Gastroenterol Clin N Am 35 (2006) 367–391

GASTROENTEROLOGY CLINICS
OF NORTH AMERICA

Diagnosis and Management of Diverticulitis and Appendicitis

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DIAGNOSIS AND MANAGEMENT OF DIVERTICULITIS

Diverticular disease of the colon is a common problem in the Western world and includes diverticulosis and diverticulitis. Colonic diverticula are outpouchings or pseudodiverticula that occur at the weak points of the colonic wall where small feeding blood vessels enter the circular muscle layer. It seems to be associated with a poor diet with low fiber and high fat [1]. Approximately two thirds of the population greater than 85 years old and one third of the population greater than 45 years old have diverticulosis [2]. The sigmoid colon is the most frequent site of involvement with 65% of patients having the disease at that site. Rarely do patients have disease isolated to other colonic locations without evidence of diverticulosis in the sigmoid colon. For example, diverticulosis isolated to the right colon is uncommon and is seen in less than 5% of patients who have diverticular disease [3–5].

Most patients who have diverticulosis remain asymptomatic; however, 15% to 30% of patients will have complications. Diverticulitis is a complication of diverticulosis that occurs when these outpouchings become infected. Diverticulitis develops in an estimated 15% to 20% of individuals who have diverticulosis [6]. Diverticulitis occurs in a spectrum that ranges from mild to severe. Mild cases of diverticulitis are uncomplicated and consist of mild clinical symptoms or confined pericolonic inflammation. Severe, complicated cases of diverticulitis may be associated with intra-abdominal abscess, generalized purulent peritonitis, fistula formation, perforation, bleeding, or obstruction [6,7]. The ideal therapy for patients who present with diverticulitis varies on the clinical presentation and severity of the disease.

Diagnosis of Diverticulitis

Clinical manifestations

Most patients who have diverticulitis have abdominal pain as their presenting symptom (Table 1). This is associated frequently with fever and a generalized

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0889-8553/06/$ – see front matter
doi:10.1016/j.gtc.2006.05.002

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Table 1
Diagnostic tests for acute diverticulitis

Tests	Advantages	Disadvantages	Comments
Contrast enema	Low cost Can confirm diagnosis in acute setting	Risk for perforation Cannot grade severity of inflammation or presence of an abscess	Use water-soluble contrast material Barium contraindicated in presence of localized peritonitis
CT	High sensitivity and specificity Can image transmural and extramural disease Patient comfort compared with contrast studies Can classify severity of disease	High cost	Now gold standard for diagnosis of acute diverticulitis Can be used for treatment in conjunction with percutaneous drainage
Ultrasound	Low cost Noninvasive	Operator dependent Difficult to perform with overlying gas-filled loops	Not used readily for diverticulitis
Colonoscopy	Useful in uncomplicated diverticulosis Can evaluate for other diseases (inflammatory bowel disease, ischemic colitis, carcinoma)	Risk for perforation Cannot evaluate extramural disease Can be difficult in setting of acute inflammation	After resolution of acute disease, useful for evaluating the entire colon for other disease processes
Magnetic resonance colonography	Can assess the entire colon accurately Patients not exposed to ionizing radiation	Long time to complete the study Images easily distorted with patient movement/ motion artifacts	May increase in use over time but limited use currently

feeling of malaise. The pain typically occurs in the left lower quadrant or suprapubic area. Other less common symptoms that may be seen include diarrhea, constipation, nausea, vomiting, dysuria, and urinary frequency. On physical examination a tender mass in the left lower quadrant is the most common finding. Laboratory examination generally demonstrates a leukocytosis with a left shift. Patients who have severe diverticulitis may present with hypotension, and findings of generalized peritonitis on physical examination [2,7].

Radiologic studies

Radiologic imaging for diverticulitis serves two roles. It allows for diagnosis of diverticulitis in patients who have abdominal pain or other associated clinical symptoms. Also, imaging can be used to assess the severity of diverticulitis and the presence of complications [8]. There are various radiologic options for the evaluation of the colon. These include barium or water-soluble enema, CT scan, ultrasound (US), and MR colonography (MRC).

Colonic contrast studies

Contrast enemas were once considered the gold standard for the diagnosis of diverticulitis; however, because diverticulitis is mostly an extraluminal process, they are now limited in usefulness. A water-soluble enema can confirm the diagnosis of diverticulitis in acute situations but it cannot grade the severity of inflammation or presence of an abscess [8–10]. If a contrast enema is being performed in the setting of acute diverticulitis, water-soluble contrast material should be used with a low-pressure single-contrast study. Barium is contraindicated if there is a presence of localized peritonitis and pericolic abscess, because of a chance of perforation that leads to barium extravasating into the abdominal cavity, which would be highly toxic [8]. With a water-soluble contrast study, the presence of extravasated contrast material outside the colon or into a fistula tract is highly suggestive of diverticulitis [11].

Barium can be used in chronic settings or in demonstrating the distribution of diverticular disease in the absence of diverticulitis. In this setting, the best results are obtained with a proper bowel preparation and using a double-contrast technique. It can be used to confirm the presence of diverticulosis when other differential diagnoses are being entertained [8].

CT scan

CT scanning is considered the imaging modality of choice for the diagnosis of diverticulitis. It has a sensitivity ranging from 85% to 97% [8,9]. It also is the most specific imaging modality for the diagnosis of acute diverticulitis [12]. CT scan is superior to contrast enemas in that it can image transmural and extraluminal disease. It also can image adjacent structures and is more comfortable for the patient. It is significantly less invasive than contrast studies and can be performed in sick patients [8,9].

