Imaging of Colonic Diverticular Disease

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ABSTRACT

Diverticular disease affects approximately two thirds of the population over the age of 70. While only a small fraction of these patients will develop diverticulitis, adequate radiological evaluation of diverticulitis and its complications is imperative in determining proper medical and surgical treatment. Clinical examination and laboratory tests alone have been found to be inaccurate in defining many aspects of the disease in up to 60% of cases. Over the past 30 years, contrast enema, computed tomography, and ultrasound have all been used extensively to diagnose the complications of diverticular disease. More recently, magnetic resonance imaging has been studied in patients with complicated diverticulitis. This article reviews the use of these different radiological modalities in diagnosing acute colonic diverticulitis and its complications.

KEYWORDS: Radiology, diverticular disease, diverticulitis, CT scan, ultrasound, MRI

Objectives: Upon completion of this article, the reader should have a clear understanding of the radiologic tests available for evaluating patients with complicated diverticular disease.

Diverticulosis of the colon continues to rise in prevalence, especially in Western countries, where up to two thirds of the population older than 70 years of age are estimated to have the disorder.¹ Medical and surgical therapy for diverticulosis is initiated primarily for the complications of diverticulitis and lower gastrointestinal hemorrhage from a diverticular source. The initial assessment of complicated diverticular disease based on history, physical examination, and laboratory data is fraught with inaccuracy and is often unreliable in detecting many aspects of the disease.²

Defining the location, severity, and presence of complications is essential to the proper management of patients, as the majority of patients with mild disease can usually be successfully treated medically. Only a small

number of patients presenting with acute diverticulitis will require urgent surgical intervention.¹ However, identifying these patients early in their hospital course is important to minimize morbidity and mortality.

Objective confirmation of the extent of the disease process by radiologic examination has been motivated over the last three decades by these inaccuracies in diagnosis and management. Plain radiographs, endoscopy, contrast enema, ultrasound (US), and computed tomography (CT) have all been studied as adjuncts to the diagnosis of complicated diverticular disease.³ Recently, studies on the application of MRI in diverticular disease have been reported.⁴ This article reviews the various radiologic modalities available for the assessment of acute complicated diverticular disease.

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PLAIN RADIOGRAPHY

The initial study for virtually all patients who present to the emergency department with abdominal pain possibly due to diverticulitis is an abdominal series. This consists of flat and upright plain views of the abdomen often accompanied by upright posterior-anterior (PA) and lateral chest radiographs. While many of the abnormalities are nonspecific, up to 30 to 50% of patients subsequently found to have diverticulitis will have abnormal findings on these plain films. Abnormal findings include an ileus or obstructive gas pattern, a soft tissue mass, or pneumoperitoneum. Free air may be present in up to 12% of cases.^{5,6} While the plain films may suggest a diagnosis of diverticulitis, other studies are required for confirmation prior to the initiation of medical or surgical therapy.

CONTRAST ENEMA

Barium contrast enema is the most sensitive test for the detection of diverticulosis. Both single contrast and air contrast studies allow ready identification of the characteristic barium-coated outpouchings from the colonic wall. The size of the individual diverticulum may range from a millimeter to several centimeters. The necks of the diverticula may also be quite variable. The segment of colon involved with extensive diverticulosis is often concentrically narrowed, and the accompanying hypertrophy of the colonic muscle layers produces an irregular appearance resembling a sawtooth.

Prior to the advent of CT, contrast enema evaluation of the colon was the examination of choice for the diagnosis of diverticulitis.⁷⁻⁹ As early as 1972, Nicholas and colleagues described the role of the barium enema in defining pericolic inflammation.¹⁰ Even after reports touting the superiority of CT scanning were published in the 1980s, Johnson and associates reported a series that indicated that barium enema was still the imaging procedure of choice in the diagnosis of acute diverticulitis.¹¹ Though the controversy regarding the appropriate choice of radiologic studies has decreased since that time, the effectiveness of contrast enema examinations in the evaluation of diverticulitis remains unquestioned and may still retain a place.

The optimal timing of examination and the choice of contrast agent are still debatable despite extensive literature.¹² Some authors advise against any enema examination during the active phase of inflammation (the first 2 weeks of the acute episode).¹³ Wexner and Thomas reported, however, that early contrast enema is safe and is associated with a lower rate of misdiagnosis and a shorter hospital stay when compared with delayed or no contrast enema.⁹ Other suggested contraindications to contrast enema include hemodynamically unstable patients and those who have had colonic biopsies in the previous week.

