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Med Clin N Am 90 (2006) 481–503

THE MEDICAL
CLINICS
OF NORTH AMERICA

Acute Abdominal Pain

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Abdominal pain is a common complaint in all settings of medical practice. In the United States in 2002, abdominal pain was the chief complaint of over 7 million patients presenting to an emergency department (ED), accounting for 6.5% of all patient visits [1]. In primary care practices in 2002, abdominal pain was a complaint of more than 13.5 million patient visits, accounting for 1.5% of patient encounters [2]. In certain situations, abdominal pain may be a symptom of a severe, life-threatening disease process, whereas in other situations, it may be a symptom of a more benign underlying condition. This review provides a framework for understanding abdominal pain, so that practitioners may determine those patients who need a more expedited evaluation, and reviews the pathophysiologic mechanisms underlying abdominal pain. A general approach to the patient is outlined, and several causes of abdominal pain are considered in detail, focusing on the most severe and commonly encountered.

A general understanding of abdominal anatomy, physiology, and pathophysiology is vital when formulating a differential diagnosis for abdominal pain. In addition, it is important to understand how abdominal pain is generated and perceived by the patient. The abdominal viscera are innervated with nociceptive afferents within the mesentery, on peritoneal surfaces, and within the mucosa and muscularis of hollow organs. These afferents respond to both mechanical and chemical stimuli, producing sensations of dull, crampy, insidious pain. The principal mechanical stimulus is stretching, whereas a variety of chemical stimuli, including substance P, serotonin, prostaglandins, and H^+ ions, are perceived as noxious by visceral chemoreceptors [3]. Abdominal pain occurs in three broad patterns, visceral, parietal, and referred. Visceral nociception typically involves stretching and

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doi:10.1016/j.mcna.2005.11.005 *medical.theclinics.com*

distension of the abdominal organs, but torsion and contraction also contribute. The pain is carried on slow-conducting C-fibers. Patients often describe pain of visceral origin as a dull ache. Visceral pain is often located at the midline because visceral innervation of abdominal organs is typically bilateral. Pain location corresponds to those dermatomes that match the innervation of the injured organ [3]. Generally, visceral pain from organs proximal to the ligament of Treitz (embryonic foregut), including the hepatobiliary organs and spleen, is felt in the epigastrum. Visceral pain from abdominal organs between the ligament of Treitz and the hepatic flexure of the colon (embryonic midgut) is felt in the periumbilical region. Visceral pain generated from organs distal to the hepatic flexure (embryonic hindgut) is perceived in the midline lower abdomen. Parietal pain is typically sharp and well localized, resulting from the direct irritation of the peritoneal lining. Parietal peritoneal afferents are A delta fibers with a rapid conduction velocity, which results in a sharp pain sensation similar to skin and muscle pain. Because parietal innervation is unilateral, lateralization of pain occurs [3]. Referred pain occurs when visceral afferents carrying stimuli from a diseased organ enter the spinal cord at the same level as somatic afferents from a remote anatomic location; it is typically well localized. A single diseased organ may produce all three types of pain. For example, when a patient develops cholecystitis, gallbladder inflammation is experienced initially as a visceral pain in the epigastric region. Eventually, the inflammation extends to the parietal peritoneum, and the patient will experience parietal pain that lateralizes to the right upper quadrant. Gallbladder pain may also refer to the right shoulder.

Awareness of the anatomy and innervation of the abdominal viscera allows one to formulate a differential diagnosis of abdominal pain based on the location of the pain (Box 1). However, there is a significant overlap among abdominal pain presentations. Furthermore, disease processes from organs outside of the abdominal cavity can present with abdominal pain. To considerably narrow the differential diagnosis, it is crucial to approach each patient in a systematic, logical, and deliberate manner. Similar to the way in which physicians are trained to read an ECG by assessing rate, rhythm, axis, and other findings, so too should physicians approach abdominal pain. In an age of expanding variety, quality, and accuracy of diagnostic tests, abdominal pain also necessitates a regimented approach, which starts with a thorough history. William Osler stated, ''By the historical method alone can many problems in medicine be approached profitably''. The history should include not only a thorough assessment of the present condition but also a thorough assessment of underlying medical problems, medications, family history, and a history of substance abuse, recent travel, and occupation. Important clues to the cause of the pain should be determined in the patient's history by inquiring about the nature of the pain, which includes its quality, location, rapidity of onset, chronicity, radiation, intensity, exacerbating factors, alleviating factors, and associated symptoms.