Another advantage of CT scans is the ability to classify diverticulitis by the severity of the disease. Buckley and colleagues [12] classified diverticulitis as mild, moderate, and severe. Mild diverticulitis was evidenced by bowel wall thickening and pericolic fat stranding. Moderate diverticulitis consists of bowel wall thickening greater than 3 mm with phlegmon or small abscess. Severe diverticulitis is defined as bowel wall thickening greater than 5 mm, localized perforation or subdiaphragmatic free air, and abscess greater than 5 cm [12]. Hinchey and colleagues [13] developed a classification for perforated diverticular disease in relation to CT scan findings. Hinchey stage I consists of pericolic abscess or phlegmon. Stage II is abscess in the pelvis, intra-abdominal cavity, or retroperitoneal space. Hinchey stage III is represented by generalized purulent peritonitis. Stage IV is generalized fecal peritonitis [14]. With these stages in mind, the approach to the management of diverticulitis can be formulated.

CT scans also can be used as a form of treatment when combined with CT-guided drainage.

Ultrasound

Another radiologic approach in the diagnosis of diverticulitis is abdominal US. This is a low cost, noninvasive imaging study; however, it is operator dependent and diverticulitis may be difficult to evaluate. Common criteria that are used for US diagnosis of diverticulitis are colonic mural thickening, pericolic inflammation, and the visualization of the diverticula. With these criteria, other etiologies, such as Crohn's disease, penetrating colonic cancer, ischemic colitis, or other inflammatory conditions, must be ruled out [15].

Hollerweger and colleagues [15] reported findings using an inflamed diverticulum as a sign of diverticulitis. The overall sensitivity was 77% and the specificity was 99%. In uncomplicated disease, the sensitivity was 96%. In patients who had complicated diverticulitis, it was difficult to visualize the diverticulum. Another sonographic finding for acute colonic diverticulitis, as reported by Kori and colleagues [16], is the "dome sign"–a hypoechoic mass protruding at the outer surface of the intestinal wall. In patients with right-sided abdominal pain, 100% of those with a dome sign had diverticulitis as the etiology of the pain. This allowed differentiation from acute appendicitis [16].

Endoscopic procedures

Colonoscopy is useful in diagnosing patients who have uncomplicated diverticulosis; however, it generally is contraindicated in patients who have acute diverticulitis because of the increased risk for perforation. It only should be considered when inflammatory bowel disease, ischemic colitis, or carcinoma are suspected highly [9,17,18]. It is a useful tool in patients who have been treated for diverticulitis. A colonoscopy is indicated in these patients to evaluate for underlying neoplastic disease [18]. When performing a colonoscopy after an episode of diverticulitis, a pediatric colonoscope may improve success if a standard adult colonoscope is difficult to pass through a fixed sigmoid because of a history of inflammation [19].

MR colonography

MRC is a new imaging technique that has been applied to patients who have diverticulitis. At times, colonoscopy can be difficult to complete all the way to the cecum. Patients with a history of severe diverticulitis may have stenosis or fixation of the sigmoid colon. Because it is important to evaluate patients who have diverticular disease for other pathology, MRC can be used to assess the remaining colon accurately. To perform an MRC, a patient undergoes the same bowel preparation as for a colonoscopy. Then, a rectal tube is passed and the colon is filled with 2000 to 2500 mL of water. The patient undergoes MRI, and three-dimensional images are obtained before and after injection of gadolinium-based contrast agents [20,21]. Hartmann and colleagues [22] reported sensitivity of 100% by MRC for detection of polyps at least 10 mm in diameter and 84.2% for polyps between 6 mm and 9 mm in diameter.

MRC also can be used for detection of diverticulitis. Heverhagen and colleagues [23] reported using MRC without any injection of contrast material. In 20 patients who had documented acute diverticulitis, MRC accurately diagnosed 19 patients. Schreyer and colleagues [24] reported correctly diagnosing diverticulitis in 14 patients when MRC results were compared with the gold standard of CT scan. More recently, Ajaj and colleagues [21] reported a sensitivity and specificity of 86% and 92% for detection of sigmoid diverticulitis with dark-lumen MRC. The advantage of MRC over CT scan or barium enema is that patients are not exposed to ionizing radiation. MRC also provides the ability to evaluate the entire colon completely in patients who are unable to tolerate colonoscopy; however, this enthusiasm must be tempered by the fact that MRC takes longer than CT scan to complete. Also, patients who have lower abdominal pain may not be able to be still for a prolonged period of time and motion artifacts could distort the images [24].

Management of Diverticulitis

Medical treatment

In general, the initial treatment for uncomplicated diverticulitis should be nonoperative unless an absolute indication for surgery (eg, peritonitis) exists (Table 2). Patients who have mild diverticulitis can be treated as an outpatient with broad-spectrum oral antibiotics that target aerobic and anaerobic gram-negative rods. These include clinically stable patients with mild symptoms and no peritoneal signs on abdominal examination, who are able to tolerate oral intake. Clear liquids should be initiated until the symptoms resolve at which time diet can be advanced slowly [11,18]. When treating a patient who has diverticulitis as an outpatient, close follow-up is important. Symptomatic improvement should be seen in 2 to 3 days. Antibiotics should be continued for 7 to 10 days. If a patient has increasing pain, fever, or the inability to tolerate oral intake, hospitalization may be necessary [11,18].

If a patient needs to be hospitalized for diverticulitis, he/she should not be allowed to have anything by mouth. Intravenous (IV) fluids and IV broad-spectrum antibiotics that target aerobic and anaerobic gram-negative rods should be instituted. Once again, symptoms should improve in 2 to 3 days. If patients respond to IV antibiotics, diet can be advanced slowly. Antibiotics can be switched to an oral agent with good bioavailability, and the patient discharged, to complete the 7- to 10-day antibiotic course. If patients do not improve, then a surgical consultation is warranted [11,18].