When performed for presumed acute diverticulitis, a water-soluble contrast enema is used. If the contrast material enters the peritoneal cavity, it is significantly less reactive and will resorb over time. Water-soluble contrast agents, however, provide poorer contrast and mucosal detail than barium, and subtle details may be missed. Additionally, water-soluble enemas are hyperosmolar and may worsen hypovolemia in a poorly resuscitated patient secondary to the resulting fluid shift. The radiologic characteristics of acute diverticulitis, however, have been well described and are usually sufficiently apparent to be detected with water-soluble contrast.⁷⁻⁹

Despite its better mucosal coating, barium has a significant disadvantage in the early assessment of diverticulitis. Extravasation of barium into the peritoneal cavity may inadvertently occur and the consequent barium peritonitis may be quite serious or fatal. Clinically it is often difficult to detect small perforations, giving value to water-soluble enemas in many of these patients. In patients known to have pneumoperitoneum, both soluble contrast and barium enemas are contraindicated.¹² In addition, retained barium may interfere or prevent further studies such as CT.¹⁴ A better use for a barium enema today is in the period after resolution of the acute inflammation, which usually occurs 4 to 6 weeks after the acute episode.

The evaluation of acute sigmoid diverticulitis is usually performed by single contrast study on unprepared bowel. Double contrast studies with the addition of air are not appropriate during the initial evaluation of these patients. The most common radiological finding in acute diverticulitis is luminal narrowing and tethering as a result of the extramucosal inflammatory process with or without an associated pericolic abscess.¹⁰ Initially this compression occurs on the mesenteric side of the colon but may progress to encircle the lumen. The appearance of the diverticula varies with the projection but they usually appear as protrusions outside of the colon joined to the colonic wall by a neck.¹¹ Spasm may be seen in association with the diverticulitis and can be reversed with glucagon. The absence of apparent diverticulosis requires reassessment of the diagnosis.¹⁵ The most reliable radiologic sign of diverticulitis seen on contrast enema examination is the appearance of extraluminal contrast.^{11,16} Contrast may track through a perforated diverticulum into a sinus tract or abscess cavity or may connect with an adjacent organ as a fistula.¹⁶ Colovenous and colosalpingeal fistulae demonstrated with barium have been reported.^{17,18} Colovesical and colovaginal fistulae, if present, may be seen only on postevacuation films. Frank extravasation into the peritoneum is encountered less frequently.¹⁶

The primary difficulty with the use of contrast enema examination in the evaluation of diverticulitis is that the inflammatory process is extramucosal, or

“peridiverticulitis,” as described by Fleischner and Ming.¹⁹ The characteristic changes seen on enema are secondary to effects of the pericolic inflammatory process and are thus not pathognomonic for diverticulitis. Overlapping radiologic findings with colon carcinoma, as well as other inflammatory processes of the colon, specifically Crohn’s disease, are occasionally encountered.^{16,20} In a double-blinded study of 73 patients with diverticular disease versus colon carcinoma imaged by barium contrast enema, the overall error rate, documented by pathologic examination, was 23%.²⁰ The absence of mucosal destruction, in addition to tapered margins of the lesion, have been shown to favor the diagnosis of diverticulitis.

Contrast enema is often unsuccessful in delineating the complications of acute diverticulitis and may underestimate the extent of pericolic disease in as many as 41% of patients.^{21,22} Contrast enema is therefore of limited value in diagnosing complications outside of the bowel wall, and diverticular abscesses that do not communicate with the colon may not be detected. Contrast enema is also poor at demonstrating communications to the bladder, with only about 20% of colovesical fistulae being demonstrated on barium contrast enema examination.²¹ Furthermore, unlike CT, contrast enema seldom elucidates alternative conditions with similar clinical presentations such as inflammation of the appendices epiploica and gynecologic pathology. Finally, and perhaps most importantly, contrast enema has absolutely no role in the therapeutic intervention of diverticulitis.

While contrast enema remains an important modality in the diagnosis and evaluation of colonic neoplasms and inflammatory diseases, its utility in evaluating patients with acute diverticulitis is diminishing. Over the past 30 years its disadvantages and inferiority to newer modalities such as US and CT have been demonstrated.

COMPUTED TOMOGRAPHY

In patients with abdominal pain consistent with possible diverticulitis the next diagnostic test after plain films of the abdomen is most often CT scan of the abdomen and pelvis. The optimal management of diverticulitis requires a complete appraisal of peritoneal involvement, including the location and extent of inflammation, and the presence or absence of complications. CT enables accurate assessment of both the intraluminal and extraluminal components of the disease as well as involvement of other nearby organs and distant disease. CT is also invaluable in deciding operative versus nonoperative therapy and response to medical therapy. The potential of the CT scan in the assessment of acute diverticulitis was not reported until 1982, when Gore and Goldberg described its ability to define the extent of pericolic

involvement and found it superior to barium enema.²³ In 1984, Hulnick and colleagues performed the first large retrospective study on the use of CT in diverticulitis and compared it to contrast enema.²⁴ The authors concluded that CT should become the preferred first line modality in patients with suspected diverticulitis. Recently, in the largest study of its kind, CT and water-soluble contrast enema were compared in a prospective evaluation of 420 patients. This study concluded that CT should be utilized as the initial radiologic examination because of its superiority to contrast enema in the detection of severe infection, especially if an abscess is present. Today, CT remains the most sensitive and specific test to document diverticulitis.