After a thorough history, a focused physical examination should be performed. Quoting Osler again, ''Don't touch the patient—state first what you see; cultivate your powers of observation''. For example, a patient who has peritonitis often lies completely still because movement further irritates the peritoneum. On the other hand, a patient who has renal colic may writhe in pain and may not be able to be consoled to comfort. Once an initial observation is complete, a review of the vital signs is imperative. Any abnormality of vital signs should prompt the physician to consider the presence of an abdominal catastrophe. Auscultation of the abdomen determines whether the intestinal peristalsis is appropriate and whether any abdominal bruits are present. Next, palpation of the abdomen should be performed to distinguish pain, a subjective sensation, from tenderness, which is an objective finding. When performing palpation, the location of tenderness should be used to narrow the differential diagnosis. Additionally, the presence of guarding or rebound tenderness should be noted because these findings imply peritoneal irritation. Furthermore, palpation can determine the presence of visceral enlargement, masses, or fluid.

The importance of a properly executed history and physical examination cannot be overstated. Although the sensitivity and specificity of a history and physical may not match that of an abdominal CT scan, there is no risk, minimal time lost, and essentially no cost. In fact, in this evidence-based era, one observational study has revealed that, based on history and a physical alone, physicians were able to correctly differentiate between organic and nonorganic causes of abdominal pain nearly 80% of the time [4]. Furthermore, historical features such as pain location have been shown in prospective investigation to be specific for certain disease states [5]. That being stated, however, some of the basic physical examination tools have come under close scrutiny when assessed independently. For example, some studies suggest that the digital rectal examination fails to alter diagnosis or management, and routine performance may not be necessary [6]. However, the present authors believe that performing the rectal examination is crucial to the evaluation of acute abdominal pain. For example, the presence of occult blood in a patient's stool may suggest the presence of luminal ischemia in the appropriate clinical setting. Additionally, rectal tenderness can be seen with anal fissures, perirectal abscesses, or acute prostatitis. Thus, although the rectal examination may lack sensitivity or specificity, it can often help bring added focus to a blurry clinical presentation.

The ability to detect warning signs of impending disaster in a patient who presents with abdominal pain is often left up to the primary physician, long before the ED physician, surgeon, gastroenterologist, or other specialist encounters the patient. Certain historical and examination findings should raise ''red flags'' that a severe life-threatening underlying abdominal process is present and prompt early triage to an emergency department or inpatient hospital bed. Red flags from the history include fever, vomiting, obstipation, light-headedness, syncope, and overt gastrointestinal blood loss. Red flags

Box 1. Anatomic origin of pain

Right upper quadrant
Peptic ulcer disease
Biliary disease
- Biliary colic
- Cholecystititis
- Choledocholithiasis,
- Cholecystitis
- Cholangitis

Liver disease
- Hepatitis
- Neoplasm
- Abscess
- Congestive hepatopathy

Lung disease
- Pneumonia
- Subphrenic abscess
- Pulmonary embolism
- Pneumothorax

Abdominal wall
- Herpes Zoster
- Muscular stain

Kidney disease
- Pyelonephritis
- Perinephric abscess
- Nephrolithiasis

Colonic causes
- Colitis
- Right-sided diverticulitis

Middle upper abdomen
Peptic ulcer disease
Pancreatitic disease
- Pancreatitis
- Pancreatic neoplasm

Biliary disease
- Biliary colic
- Cholecystititis
- Choledocholithiasis
- Cholecystitis
- Cholangitis

Esophageal disease
- Reflux esophagitis
- Infectious esophagitis
- Pill esophagitis

Cardiac disease
- Myocardial ischemia or infarction
- Pericarditis

Abdominal aortic aneurysm (AAA) rupture/dissection
Mesenteric ischemia

Left upper quadrant
Peptic ulcer disease
Splenic disease
- Splenic rupture
- Splenic infarct