Patients respond well to nonoperative treatment. For first episodes of diverticulitis, 50% to 85% of patients respond to antibiotics and do not require surgery. Only 15% to 30% of patients who are admitted after their first diverticulitis episode require surgery during the same hospitalization [4,11,18,25]. The question about patients who respond to medical management is "Who will recur and who will benefit from elective surgery?".

Table 2
Controversies in the management of acute diverticulitis

Topic	Recommended	Alternative	Comments
Abscess management	CT-guided percutaneous drainage	Resection with diverting ostomy and Hartman's Pouch Resection with primary anastomosis	Primary anastomosis is controversial but some studies report good success
Indications for early surgery	After first episode of severe diverticulitis in young patients Patients who have complications from diverticulitis after the first episode Patients who require chronic immunosuppression	Use same criteria for young patients as for older patients	Indications for early surgery is controversial and there are no universally accepted criteria
Indications for elective surgery	After the second episode of diverticulitis	No surgery unless patients develop complications	Criteria for elective surgery not defined clearly Must evaluate risk and benefits for each individual
Method of surgery (open versus laparoscopic)			No definite criteria for recommendation of laparoscopic versus open surgery. Depends on patient and the experience and comfort level of the surgeon.

CT-guided drainage

When perforation of a diverticulum occurs, an intra-abdominal abscess may form. A CT scan will identify the size and location of the abscess. A small localized abscess may be treated with antibiotics [4,9,11]; however, if there is a large abscess or patients do not respond to antibiotics, a CT scan–guided drainage can be performed [4,6,9,11,18]. Percutaneous drainage has a great advantage in that it can control sepsis immediately without the need for general anesthesia. It also can eliminate the need for a two-stage procedure with an interval colostomy, and allow a patient to be prepared properly for a single-stage procedure [4,6,11]. CT-guided drainage is successful. The success rates for stabilizing patients and allowing for a subsequent one-stage procedure ranges from 74% to 93.7% [4,6,9]. Percutaneous drainage is a palliative procedure and should not be considered a definitive treatment. Patients should have an elective resection performed in approximately 3 to 4 weeks.

Surgical treatment

If patients do not respond to medical management or cannot be controlled with percutaneous drainage, surgery should be considered. There are various discussions on the type of surgical resection for a patient who does not respond to nonoperative management. The consensus development conference from 1999 stated that there was no valid data regarding the best treatment for purulent peritonitis. The options include resection of the diseased segment with a Hartmann's pouch and end-colostomy or resection with primary anastomosis with or without a diverting stoma [25]. A review of other articles gives the same type of options without a definitive choice of surgery. It reports a feasibility of resection with primary anastomosis without diversion. Wasvary and colleagues [26] reported no need for a proximal diversion after primary anastomosis in patients who had pericolic or pelvic abscess. This one-stage approach results in a shorter hospital stay and does not require a second operation; however, a two-stage procedure with an initial resection and proximal diversion is indicated in patients who have severe inflammation and substantial fecal contamination [27,28].

The timing for an elective operation to treat diverticulitis is not defined clearly. Of those patients who respond to antibiotics, 7% to 62% have a recurrence of acute diverticulitis [1,4,11]. After the second episode of diverticulitis, the probability of a third episode is greater than 50% [18]. Recurrent attacks of diverticulitis are less likely to respond to medical management. Therefore, elective surgery is recommended by many surgeons after the second episode of diverticulitis [4,9,11,25,28]. Patients who have complicated diverticulitis may benefit from resection after the first episode [28]; however, this is not a hard and fast rule and the risks and benefits for each individual patient must be evaluated. A patient who requires chronic immunosuppression may benefit from elective surgery after the first episode of diverticulitis. There also is controversy about whether younger patients should have an elective resection after the first episode [4,11,25]. Broderick-Villa and colleagues [29] and Lorimer [30] reported low recurrence rates after initial response to medical management, and elective resection did not prevent late major complications of diverticular disease. Therefore, elective resection was not recommended.

Young patients

The prevalence of diverticulitis in patients who are younger than 50 years old ranges from 5% to 10% [31–33]. Controversy exists on how to treat these patients. Some investigators describe younger patients as having more virulent disease with more complications than do older patients, whereas others do not report a particularly aggressive course [31,33]. There is no agreement on the timing for elective surgical resection. There are reports in the literature that support early resection after the first episode of diverticulitis in younger patients [32,34]. Other reports indicate that there is no absolute need for surgical resection after the first episode, and similar factors should be considered before elective surgery as for older patients [31,33,35]. Chautems and colleagues [36] recommended elective surgical resection for patients less than 50 years old after the first acute episode only if they had severe diverticulitis on CT scan.

Laparoscopic surgery

There has been an increasing volume of data for laparoscopic resection for diverticular disease. It has shown a low complication rate (<10%), shortened hospital stay (2–5 days), and a decrease in length of ileus (1–3 days) [37]. When performed by experienced laparoscopic surgeons, there was no increase in morbidity for laparoscopic surgery for diverticulitis compared with laparoscopic surgery for other diseases [38]. Higher conversion rates seem to be limited to patients who have complicated diverticulitis to include severe inflammation, abscess, and fistulas. For uncomplicated diverticulitis, the conversion rate is acceptable and the laparoscopic approach is a great option [38,39]. Recently, there are reports that even in the presence of abscesses or fistulas, laparoscopic colon resection is feasible with good results when performed by experienced surgeons [40,41].