Lieberman and Haaga first documented the CT features of acute diverticulitis as bowel wall thickening, increased soft tissue density within the pericolic fat secondary to inflammation, and soft tissue masses representing either phlegmon or abscess. Since then, numerous CT findings in acute diverticulitis have been described which directly reflect the severity of the inflammatory process (Table 1).^{22,24–27}

The timing of CT has an important impact on both medical and surgical therapy of acute diverticulitis. Brengman and Otchy found that the routine performance of CT scan at the time of presentation in patients with abdominal pain led to more accurate diagnosis, earlier identification of complications, and decreased hospital costs.²⁸ Furthermore, CT was shown to be superior to contrast enema in identifying alternative diagnoses. In the same study, 36% of patients suspected of having diverticulitis were found to have normal CT evaluations, indicating probable inaccurate clinical diagnosis. Misdiagnosis rates of up to 67% for diverticulitis have been reported in other studies on abdominal pain managed clinically without imaging on hospitalized patients of all age groups.²⁵ Finally, CT can be of great value in the treatment of diverticular complications by

Table 1 Findings of Acute Diverticulitis on Computed Tomography in Decreasing Frequency of Occurrence

COMPUTED TOMOGRAPHY
Pericolic inflammation/edema
Diverticula
Colonic wall thickening (> 4 mm)
Pericolic abscess
“Arrowhead” sign
“Inflamed diverticulum”
Fistula
Extrapelvic abscess
Colonic obstruction
Intramural sinus tracks
Small bowel obstruction
Ureteral obstruction

allowing percutaneous drainage of abscesses and thus delaying (or avoiding) surgery and minimizing multi-stage therapy.²⁹⁻³¹

As with any radiological modality, the technical aspects of the performance of CT are of utmost importance. Both conventional and helical techniques have been used for diverticular disease. Optimal scanning requires oral, intravenous, and rectal contrast. Many emergent abdominal and pelvic CT scans are performed, however, with only oral and intravenous contrast. CT with intravenous and oral contrast administration alone is reported to be 93% sensitive and 100% specific.³² CT with colonic contrast introduced retrograde without oral or intravenous contrast has produced sensitivities between 93% and 97% with 100% specificity.³² When Rao and colleagues studied the use of helical CT with only colonic contrast,²⁵ they found that in addition to its high sensitivity (93%), the technique could be performed immediately without the additional risks of intravenous contrast and discomfort of contrast administered orally. The safety of slow administration of water-soluble contrast material through soft rubber tubing was demonstrated in diverticular disease in the same trial. The appropriate use of colonic contrast achieves both colonic opacification as well as colonic distention. Optimal colonic opacification by the use of water-soluble contrast material administered rectally should be an essential component of CT evaluation of patients suspected of having diverticulitis.²⁵ Colonic opacification permits the sigmoid colon to be seen in much greater detail, helping to identify and distinguish intraluminal from extraluminal air and fluid collections.^{25,33} In addition, rectal contrast often facilitates differentiating diverticulitis from colon cancers. Incomplete luminal distention is a common technical pitfall that can lead to an inability to identify true focal sigmoidal wall thickening from apparent lumen thickening secondary to poor lumen distention. This factor may account for the occasional normal CT scan in patients with minimal or very early disease.

Other researchers strongly advocate the routine administration of intravenous contrast while citing the low incidence of significant reactions and improved ability to characterize the mural enhancement pattern that may be critical in distinguishing diverticulitis from other inflammatory or malignant processes. Furthermore, mural edema, sinus tracts, and fistulae may be apparent only after the administration of intravenous contrast.²⁶

The normal colon appears on CT images to have a thin wall with haustrations and no apparent diverticula.³⁴ In contrast, segmental thickening of the colonic wall, defined as a thickness of more than 4 mm on a scan perpendicular to or through the long axis of a slightly distended colon lumen, is a common finding in diverticulitis.^{22,24-26,35} Colonic thickening as great as 12 mm

has been documented.²⁴ Inflammatory changes of the pericolic fat characterized by a poorly margined, hazy soft tissue attenuation within the adjacent pericolic fat of the involved colon were first characterized in 98% of patients with acute diverticulitis by Hulnick and coworkers and were the most common CT finding in their series.²⁴ Fine linear stranding within the pericolic inflammatory process is also often present. Diverticula are identified as flask-shaped structures filled with air, barium, or fecal material seen in cross-section projecting through the wall of the colon. The presence of diverticula in the involved segment is helpful in distinguishing diverticulitis from other inflammatory conditions that affect the sigmoid colon, such as inflammatory bowel disease and ischemia.