Pancreatic disease
- Pancreatitits
- Pancreatic neoplasm

Lung disease
- Pneumonia
- Subphrenic abscess
- Pulmonary embolism
- Pneumothorax

Kidney disease
- Pyelonephritis
- Perinephric abscess
- Nephrolithiasis

Periumbilical
Appendicitis (early)
Small bowel obstruction
Gastroenteritis
Mesenteric ischemia
AAA rupture
AAA dissection

Right lower quadrant
Appendicitis
Inflammatory bowel disease (IBD)
OB-GYN causes
- Ovarian tumor
- Ovarian torsion
- Ectopic pregnancy
- Pelvic inflammatory disease (PID)
- Tubo-ovarian abscess

Kidney disease
- Pyelonephritis
- Perinephric abscess
- Nephrolithiasis

Intestinal disease
- Right-sided diverticulitis
- Ileocolitis
- Gastroenteritis
- Hernia

Suprapubic
IBD
OB-GYN causes
- Ovarian tumor
- Ovarian torsion
- Ectopic pregnancy
- PID
- Tubo-ovarian abscess
- Dysmenorrhea

Colonic disease
- Proctocolitis
- Diverticulitis

Urinary tract disease
- Cystitis
- Nephrolithiasis
- Prostatitis

Left lower quadrant
IBD
OB-GYN causes
- Ovarian tumor
- Ovarian torsion
- Ectopic pregnancy
- PID
- Tubo-ovarian abscess

Kidney disease
- Pyelonephritis
- Perinephric abscess
- Nephrolithiasis

Intestinal disease
- Sigmoid diverticulitis
- Ileocolitis
- Gastroenteritis
- Hernia

Diffuse
Gastroenteritis
Bowel obstruction
Peritonitis
Mesenteric ischemia
IBD
Diabetic ketoacidosis
Porphyria
Uremia
Hypercalcemia
Sickle cell crisis
Vasculitis
Heavy metal intoxication
Opiate withdrawl
Familial Mediterranean fever
Hereditary angioedema

from the physical examination include any abnormality of the vital signs, mental status changes, involuntary guarding, rebound tenderness, the complete absence of bowel sounds, and pain out of proportion to the physical examination.

Although cardiac, pulmonary, urologic, musculoskeletal, and gynecologic causes of abdominal pain will not be specifically addressed in this article, it is imperative to keep these extra-abdominal disease processes in the differential diagnosis of abdominal pain. Red-flag indications that a life-threatening extra-abdominal cause of abdominal pain is present include chest pain, back pain, shortness of breath, vaginal bleeding, and hemodynamic instability. Finally, there are a multitude of systemic medical disorders, such as adrenal insufficiency, diabetic ketoacidosis, porphyria, and sickle cell pain crisis, that can present with abdominal pain. Evidence of these disorders in the patient's medical history, medications, or physical examination should prompt their consideration as the cause of the patient's pain.

The selection of imaging studies to evaluate abdominal pain should be guided by the differential diagnoses generated from the initial evaluation. Historically, plain abdominal radiographs have been the first imaging modality chosen for abdominal pain. They can be obtained rapidly and at a relatively low cost. However, with the evolution of more sensitive and specific modalities such as CT and ultrasonography, the value of the plain abdominal radiographic series has been debated. Nonetheless, plain films should be the initial imaging modality in patients who are suspected of having visceral perforation, obstruction, or foreign body ingestion or insertion.

The abdominal plain film series should include supine and upright abdominal films in conjunction with an upright chest (or lateral decubitus abdominal) film. Plain abdominal imaging has been estimated to be diagnostic in up to 60% of cases of suspected small bowel obstruction [7], although sensitivity is more limited in cases of low-grade obstruction [8]. The location, volume, and distribution of intraluminal air, the presence and distribution of air–fluid levels, and the luminal diameter can often be helpful in differentiating between an obstructive and nonobstructive process, such as a partial or complete large or small bowel obstruction, ileus, pseudo-obstruction, or a normal variant. Unfortunately, overlap in the radiographic appearance of obstructive and nonobstructive processes limits the sensitivity and specificity of plain films in this setting.