Complications

Diverticulitis can lead to various complications. These include intra-abdominal abscess, fistula, obstruction, and hemorrhage. Patients with an abscess can be managed with antibiotics for a small abscess or CT-guided drainage for a larger abscess. If the patient continues to deteriorate, emergent surgery is needed with a single-stage or two-stage surgical resection. Fistulas are managed surgically during resection of the diseased segment. If a patient has bowel obstruction, he/she usually can be managed with nonoperative therapy–bowel rest and treatment of diverticulitis with antibiotics. Complete obstruction is unusual. Recurrent attacks of diverticulitis can lead to strictures that are diagnosed by a barium enema. A colonoscopy should be performed to rule out stricture that is due to a neoplasm. If the bowel obstruction does not resolve with bowel rest and nasogastric decompression, surgical intervention is necessary [4,9,28]. Finally, patients may experience hemorrhage from diverticular disease. For most patients, diverticular bleeding is self-limited. The first step is to resuscitate and stabilize the patient. Then, the bleeding source needs to be identified. This can be done with a nuclear medicine scan, angiography, or colonoscopy. Although most diverticular disease occurs in the left colon, bleeding occurs more from right-sided diverticular disease. Angiographic embolization can be used to stop the bleeding. Colonoscopy also can be therapeutic in conjunction with injection, heater probe, or fibrin sealant. If bleeding continues, surgical intervention with segmental resection is performed. If patients have persistent bleeding and no definite bleeding site is identified, a subtotal colectomy may be required [4,9].

Conclusion

Diverticulitis is a disease of the elderly but more young people are being diagnosed in recent years. There are many diagnostic tools available. This is a disease that can be treated successfully by medical treatment or surgery. There are many controversies on the proper timing for elective surgical intervention. Successful diagnosis and treatment of diverticulitis requires a multidisciplinary approach among the gastroenterologists, surgeons, and radiologists.

DIAGNOSIS AND MANAGEMENT OF APPENDICITIS

The term "appendicitis" and the recognition that the definitive therapy for appendicitis is removal of the inflamed appendix date back to the 1890s. The appendectomy is the most commonly performed emergent operation in the world. More than 250,000 appendicitis-related admissions occur annually in the United States, totaling nearly three billion dollars in hospital charges [42]. The current incidence of appendicitis is 86 per 100,000 patients per year with a lifetime risk of 6.7% for women and 8.6% for men [43,44].

Appendicitis occurs when the appendiceal lumen becomes obstructed by fecaliths, hypertrophied lymphatic tissue, tumor, or foreign bodies. The appendix becomes distended as mucosal secretion and bacterial proliferation continue in the face of the obstructed appendiceal lumen. The distension of the appendix initially causes a vague dull pain in the periumbilical area, secondary to stimulation of visceral afferent nerves. As the serosal covering of the appendix becomes inflamed, the parietal localization in the right lower quadrant begins. If the process continues without relief, perforation of the appendix occurs. The organisms that are involved in appendicitis typically are *Bacteroides fragilis* and *Escherichia coli*, but polymicrobial isolates are common.

A timely and accurate diagnosis of appendicitis is important to prevent appendiceal perforation. Therefore, surgeons will accept a certain number of normal or negative appendectomies to minimize the incidence of perforated appendicitis. Negative appendectomy rates are acceptable because perforated appendicitis is associated with a fourfold increase in morbidity and an 11-fold increase in mortality compared with acute appendicitis [45]. There is an inverse relationship between the negative appendectomy rate and the perforation rate [46,47]. In the United States, a 15% negative appendectomy rate has been reported and is more common in women than in men (22% versus 9%, respectively) [44,49]. In cases where the diagnosis of appendicitis has been missed and litigation has been pursued, the perforation rate approached 95% [50]. Patients who have perforated appendicitis have been reported to wait up to 2.5 times longer to seek medical care than those who have acute appendicitis [46,51]. Patients in whom the diagnosis of appendicitis has been missed are less likely to appear in distress, have right lower quadrant pain, or complain of nausea [50]. These atypical presentations prompt less surgical evaluations and more misdiagnoses of gastroenteritis.

Diagnosis of Appendicitis

Clinical diagnosis

Despite advances in diagnostics, the clinical history and physical examination remain paramount to the diagnosis of appendicitis (Table 3). Although a variety of presentations may be noted, the classic order of events, as described by Sir

Table 3
Diagnostic tests for suspected acute appendicitis

Tests	Advantages	Disadvantages	Comments
Blood studies alone without imaging	Cheap, readily available	Not specific enough to be used alone	Usually coupled with imaging unless high clinical suspicion
CT	Identifies other intra-abdominal pathology; diagnostic accuracy increasing	Expensive, must have timely reading from radiologist; reluctance of use in pregnancy	Most commonly ordered imaging test; no consensus on contrast route
CT with oral contrast	Visualizes the bowel and surrounding structures	Aspiration risk, not tolerated well by ill patients	Used routinely in many centers; controversial
CT with IV contrast	Visualizes the bowel wall and mesenteric vessels	Extravasation, skin reaction, potential renal damage	Used routinely in some centers; controversial
Ultrasound	Noninvasive, no contrast required; safe in pregnancy	Highly operator dependent	Based on an individual center's experience; typically first test in pregnancy
Tagged leukocyte study	Helpful in intermediate cases	Expensive, time consuming; false positives, not widely available	Not used widely
Colonoscopy	Highly sensitive; evaluates entire colon for other pathology	Risk for perforation; requires bowel preparation	Helpful in nonacute setting where diagnosis is in question

Zachary Cope [52], of pain, followed by nausea and vomiting, local iliac tenderness, fever, and leukocytosis still apply. Classically, the pain is recognized initially in the periumbilical or epigastric regions and subsequently localizes to the right lower quadrant over several hours; however, pain descriptions may differ based on the position of the appendix. For example, when the appendix is retrocecal, the initial pain manifestation may be in the right iliac or flank region. Additionally, a long appendix that crosses the midline may cause left lower quadrant pain. Nausea and anorexia are present nearly always and typically occur after the onset of pain. Vomiting may accompany the nausea, but rarely occurs before the onset of pain if appendicitis is present.