Numerous less-common findings are also seen on CT scanning of acute colonic diverticulitis. In 1998, Rao and Rhea described the "arrowhead" sign and the inflamed diverticulum in the CT diagnosis of diverticulitis.³⁶ The arrowhead sign is seen as contrast material collecting in an arrowhead shape adjacent to the focally inflamed colonic wall. An inflamed diverticulum is recognized as a rounded, paracolic outpouching centered within an area of pericolic inflammation. It has similar attenuation to soft tissue, calcium, barium, or air. The arrowhead sign and the finding of an inflamed diverticulum have sensitivity rates of 27% and 33%, respectively. Significantly, the specificity of these CT findings is 100% and, when present, they aid in the definitive diagnosis of diverticulitis and the exclusion of other colonic inflammatory processes.³⁶

Thickening of the root of the sigmoid mesocolon appears as a high-attenuation line along the pelvic wall anterior to the iliopsoas muscle. Often a thin rim of fluid may track along this region and is a sensitive finding for acute diverticulitis. Mesenteric venous engorgement is also commonly noted.^{24,35,37,38} Intramural sinus tracts can be visualized as linear fluid collections within a thickened colon wall or as tubes of soft tissue attenuation that may enhance with the administration of intravenous contrast. Pneumoperitoneum is not a common finding. However, microperforation of a diverticulum often leads to the development of focal contained collections appearing as small extraluminal pockets of air, gas bubbles, or extravasation of rectal contrast material.³⁴ This situation may still be amenable to medical management. On the other hand, extraluminal air identified on CT scan in the mesenteric venous branches and portal venous branches is a rare but ominous finding of sigmoid diverticulitis, requiring urgent surgical intervention.^{39,40}

Large bowel obstructions can sometimes be seen in the setting of an acute episode of inflammation but usually reflect repeated prior episodes of diverticulitis with stricture formation.²⁴ In this setting, differentiating a diverticular stricture from colon cancer can be quite difficult. Length of the involved segment over 10 cm, as

well as lack of shoulder formation within the lumen, are more suggestive of diverticulitis.³⁸ Small bowel obstruction is less common, and a transition zone or dilated small bowel may be seen in close proximity to an area of pericolonic inflammation. Delaying surgery and allowing the obstruction to resolve by treatment of the inflammatory process with antibiotics is often possible.⁴¹ Ureteral obstruction secondary to extrinsic compression by inflammation, phlegmon, or abscess was seen in three patients in Hulnick's series.

The above findings are most typical for diverticulitis involving the sigmoid colon. Jang and associates recently suggested different diagnostic criteria for diverticulitis involving the cecal and ascending colon.⁴² Mural thickening and pericolonic inflammatory changes were less specific when seen alone than when these findings were seen in association with thick-walled, enhancing diverticula. The authors also found that the degree of central low-attenuation wall thickening in right-sided diverticulitis varied from 1 to 3 cm greater than that described for sigmoid diverticulitis. Lastly, a preserved layering enhancing pattern of the thickened colonic wall was highly specific in differentiating right-sided diverticulitis from colon cancer.⁴²

Complications are present in up to 30% of cases of diverticulitis and usually necessitate radiological or surgical intervention. The most common is a peridiverticular abscess followed by colovesical, colovaginal, or colocutaneous fistulae.²² Abscesses are usually pericolonic or intramural and appear as an abnormal fluid collection within an area of inflammatory changes. The center of the collection may contain air, air-fluid levels, or tissue with low attenuation representing necrotic debris. Distant abscesses in the flank, psoas muscle, subphrenic space, and liver can also occur from both hematogenous spread and distant intraperitoneal seeding of ruptured diverticula.²⁴

Colovesical and colovaginal fistulae, although the tract may not be well visualized, are accurately diagnosed on CT scans when air is seen in the bladder or vagina in association with thickening of the bladder wall adjacent to an inflamed segment of sigmoid colon.^{35,43} To confirm the presence of a colovesical fistula in a patient whose history is suspicious, rectal contrast should be given without intravenous contrast material so that there is no confusion as to the origin of contrast found in the bladder. Vaginal contrast may be occasionally useful in defining colovaginal fistulae. Air can also be found in the abdominal wall with colocutaneous fistulae.²⁴

The reported accuracy of CT for the diagnosis of sigmoid diverticulitis in multiple series ranges from 93 to 99%.^{24,25,32,35} This sensitivity and accuracy clearly diminish in early or mild disease as the inflammatory changes may not be radiologically evident. A false negative rate of 2 to 21% has been reported.²² When there is a high clinical suspicion for acute diverticulitis,

despite a negative CT scan, a contrast enema can serve as a complementary exam.

