclusions

Multidetector CT is an extremely useful noninvasive method for evaluation of patients with acute RLQP, allowing diagnosis and management of not only the most common conditions such as appendicitis but also less common conditions. With the widespread use of multidetector CT, some conditions that have been considered rare will be more often detected prospectively.

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Beyond Appendicitis: Common and Uncommon Gastrointestinal Causes of Right Lower Quadrant Abdominal Pain at Multidetector CT

Andrei S. Purysko, MD • Erick M. Remer, MD • Hilton M. Leão Filho, MD Leonardo K. Bittencourt, MD • Rodrigo V. Lima, MD • Douglas J. Racy, MD

RadioGraphics 2011; 31:927–947 • Published online 10.1148/rg.314105065 • Content Codes: **CT** **GI**

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Because a normal or even a nonvisualized appendix at CT virtually allows exclusion of appendicitis, an alternative diagnosis should be sought (8).

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Typhlitis must be suggested in immunocompromised patients with circumferential and symmetric wall thickening of the cecum and ascending colon to allow prompt medical or surgical intervention (30).

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When the cecum or right colon is affected, demonstration of inflamed diverticula, usually located at the level of maximum pericolic inflammation, along with a normal appendix are key elements in differentiation from appendicitis (32) (Fig 6).

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Multidetector CT is the modality with the highest diagnostic accuracy. The typical characteristics are a complex soft-tissue mass composed of an outer intussusciens and inner intussusceptum and an eccentric area of fat attenuation representing mesentery with mesenteric vessels (Fig 20). A target-shaped bowel-within-bowel appearance is the classic appearance on axial scans and is pathognomonic (63).

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The combination of a distended ectopic cecum and the swirl of the mesenteric vessels is seen in type I and II cecal volvulus. In type II volvulus (the loop type), the cecum usually occupies the left upper quadrant. In the bascule type, the swirl of the vessels is not present (64).