Perhaps no other pathologic process in the abdomen has better known physical examination findings than does appendicitis. An examiner often finds the subjects laying flat and motionless with their right leg drawn up to relieve the pressure of the right lower quadrant inflammatory mass. It should be emphasized that, as with pain location, physical examination findings are widely dependent on the position of the appendix. Most patients, at some time in their course, exhibit tenderness in the right lower quadrant. Direct rebound tenderness in this area is a response to the inflamed appendix and its proximity to the peritoneal surface. This localized peritoneal irritation also may be demonstrated by indirect referred tenderness in the right lower quadrant that is elicited with left lower quadrant pressure (ie, Rovsing's sign). Involuntary guarding refers to muscle contraction in response to the inflamed parietal peritoneum. This finding, along with rebound tenderness, is an independent predictor of appendicitis [53]. Cutaneous hyperesthesias on the right at the levels of T10, T11, and T12 dermatomes may be present, but are assessed rarely. A positive "psoas sign" occurs when a patient experiences pain while on their left side and an examiner slowly extends the right thigh. Pain occurs as the iliopsoas is irritated by the inflamed appendix. In turn, the obturator sign may be elicited by an examiner internally rotating the flexed right thigh while the patient is supine. This brings the obturator internus in contact with an irritated pelvis, which produces hypogastric pain. Finally, the patient's temperature is a poor predictor of appendicitis [54], but when high and accompanied by tachycardia, a ruptured appendicitis with intra-abdominal abscess should be suspected.

Often, the patient has been premedicated with narcotics before surgical evaluation. This remains a controversial practice that is promoted by emergency physicians and discouraged by surgeons. Keeping with classic surgical dogma, surgeons worry that adequate analgesic relief may alter the accuracy of diagnosis and the ability to obtain informed consent [52,55]. The logistical difficulties that are inherent to this problem, including patient randomization, adequate sample sizes, blinding of patient and examiner, actual disease process causing the pain, and varied availability of operating rooms, have made multicenter studies and evidence-based approaches unobtainable [56]. In the small studies that exist, judicious and appropriate doses of narcotic analgesia seem to provide significant pain relief without altering physical examination findings or the diagnostic process in patients who truly have appendicitis [56–58]. LoVecchio and colleagues [59] reported that 5 mg or 10 mg of morphine, given to patients who have acute abdominal pain, significantly alters their physical examination findings (tenderness and localization) without altering their diagnosis or management when compared with placebo. In one retrospective review, up to 50% of patients with a misdiagnosis of appendicitis required narcotic pain medicine before discharge from the emergency room, which emphasizes the need for observation and experienced surgical evaluation if narcotics are given [50].

Laboratory diagnosis

As radiographic diagnostic modalities have improved, less emphasis has been placed on laboratory diagnosis in patients who present with suspected appendicitis. Although laboratory evaluation is cheap, rapid, and readily available, elevated values are weak predictors of appendicitis when viewed alone. Several studies have demonstrated the proportion of polymorphonuclear cells and the white blood cell (WBC) count are important diagnostic predictors of appendicitis [46,53,60–62]. One such study suggested that a WBC count of greater than 12,300/mL is associated with a twofold increase in appendicitis in patients who had suspected appendicitis [63]; however, several studies have reported that WBC counts of greater than 10,000/mL was only 76% to 93% sensitive and 38% to 63% specific for appendicitis [54,64]. This lack of specificity precludes surgeons from taking a patient to surgery based on WBC count alone.

Although there is no single laboratory value that is particularly accurate by itself, a combination of values may be promising. Dueholm and colleagues [64] reported that when WBC count, neutrophil differential, and C-reactive protein levels are within the normal reference ranges, the negative predictive value is 100%. When the diagnosis is otherwise in doubt, this "triple test" may identify patients who warrant further observation rather than undergoing a likely negative laparotomy. Similar findings have been reported when combining WBC and C-reactive protein with and without phospholipase A2 [65,66]. If the patient has a WBC count of greater than 18,000/mL perforation or another diagnosis should be entertained. A urine analysis sample may have red blood cells or WBCs, but typically not bacteria.

Role of imaging in diagnosis

Advances in the diagnostic accuracy of imaging have altered the approach to patients who have suspected appendicitis. Adjunctive diagnostic tests may be used in cases where the presentation is atypical or other tests are equivocal. This is especially applicable in the pediatric population and in women of child-bearing age in whom the correct diagnosis may be elusive. Plain films are not performed routinely or considered mandatory but may reveal an appendicolith, a localized ileus, or a unsuspected pneumonia. Barium enema is used rarely as a diagnostic modality in this disease. Some of the more commonly recommended diagnostic images include leukocyte-tagged studies, US, and computed tomography.

Leukocyte-tagged studies

Technetium-labeled WBC scans have been used in atypical presentations with sensitivities of 85% to 98%, accuracies of 89% to 97%, and a reduction in negative appendectomy rates [67–69]. These tests are expensive, time consuming, not universally available, and susceptible to false positives because any inflammation may cause WBC accumulation. For these reasons, leukoscintingraphy is not used widely as an aid in the diagnosis of appendicitis.