A few reports indicate that there is a potentially significant overlap in the imaging appearance of carcinoma of the colon and diverticulitis. This occurs in approximately 10% of cases. Balthazar and coworkers⁴⁴ reported excessive wall thickening on CT of up to 3 cm in 10% of patients with sigmoid diverticulitis that made it indistinguishable from colonic carcinoma and required further evaluation. Chintapalli and associates³⁸ undertook a combined retrospective and prospective study to determine CT findings helpful in distinguishing the two diseases. Their data, which were significantly higher than in previous series, revealed a 51% rate of overlap in the CT scan abnormalities. The authors concluded that the presence of pericolonic inflammation and segment involvement greater than 10 cm were the most significant findings for diverticulitis. The presence of pericolonic edema favored diverticulitis but did not reach statistical significance. Pericolonic lymph nodes and luminal masses were the most helpful criteria for colon cancer. Histologic diagnosis by colonoscopy or surgery is sometimes the only way to differentiate the two.³⁸

ULTRASOUND

High-resolution real-time sonography, although not commonly used in the United States for this purpose, has been proven to have an effective role in diagnosing acute diverticulitis and its complications.⁴⁵⁻⁴⁹ In some European countries, US is routinely used as the initial imaging technique in patients clinically suspected of having acute colonic diverticulitis.^{46,49}

The accuracy of US in the diagnosis of diverticulitis was not extensively documented until 1985 when Parulekar⁴⁵ described the sonographic findings in 16 patients. Since then, the effectiveness of ultrasonography has been documented in several prospective studies.^{35,46,47} Verbanck and colleagues reported sensitivities and specificities of 85% and 80%, respectively, in 123 patients with abdominal pain.⁴⁷ Another study from Germany yielded an overall accuracy of 98%, suggesting that US is diagnostically equivalent to CT scanning.⁴⁶ Even more recently, US and CT findings resulted in similar accuracy in a prospective trial of 64 patients suspected of having diverticulitis.³⁵

The use of US for imaging in appendicitis and inflammatory bowel disease preceded its use in diverticular disease and laid the foundation for a greater knowledge of echographic appearances of normal and abnormal bowel.⁵⁰⁻⁵³ Various degrees of transmural spread of inflammation result in different characteristics in the echo-architecture of the bowel wall. This factor, coupled with advances in equipment and image resolution of the images over the last 20 years, has greatly

contributed to the accuracy of ultrasonographic examination of the intestinal tract.

The normal colonic wall measures 3 mm or less in thickness and can seldom be recognized on routine US. Accurate examination of the sigmoid colon relies on differentiating the colonic lumen from that of the small bowel. This difference can be ascertained by the typical location of the sigmoid colon, its lack of valvulae conniventes, and absence of typical small bowel peristalsis.⁴⁵ Fleischer and associates were the first to conclude that a bowel wall greater than 5 mm in thickness should be considered pathologic.⁵⁴

Abdominal US is traditionally performed with high-resolution real-time scanners with 3.5- or 5-MHz curved-array transducers. Sonographic examination in patients with acute diverticulitis demonstrates hypoechoic thickening of the wall of the involved segment of colon greater than 5 mm with a central echogenic focus.⁴⁶ In the transverse orientation, this finding results in a "target" or "pseudokidney" appearance, as described by Parulekar.⁴⁵ Histologic examination of surgical specimens have revealed that edema, inflammation, and an abnormal muscular hypertrophy account for the mural thickening represented by this hypoechoic external wall layer.⁴⁶ In longitudinal sectioning, a more tubular pattern with narrowing or complete obstruction of the lumen is seen. Repeat examination during a resolving episode of acute diverticulitis will demonstrate regression of the colonic thickening.⁴⁵ A rigid zone of increased echogenicity adjacent to the colon wall represents omental or pericolic fat encasing the inflammatory process. Intramural and extramural diverticula can also be visualized as hyperechoic foci within the inflamed wall of the colon.⁴⁶ These foci represent air or residue within the lumen of the diverticulum causing some associated acoustic shadowing. Lastly, Schwerk and colleagues⁵³ emphasized the importance of local pain and tenderness on gradual compression of the affected area, analogous to the sonographic Murphy's sign of acute appendicitis (Table 2).

Diverticular abscesses can present with a spectrum of ultrasonic findings but usually appear as predominantly cystic masses containing echogenic debris. Occa-

sionally they have the appearance of solid lesions, or they may contain gas. Abscesses are differentiated from free peritoneal fluid by their resistance to change, shape, or location under external compression. Thickening of adjacent bowel loops secondary to edema and inflammation and a surrounding rigid zone of increased echogenicity are exhibited by almost all intra-abdominal abscesses. Intramural abscesses appear as well-circumscribed anechoic masses within a thickened colonic wall. Infrequently, sinus tracts connecting abscesses with the colonic wall are also visible.^{45-48,52}