The ability of plain films to detect free air depends on the volume of free air within the peritoneal cavity. For the detection of large volumes, as would be expected with a perforated viscus, the sensitivity of plain films is reported to be as high as 100%. Sensitivity is maximized if the patient is placed in the upright or decubitus position for 5 to 10 minutes before obtaining an upright chest or lateral decubitus film, thereby allowing small volumes of air to redistribute to and collect within nondependent areas. Volumes as small as 1 to 2 cm^3 of air have been reported using this method [8,9]. The instillation of

intraluminal water-soluble contrast media in cases of suspected perforation can also improve sensitivity [10].

CT is a widely available imaging tool that is very sensitive for many causes of abdominal pain. With newer rapid helical scanning methods, advances in intravenous and oral contrast agents, three-dimensional reformatting, and other advanced software capabilities, CT has become the imaging modality of choice for the evaluation of most presentations of acute abdominal pain. For example, CT can diagnose acute appendicitis with a reported sensitivity and specificity as high as 98% and 97%, respectively [11]. In fact, the superior diagnostic capability of CT is rendering plain films obsolete. Even in situations in which plain films have a proven diagnostic accuracy, such as perforated viscus or small bowel obstruction, many physicians now opt for CT as the initial imaging study. CT has proven to be more sensitive and specific for nearly all causes of acute abdominal pain [12–14].

Ultrasonography should be the initial imaging modality for patients who are suspected of having biliary tract disease. It is accurate for the detection of gallstones and dilation of the biliary tree. Ultrasonography is less sensitive for choledocholithiasis, and patients who are suspected of having common bile duct stones should be evaluated further with magnetic resonance cholangiopancreatography, endoscopic retrograde cholangiopancreatography (ERCP), or possibly endoscopic ultrasonography. Although MRI can be highly accurate in the diagnosis of acute abdominal pain, its high cost and lack of immediate availability limit its use in the acute care setting.

After clinically evaluating patients who have abdominal pain, the primary physician must appropriately triage the patient. There are several history, physical examination, laboratory, and radiographic red flags that should alert the physician of a potentially more serious cause of the abdominal pain (Box 2). The chronicity of symptoms is an important factor in this decision. Patients with chronic symptoms can usually be evaluated on an outpatient basis. On the other hand, patients who have new-onset symptoms are more likely to have a significant disease process, which can bring harm to them within hours to days. Depending on the differential diagnosis, the physician should consider expediting the evaluation. Although a detailed discussion of all the potential causes of acute abdominal pain is beyond the scope and aim of this article, there are some causes that merit a more detailed discussion. Following is an overview of those causes of abdominal pain that are seen commonly in the outpatient setting, with a focus on causes that are prone to more serious or life-threatening complications. The consideration of most of the following entities should prompt urgent or emergent transfer to an ED or admission to an inpatient hospital bed.

Cholecystitis

Acute cholecystitis is caused most commonly by the obstruction of the cystic duct by a gallstone. More than 90% of cases of cholecystitis are

Box 2. Red flags in abdominal pain

History
- Inability to maintain po intake
- Projectile vomiting
- Overt gastrointestinal blood loss
- Syncope
- Pregnancy
- Recent surgery or endoscopic procedure
- Fever
- Caustic or foreign body ingestion

Physical examination
- Pathologic changes in vital signs
- Bloody, maroon, or melenic stool
- Hernia (incarcerated and tender)
- Hypoxia
- Cyanosis
- Altered mentation
- Jaundice
- Peritoneal signs
- Abdominal pain out of proportion to examination

Laboratory results
- Renal failure
- Metabolic acidosis
- Leukocytosis
- Elevated transaminases
- Elevated alkaline phosphatase and bilirubin
- Anemia or polycythemia
- Hyperlipasemia/hyperamylasemia
- Hyperglycemia/hypoglycemia

Radiography
- Abdominal free air
- Gallbladder wall thickening
- Pericholecystic fluid
- Dilated biliary tree
- Bowel obstruction
- Dilated small bowel loops ± air fluid levels
- Intra-abdominal abscess
- Bowel wall thickening
- Air in the portal venous system
- Pneumatosis intestinalis

caused by gallstones (calculous cholecystitis) [15]. Simple biliary colic is also caused by gallbladder calculi obstructing the cystic duct, but the duration of obstruction is more short-lived. Generally, biliary colic should not last more than 6 hours, whereas the symptoms of acute cholecystitis last much longer. Prolonged obstruction of the cystic duct impairs gallbladder emptying, leading to inflammation of the gallbladder mucosa. Secondary bacterial infection of the gallbladder may ensue, leading to possible empyema, gallbladder necrosis, and perforation. Approximately 8% to 12% of cases of acute cholecystitis result in gallbladder perforation, carrying a mortality of 20% [9]. Emphysematous cholecystitis, characterized by air in the wall of the gallbladder, is most often seen in patients who have diabetes mellitus.