Ultrasound

Much has been written in the surgical, radiology, and gastroenterology literature about the efficacy of US in the setting of appendicitis. US is an attractive diagnostic imaging option because it is inexpensive, rapid, noninvasive, safe in pregnancy, and does not require contrast; however, US can be considered useful in the evaluation for appendicitis only if it improves upon the most commonly used diagnostic tool: clinical impression. Findings that are suggestive of appendicitis include a thickened, noncompressible, blind-ended wall that is greater than 6 mm in diameter. Other findings include the absence of gas in the appendiceal lumen, the presence of blood flow in the appendiceal wall, and appendicoliths [70,71]. If the diameter of the outer appendiceal wall is greater than 6 mm in the anterior–posterior direction, sensitivities and negative predictive values up to 98% to 100% have been reported, but with a specificity of only 68% [72,73]. Franke and colleagues [70] reported the presence of a target sign as the most clinically diagnostic finding. Other potentially important findings that are identified by US include right-sided diverticulitis, colitis, terminal ileitis, mesenteric lymphadenitis, ovarian cysts, tubo-ovarian abscesses, and ectopic pregnancies [74,75]. If the symptoms suggest a gynecologic origin, an endovaginal US should be considered. The accuracy of using US findings to diagnose appendicitis is operator dependent [74,76,77].

CT

Findings on CT that are suggestive of appendicitis include abnormalities of the appendix, such as an enlarged appendix greater than 6 mm, wall thickening, and appendicoliths, as well as right lower quadrant inflammatory changes (eg, fat stranding, fluid, phlegmon, abscess, free air, adenopathy, adjacent bowel thickening) [78]. Rao and colleagues [78] reported finding an enlarged appendix greater than 6 mm and right lower quadrant fatty stranding in 93% of patients who had appendicitis. Using focused, helical imaging after administration of rectal contrast, the same group reported an accuracy, sensitivity, and specificity of 98% [79]. This technique resulted in a change in management in more than 50% of patients in whom appendicitis was suspected, which prevented unnecessary appendectomies and admissions and identified other diagnoses [79]. The same group increased the sensitivity to 100% when adding oral contrast while limiting the overall radiation exposure to one third of a standard CT of the abdomen and pelvis [80].

During this same time period, this group also convincingly described a significant reduction in cost when CT was used routinely in the evaluation by preventing unnecessary appendectomies, observations before necessary appendectomies, and admissions when appendicitis was not present [79,81]. Five years later, using various contrast regimens and thin, focused cuts, this group reported a negative appendectomy rate of 3% [82]. In this latest series, only 12% of patients went to surgery without CT evaluation and equivocal readings were reported in only 1.9% of adult cases. These results indicate that the diagnostic value of CT improves as a center's experience increases.

Compare and "contrast"

Controversy abounds as to the best CT technique to use with arguments for and against oral contrast, rectal contrast, IV contrast, triple contrast, and no contrast at all. The use of IV contrast aids in visualization of the bowel wall and may increase visualization of an inflamed appendix without the delay or burden of oral or rectal contrast administration. Studies that evaluated IV contrast have reported only adequate sensitivities of 92% and accuracies from 91% to 98% [83,84]. Jacobs and colleagues [85] compared a focused approach using oral contrast with an unfocused approach with IV contrast added; IV contrast significantly improved the reader's ability to identify appendicitis as well as alternative diagnoses.

Evaluation of the abdomen without any contrast enhancement avoids the administration of IV contrast and the potential for injection site extravasation, renal damage, contrast allergy, skin rash, respiratory compromise, and death [86]. Additionally, the routine administration of oral contrast, which may not be tolerated well by a patient who is nauseated, presents an additional risk of aspiration if general anesthesia is required and commonly delays study completion for several hours [87]. Additionally, unenhanced CT is generally less expensive, does not require the presence of a radiologist, and avoids the discomfort and theoretic perforation risk of rectal contrast administration [88]. Unenhanced CT evaluation has sensitivities reported from 96%, specificities of 99%, and accuracy of 97% [89]. Peck and colleagues [88], in a large rural setting, described reducing their negative appendectomy rates to 5% while maintaining an accuracy of 97% with unenhanced CT scans. Without any contrast a normal appendix was reported to be visualized in 79% of cases with adequate interobserver agreement [90].

Recently, Anderson and colleagues [91] systematically reviewed 23 mostly prospective reports and compared the diagnostic value of CT with rectal, oral, rectal and oral, oral and IV, and no contrast. Overall, sensitivities ranged from 83% to 97%, specificities ranged from 93% to 98%, and accuracies ranged from 92% to 97%. Unenhanced studies exhibited higher specificity, positive predictive value, and accuracy, while maintaining similar sensitivity and negative predictive value as compared with contrast studies [91]. The explanation for this is unclear and may be due, in part, to publication bias. Regardless, a limited number of prospective, randomized studies have led to a lack of a national standard.

CT controversies

Not all reports have been supportive of routine CT usage. Lee and colleagues [92] found that rather than increasing diagnostic accuracy, CT delayed management and provided less benefit than did diagnostic laparoscopy. Recently, Garfield and colleagues [93] reported that the routine use of CT increased time in the emergency room by an average of 9 hours without increasing diagnostic accuracy. Perez and colleagues [94], however, reported that their negative appendectomy rate increased from 12% to 17% after CT was introduced in their series, while significantly increasing the length of stay in the emergency room. A recent prospective, randomized comparison of clinical assessment versus CT with IV and oral contrast revealed similar accuracies (90% versus 92%) and a higher sensitivity for clinical assessment (100% versus 91%) [95]. Length of stay and total costs were similar, but time to operating room was increased when CT was used. These studies call to light the legitimate concerns about institutional variability between who orders the CT and who interprets it, which ultimately may lead to discrepancies [96]. Recently, Flum and colleagues

[48] analyzed the records of patients who had appendicitis in a large health care system and found no increase in the accuracy of diagnosis, despite the increasing use of CT and US.