Abdominal US is often limited by overlying gas that obscures the diseased segment and may produce false negative results. This problem is accentuated by obesity as well as acute diverticulitis where inflammation may cause a localized ileus in neighboring small bowel segments. Disease in the distal sigmoid colon is also more difficult to assess, as it can be poorly accessible to the US due to interference from the bladder and other pelvic structures. Recently, some institutions have employed transrectal sonography with an end-firing endocavitary probe to complement transabdominal sonography. Hollerweger and coworkers⁴⁹ found that routine use of such a probe aided in the diagnosis of acute diverticulitis in the lower sigmoid colon. Superior visualization of the sonographic features of diverticulitis is afforded by the high resolution available with transrectal sonography. These authors advocate routine transrectal sonography as a complementary imaging technique to abdominal US in patients suspected of having acute sigmoid diverticulitis.⁴⁶

Similar to CT, US is capable of evaluating the transmural involvement of diverticular disease by using a quick noninvasive technique that eliminates the need for intravenous or intraluminal contrast. Supporters of its use argue that initial use of US may obviate the need for a contrast study or CT examination in the acute stage of diverticulitis, especially in an ill patient. In addition, US is highly sensitive in detecting complications of diverticular disease.^{35,45-48} However, in most centers in the United States US has a minimal role in patients with suspected diverticulitis. Its main limitation lies in the operator variability inherent in ultrasonography compared with CT in which subjective interpretation is much less problematic. This problem is clearly illustrated by the wide fluctuations in the reported rate of detection of diverticula ranging from 5 to 72%.^{47,48} In addition, US is potentially less useful in patients with abdominal pain who have disease processes that mimic diverticulitis, such as Crohn's disease or ischemic colitis.

Table 2 Findings of Acute Diverticulitis on Ultrasound Evaluation

ULTRASOUND

Colonic wall > 5 mm

"Target"/"pseudokidney" sign

Diverticulum

Pain/tenderness on compression of involved area

Diverticular abscess (cystic masses)

Intramural abscesses

Colovesicle fistula

MRI

The possible role of magnetic resonance imaging (MRI) in inflammatory conditions of the gastrointestinal tract has only recently been evaluated. Incesu and coworkers

reported a sensitivity of 97% and specificity of 100% in adults and children with suspected appendicitis, encouraging others to evaluate its use in acute colonic diverticulitis, which demonstrates similar diagnostic features.⁵⁵ MRI produces quality images with subtle details superior to those from both CT and US. MRI does not require the intravenous, oral, and rectal contrast necessary for optimal CT scans. In addition, MRI is not limited by poor visualization due to overlying gas and fat and by the requirement for experienced radiologists and technicians that has limited the use of US in this country.⁴

The specific MR imaging diagnosis of acute diverticulitis is based on the findings of at least one diverticulum, pericolic exudation and edema, and thickening of the colonic wall. In addition, segmental narrowing and ascites are considered supportive of the diagnosis of diverticulitis.⁴ Abscesses, perforations, and other complications of diverticular disease have not yet been critically assessed by using MRI. However, one would expect that the use of intravenous contrast media with acquisition of high-resolution T1-weighted images should allow clear delineation of these complications with accuracy equal or superior to CT and US.

Despite the reported accuracy of MRI in several small series of patients, we do not endorse its widespread use because its relative advantages appear outweighed by higher cost, limited availability, and contraindication with patients having metallic implants.

NUCLEAR IMAGING

Nuclear imaging has limited use in the diagnostic evaluation of diverticulitis and is primarily used to localize septic foci not found with other imaging modalities. Radiopharmaceuticals, using Indium-labeled white blood cells and Gallium citrate, are the two current options available. Neither agent is able to differentiate between an abscess and an inflammatory phlegmon.

CONCLUSIONS

Various radiologic modalities exist for the evaluation of patients suspected of having complicated diverticular disease. Each has its own advantages and limitations.

US has a proven track record in European countries, but its operator variability and subjective interpretation have limited its use in the United States.

As shown in multiple studies, CT consistently has the highest accuracy in detection of diverticulitis. It is also the most capable of diagnosing alternative conditions. CT scans permit the complete evaluation of the location and extent of the inflammatory process, allowing appropriate clinical management. Furthermore, it can aid in the nonoperative treatment of complicated diverticulitis by allowing percutaneous drainage of ab-

cesses and permitting interval surgery without the need for a colostomy. As a result, CT scanning continues to be the initial radiologic imaging test of choice in the United States.

MRI has demonstrated similar or better sensitivities and specificities to CT scanning in small studies of patients and may eventually supplant CT. Its high cost and current limited availability do not make it feasible for routine use at this time. Further studies comparing it to CT scan in larger groups of patients are needed to determine its future role in the management of diverticular disease.