These studies fuel the skepticism that some surgeons have over relying on imaging to diagnose a clinical disease. In a recent survey of practicing surgeons, 62% believed that CT scan was overused and 74% believed its accuracy to be less than the stated 98% [97]. As a result, most of these respondents order CT scans in the evaluation of appendicitis less than 50% of the time. In most cases (63%), the CT is ordered by an emergency medicine physician, and, alarmingly, in more than 30% of cases the scan may be interpreted by someone other than an attending radiologist [97].

Less than 1% of all appendectomies turn out to be for neoplasms, and up to 40% of these may present clinically as appendicitis [98]. CT evaluation may suggest an appendiceal neoplasm in some cases, which could alter the operative approach. Pickhardt and colleagues [98] reported that 95% of primary appendiceal neoplasms were larger than 15 mm on CT or had concerning morphologic abnormalities.

Role of colonoscopy in diagnosis of appendicitis

Gastroenterologists are not asked to perform colonoscopies infrequently in patients who present with right lower quadrant pain when symptoms are not specific, when imaging studies are nondiagnostic, when appendectomy has been performed, or when the symptoms are chronic [99]. These patients often have CT scans that suggest diagnoses other than appendicitis, including inflammatory bowel disease, diverticulitis, colitis, or cecal cancer. Findings that are suggestive of appendicitis include mucosal hyperemia, bulging at the area of the orifice, spontaneous discharge of pus, and discharge of pus following forceps biopsy [100,101]. Uehara and colleagues [100] reported these findings during a routine colonoscopy in an asymptomatic patient who underwent immediate appendectomy with pathologically confirmed appendicitis. Inflammation in the remainder of the appendix following appendectomy, referred to as stump appendicitis, also has been diagnosed in this fashion [102]. Although determining the exact diagnostic accuracy of colonoscopy for appendicitis is challenging, Chang and colleagues [101], in their retrospective review, estimated a sensitivity of 100% and a specificity of 99%. Ohtaka and colleagues [103] reported the diagnosis of a suspected periappendiceal abscess found by chance during a colonoscopic biopsy near a cecal lesion leading to successful endoscopic drainage of pus. Colonoscopy does present the theoretic risk for furthering or creating abscess formation with insufflation and bowel preparation as well as aggravating symptoms.

Management of Appendicitis

Except in areas of remote medical care, appendectomy has been the treatment of appendicitis since the entity was described first. A decade ago, Erickson and Granstrom [104] randomized patients who had appendicitis to antibiotic therapy for 10 days or appendectomy. The nonoperative group was treated successfully in 95% of cases; however, 35% of cases recurred with rupture or phlegmon within an average of 7 months.

Patients who are diagnosed with appendicitis should be hydrated adequately and started on antibiotics. In the case of uncomplicated appendicitis, a third-generation cephalosporin is administered for 24 hours or less. For more complicated infections, broader antibiotic coverage with carbapenems or triple coverage with a cephalosporin, metronidazole, and an aminoglycoside is instituted before appendectomy (Table 4).

Open appendectomy

The incision of choice for an open appendectomy (OA; McBurney's, Rocky-Davis, midline) is based on the point of maximal tenderness or image findings that facilitate localizing the appendix and the ligating appendiceal artery. The inflamed appendix is removed by simple ligation, purse string ligation, or gastrointestinal stapler, and the peritoneal cavity is irrigated. The remaining wound is closed in layers, except in the case of perforation whereby the skin and subcutaneous tissue are packed open to minimize the risk for wound infection. If, upon evaluation, the appendix is normal, a methodical search is performed to find the source of pathology with special attention to the small bowel and, in the female patient, pelvic structures.

Laparoscopic appendectomy

To perform a laparoscopic appendectomy (LA), access to the abdominal cavity is gained in the periumbilical region and a laparoscope is inserted. This allows for visualization of the entire abdominal cavity. Two or three additional

Table 4
Controversies in the management of suspected acute appendicitis

Topic	Recommended	Alternative	Comments
Pain management	Judicious use for patient comfort during work-up	Withhold all pain medicines before evaluation by surgical team	Most recent studies show small incremental doses of narcotics do not alter diagnostic accuracy
Prophylactic antibiotics	Acute: perioperative abx only Ruptured: IV abx until hospital discharge followed by po abx for 7–10 days	Ruptured: IV abx while in hospital and no abx at discharge	No consensus but most surgeons continue oral abx after discharge when appendix was ruptured
Open versus laparoscopic	Laparoscopic	Open	Should be based on surgeon's experience and preference
Abscess management	CT-guided percutaneous drainage, IV abx, interval appendectomy	Open exploration, appendectomy, drainage	Excellent results reported with initial percutaneous drainage

Abbreviations: abx, antibiotics; po, by mouth.

operating trocars are placed to facilitate exposure and dissection of the appendix. The base of the appendix and the appendiceal mesentery are transected using an endoscopic stapling device. The specimen is removed from the abdomen using a small specimen bag and the small incisions are closed. As with an OA, if the appendix appears grossly normal an extensive search for other pathology is undertaken.

Laparoscopic versus open appendectomy: which approach is better?

The advantages of an LA compared with a conventional OA are debatable. A recent review of a nationwide database and several meta-analyses have reported less wound infections, less pain, less complications, and faster recovery following LA [105–107]; however, there is no consensus among the most recent prospective randomized trials over the last 10 years [108–124]. Some studies have revealed that LA is associated with less pain medication and shorter hospital stay [109–111,118–120], whereas others reported fewer wound infections [109,111,113,119,120]. Others demonstrate no difference between LA and OA in wound infection rates, complications [108,110,112–118,121,124], or hospital stay [108,112–115,117,121,124]. A recent, well-designed, prospective, randomized, double-blinded study revealed no differences in complications, pain, activity, hospital discharge, or resumption of diet [123].

LA, on average, takes 18 minutes longer than does OA, and conversion rates from LA to OA range from 5% to 23% [108–124]. Longer operating room times result in higher costs unless patients are sent home earlier. LA may be associated with less cost when indirect costs are considered, such as return to work, in otherwise healthy patients [116,118]. Several of the prospective, randomized studies suggest this advantage by demonstrating quicker time to full recovery and activity [109–111,114,116–119,121,124], whereas others have refuted this advantage [115,122,123]. Laine and colleagues [114] randomized young women who had presumed appendicitis to open exploration or laparoscopy, and revealed the added benefit of laparoscopy by establishing the diagnosis in 96% versus 72% for open surgery, which resulted in a lower negative appendectomy rate (44% to 4%). In a similarly designed trial, Larsson and colleagues [125] reduced the negative appendectomy rate from 34% to 7%, and identified gynecologic pathology when the appendix was normal that was not picked up during OA. In men, the advantages are less clear [110,112,122]. When the appendix is found to be ruptured during laparoscopy, appendectomy can be performed safely, but open conversion rates are higher [126–128]. We advocate LA at Baylor College of Medicine for two reasons. The laparoscopic approach provides superior visualization of the abdominal cavity and allows for a more thorough exploration of the abdominal cavity should the appendix appear normal. Additionally, it is an advanced laparoscopic procedure that gives surgeons experience with manipulating the bowel laparoscopically; this makes them more comfortable with laparoscopic techniques that are essential for small and large intestinal resections.

Abscess

In up to 25% of cases the appendix is ruptured or a periappendiceal abscess is present [49]. If ruptured appendicitis or abscess is noted, the appendix is removed, the peritoneum is irrigated, and the wound is allowed to heal by secondary intention or delayed primary closer to avoid infection. If broad-spectrum antibiotics are initiated, sampling of peritoneal fluid for culture seems to be unnecessary, except in immunocompromised patients [129]. With the increasing use of preoperative imaging, patients who have periappendiceal abscesses often are diagnosed preoperatively. These patients are treated best with nonoperative management and selective image-guided percutaneous drainage. Immediate operation in these patients results in higher complication rates and longer hospital stays [130,131]. After drainage and antibiotic therapy, these patients should be encouraged to return for interval appendectomy. A significant number of these patients has recurrent appendicitis, but it often is difficult to convince a patient to return for surgery when they are asymptomatic.

Postoperative care

Postoperative complications include wound infections, intra-abdominal abscess, bowel obstruction, and rarely, hernia. These are more likely to occur in patients who have had ruptured appendicitis. Following successful appendectomy for acute, nonruptured appendicitis, antibiotics are discontinued and a diet is resumed. Typically, patients are discharged the next day. In the case of ruptured appendicitis, broad-spectrum IV antibiotics are continued postoperatively. Recently, Taylor and colleagues [132] randomized patients who had acute and perforated appendicitis to placebo or oral antibiotics following IV antibiotics. They reported no significant difference in postoperative infections between groups, which suggests that hospital discharge with oral antibiotics may be unnecessary; however, it is common clinical practice to discharge patients who had ruptured appendicitis with oral antibiotics for 7 to 10 days.

Appendicitis in Pregnancy

Appendicitis complicates 1 in 1500 pregnancies, and is the most frequent reason for nonobstetric surgery during pregnancy [133]. The diagnosis of appendicitis in pregnancy is challenging secondary to the altered location of the appendix, the overlap of signs and symptoms, and the reluctance to perform unnecessary surgery in a pregnant patient. The danger of a missed diagnosis of appendicitis is associated with an increase risk for ruptured appendicitis and peritonitis, which are associated with 10% fetal loss rates [134]. Perforation rates were reported to range from 12% to 55% [133,135].

Because of the limitations of imaging modalities in these patients, physical examination and history are the most important parts of the evaluation. Often, US is the first image obtained, but operator experience and the inconsistent location of the appendix in this population hampers the accuracy, especially in the third trimester. CT is beneficial in diagnosis when used with limited helical scanning at less than 0.003 Gy [136]. Because of potential teratogenesis, emphasis is placed on balancing the image quality and the radiation dose [137]. Several small studies demonstrated the successful use of MRI in this group citing the avoidance of contrast and the lack of biologic risk [138,139]. When appendicitis is suspected, a laparoscopic approach is a safe and effective surgical option [140].

Appendicitis in the Elderly

As life expectancy increases, the frequency of appendicitis in the elderly is more common. Up to 74% may have atypical presentations and often delay seeking medical evaluation, which contributes to the difficulty in making an accurate diagnosis [141]. Even after presentation, these patients often are misdiagnosed by physicians who assume other diagnoses or are more concerned with the comorbidities. These patients often end up being admitted with presumed diverticulitis or partial small bowel obstruction. Not surprisingly, this population has perforation rates that range from 51% to 72% [43,141,142] and higher morbidity and mortality [142]. Storm-Dickerson and Horattas [141] reported a decrease in ruptured appendicitis in this population from 72% to 51% with the earlier use of CT. Additionally, a recent, large observational study revealed that a laparoscopic approach in this population was safe and resulted in shorter hospital stays and fewer complications [143]. Whatever the operative approach, the best outcomes in this population result from a high index of suspicion for appendicitis and abdominal imaging when necessary.

SUMMARY

Diverticulitis and appendicitis are common infections of the gastrointestinal tract that require urgent medical and surgical attention. Successful management of these conditions requires a multidisciplinary approach among primary care providers, gastroenterologists, surgeons, and radiologists. The diagnosis of appendicitis, in particular, can be difficult. Advances in radiographic imaging have improved the diagnostic accuracy in these infections. Minimally invasive surgical techniques have improved the patient's postoperative recovery when surgery is necessary in the management of these conditions.

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