REFERENCES

1. Parks TG. Natural history of diverticular disease of the colon. *Clin Gastroenterol* 1975;4:53-69
2. Labs JD, Sarr MG, Fishman EK, Siegelman SS, Cameron JL. Complications of acute diverticulitis of the colon: improved early diagnosis with computerized tomography. *Am J Surg* 1988;155:331-336
3. Freeman SR, McNally PR. Diverticulitis. *Med Clin North Am* 1993;77:1149-1167
4. Heverhagen JT, Zielke A, Ishaque N, Bohrer T, El-Sheik M, Klose KJ. Acute colonic diverticulitis: visualization in magnetic resonance imaging. *Magn Reson Imaging* 2001; 19:1275-1277
5. Hayward MW, Hayward C, Ennis WP, et al. A pilot evaluation of radiography of the acute abdomen. *Clin Radiol* 1984;35:289-291
6. Field S, Guy PJ, Upsdell SM, et al. The erect abdominal radiograph in the acute abdomen: should its routine use be abandoned? *BMJ* 1985;290:1934-1936
7. Gottesman L, Zevon SJ, Brabbee GW, Darley T, Wicheru WA. The use of water-soluble contrast enema in the diagnosis of acute lower left quadrant peritonitis. *Dis Colon Rectum* 1984;27:84-88
8. Hiltunen KM, Kolehmainen H, Vuorinen T, Matikainen M. Early water-soluble contrast enema in the diagnosis of acute colonic diverticulitis. *Int J Colorectal Dis* 1991;6:190-192
9. Wexner SD, Thomas TH. The initial management of left lower quadrant peritonitis. *Dis Colon Rectum* 1986;29:635-638
10. Nicholas GG, Miller WT, Fitts WT, Tondreau PL. Diagnosis of diverticulitis of the colon: role of the barium enema in defining pericolic inflammation. *Ann Surg* 1972; 176:205-209
11. Johnson CD, Baker ME, Rice RP, Silverman P, Thompson WM. Diagnosis of diverticulitis: comparison of barium enema and CT. *AJR Am J Roentgenol* 1987;148:541-546
12. Doris PE, Strauss RW. The expanded role of the barium enema in the evaluation of patients presenting with acute abdominal pain. *J Emerg Med* 1985;3:93-100
13. Veidenheimer MC, Berman I, Castro AF, Gallagher BM, Hales H, Salvati EP. Surgical management of diverticulitis. *Dis Colon Rectum* 1981;24:65-72
14. McKee RF, Deignan RW, Krukowski ZH. Radiological investigation in acute diverticulitis. *Br J Surg* 1993;80:560-565
15. Chappuis CW, Cohn I Jr. Acute colonic diverticulitis. *Surg Clin North Am* 1988;68:301-313

16. Stein GN. Radiology of colonic diverticular disease. *Postgrad Med* 1976;60:95-102
17. Williams SM, Nolan DJ. Colosalpingeal fistula: a rare complication of colonic diverticular disease. *Eur Radiol* 1999;9:1432-1433
18. Rossman MD, Burr LJ, Thorpe PE. Colovenous fistula complicating diverticulitis: CT and radiographic findings. *Abdom Imaging* 1997;22:513-515
19. Fleischner FG, Ming SC. Revised concepts on diverticular disease of the colon. II. So-called diverticulitis: diverticular sigmoiditis and perisigmoiditis; diverticular abscess, fistula, and frank peritonitis. *Radiology* 1965;84:599-609
20. Schnyder P, Moss AA, Thoeni RF, Margulis AR. A double-blind study of radiological accuracy in diverticulitis, diverticulosis, and carcinomas of the sigmoid colon. *J Clin Gastroenterol* 1979;1:55-66
21. Ambrosetti P, Jenny A, Becker C, Terrier F, Morel P. Acute left colonic diverticulitis—compared performance of computed tomography and water-soluble contrast enema. *Dis Colon Rectum* 2000;43:1363-1367
22. Birnbaum BA, Balthazar EJ. CT of appendicitis and diverticulitis. *Radiol Clin North Am* 1994;32:885-898
23. Gore RM, Goldberg HI. Computed tomographic evaluation of the gastrointestinal tract in diseases other than first-degree adenocarcinoma. *Radiol Clin North Am* 1982;20:781-796
24. Hulnick DH, Megibow AJ, Balthazar EJ, Naidich DP, Bosniak MA. Computed tomography in the evaluation of diverticulitis. *Radiology* 1984;152:491-495
25. Rao PM, Rhea JT, Novelline RA, et al. Helical CT with only colonic contrast material for diagnosing diverticulitis: prospective evaluation of 150 patients. *AJR Am J Roentgenol* 1998;170:1445-1449
26. Birnbaum BA, Jeffrey RB. CT and sonographic evaluation of acute right lower quadrant abdominal pain. *AJR Am J Roentgenol* 1998;170:361-371
27. Lieberman JM, Haaga JR. Computed tomography of diverticulitis. *J Comput Assist Tomogr* 1983;7:431-433
28. Brengman ML, Otchy DP. Timing of computed tomography in acute diverticulitis. *Dis Colon Rectum* 1998;41:1023-1028
29. Neff CC, vanSonnenberg E. CT of diverticulitis. Diagnosis and treatment. *Radiol Clin North Am* 1989;27:743-752
30. Mueller PR, Saini S, Wittenberg J, et al. Sigmoid diverticular abscesses: percutaneous drainage as an adjunct to surgical resection in 24 cases. *Radiology* 1987;164:321-325
31. Saini S, Mueller PR, Wittenberg J, et al. Percutaneous drainage of diverticular abscess. *Arch Surg* 1986;121:475-478
32. Cho KC, Morehouse HT, Altman DD, Thornhill BA. Sigmoid diverticulitis: diagnostic role of CT—comparison with barium enema studies. *Radiology* 1990;176:111-115
33. Rao PM, Rhea JT, Novelline RA. Helical CT of appendicitis and diverticulitis. *Radiol Clin North Am* 1999;37:895-909
34. Horton KM, Corl FM, Fishman EK. CT evaluation of the colon: inflammatory disease. *Radiographics* 2000;20:399-418
35. Pradel JA, Adell JF, Taourel P, Djafari M, Monnin-Delhom E, Bruel JM. Acute colonic diverticulitis: prospective comparative evaluation with US and CT. *Radiology* 1997;205:503-512
36. Rao PM, Rhea JT. Colonic diverticulitis: evaluation of the arrowhead sign and the inflamed diverticulum for CT diagnosis. *Radiology* 1998;209:775-779
37. Balthazar E. Diverticular disease. *Textbook of Gastrointestinal Radiology*. Philadelphia, PA: Saunders; 1994:1072-1097
38. Chintapalli KN, Chopra S, Ghiatas AA, Esola CC, Fields SF, Dodd GD 3rd. Diverticulitis versus colon cancer: differentiation with helical CT findings. *Radiology* 1999;210:429-435
39. Molitch HI. Septic thrombophlebitis of the inferior mesenteric vein complicating sigmoid diverticulitis: CT findings. *AJR Am J Roentgenol* 1996;167:1014-1016
40. White TB, Allen HA III, Ives CE. Portal and mesenteric vein gas in diverticulitis: CT findings. *AJR Am J Roentgenol* 1998;171:525-526
41. Kim AY, Bennett GL, Bashist B, Perlman B, Megibow AJ. Small bowel obstruction associated with sigmoid diverticulitis: CT evaluation in 16 patients. *AJR Am J Roentgenol* 1998;170:1311-1313
42. Jang HJ, Lim HK, Lee SJ, Choi SH, Lee MH, Choi MH. Acute diverticulitis of the cecum and ascending colon: thin-section helical CT findings. *AJR Am J Roentgenol* 1999;172:601-604
43. Goldman SM, Fishman EK, Gatewood OMB. CT demonstration of colovesical fistula secondary to diverticulitis. *J Comput Assist Tomogr* 1984;8:462-468
44. Balthazar EJ, Megibow A, Schinella RA, et al. Limitations in the CT diagnosis of acute diverticulitis; comparison of CT, contrast enema, and pathologic findings in 16 patients. *AJR Am J Roentgenol* 1990;154:281-285
45. Parulekar SG. Sonography of colonic diverticulitis. *J Ultrasound Med* 1985;4:659-666
46. Schwerek WB, Schwarz S, Rothmund M. Sonography in acute colonic diverticulitis. a prospective study. *Dis Colon Rectum* 1992;35:1077-1084
47. Verbanck J, Lambrecht S, Rutgeerts L, et al. Can sonography diagnose acute colonic diverticulitis in patients with acute intestinal inflammation? A prospective study. *J Clin Ultrasound* 1989;17:661-666
48. Wilson SR, Toi A. The value of sonography in the diagnosis of acute diverticulitis of the colon. *AJR Am J Roentgenol* 1990;154:1199-1202
49. Hollerweger A, Rettenbacher T, Macheiner P, Brunner W, Gritzmanner N. Sigmoid diverticulitis: value of transrectal sonography in addition to transabdominal sonography. *AJR Am J Roentgenol* 2000;175:1155-1160
50. Pozniak M, Scanlan K, Yandow D. Ultrasound in the evaluation of bowel disorders. *Semin Ultrasound CT MR* 1987;8:366-384
51. Kimmey MB, Martin RW, Haggitt RC, et al. Histologic correlates of gastrointestinal ultrasound images. *Gastroenterology* 1989;96:433-441
52. Jeffrey RB, Laing FC, Townsend RR. Acute appendicitis: sonographic criteria based on 250 cases. *Radiology* 1988;167:327-329
53. Schwerek WB, Wichtrup B, Rothmund M, Ruschoff J. Ultrasonography in the diagnosis of acute appendicitis: a prospective study. *Gastroenterology* 1989;97:630-639
54. Fleischer AC, Muhlethaler CA, James AE. Sonographic assessment of the bowel wall. *AJR Am J Roentgenol* 1981;136:887-891
55. Incesu L, Coskun A, Selcuk MB, Akan H, Sozubir S, Bernay F. Acute appendicitis: MR imaging and sonographic correlation. *AJR Am J Roentgenol* 1997;168:669-674