Approximately 75% of patients who develop acute cholecystitis have a history of biliary colic [16]. The pain caused by biliary colic is a visceral pain that results from tonic spasm of the cystic duct [17]. It is most commonly felt in the epigastrum and may radiate to the right shoulder. The pain has a sudden onset, worsens in severity during the first 15 to 30 minutes, reaches a plateau, and then slowly resolves over the next 6 hours. The pain may be precipitated by fatty food intake, which stimulates gallbladder contraction through the release of cholecystokinin. It is associated commonly with nausea and vomiting. If the pain lasts longer than 6 hours, acute cholecystitis should be suspected. As acute gallbladder inflammation irritates the

parietal peritoneum, the pain may shift from the epigastrum to the right upper quadrant.

The physical examination of patients who have acute calculous cholecystitis reveals right upper quadrant tenderness. An inspiratory arrest during deep right upper quadrant palpation is referred to as Murphy's sign.

Frequently encountered laboratory abnormalities include leukocytosis with a left shift and elevation of alkaline phosphatase and transaminase. Generally, hyperbilirubinemia does not occur with acute cholecystitis because the flow of bile through the common bile duct is not impaired. Mirizzi's syndrome is an exception to this rule. Mirizzi's syndrome occurs when a large stone in the cystic duct compresses or erodes into the common hepatic duct, resulting in variable degrees of biliary obstruction.

Right upper quadrant ultrasonography should be the initial imaging test for patients who are suspected of having acute cholecystitis, with reported sensitivity, specificity, and accuracy approaching 95% [9]. Common findings include cholelithiasis, gallbladder wall thickening, pericholecystic fluid, and a sonographic Murphy's sign. The latter finding occurs when the ultrasound transducer pressure on the gallbladder results in tenderness with inspiratory arrest. The finding of cholelithiasis and a positive sonographic Murphy's sign has a positive predictive value (PPV) of 92% for acute cholecystitis. Conversely, when these findings are absent, the negative predictive value (NPV) is 95% [9]. Radionuclide cholescintigraphy scans, such as the hepatobiliary iminodiacetic acid scan, can be used to confirm the diagnosis of acute cholecystitis when ultrasonography findings are equivocal. The sensitivity, specificity, and PPV for acute calculous cholecystitis are 95%, 99%, and 97%, respectively [18].

Acalculous cholecystitis accounts for 5% to 10% of cases of acute cholecystitis [15]. Bile stasis, superconcentration of bile, and gallbladder ischemia are believed to play a role in the pathogenesis. Acalculous cholecystitis is rarely seen in the outpatient setting because it typically occurs in critically ill patients. Furthermore, it tends to carry a higher mortality and perforation rate than calculous cholecystitis, secondary in large part to the severity of comorbid illnesses. Other risk factors include total parenteral nutrition (TPN), diabetes, HIV, prolonged fasting, vasculitides, acute renal failure, and immunosuppression. Idiopathic cases have also been described.

The initial management for acute calculous cholecystitis includes bowel rest, intravenous fluids, analgesia, and parenterally administered antibiotics that cover typical enteric pathogens. The appropriate timing for cholecystectomy has been a much-debated topic, in which most authors favor early surgical intervention. A cholecystectomy performed within 24 to 48 hours of presentation has been shown to reduce mortality and shorten hospital stay compared with surgery performed after weeks of conservative management aimed at "cooling off" the gallbladder [19–21]. The benefits of early cholecystectomy have been validated prospectively for the laparoscopic approach as well [22–26]. The surgical management of acute acalculous

cholecystitis is similar to that of calculous cholecystitis but more dependent on the patient's ability to undergo surgery. Many patients who are too ill to undergo surgery are managed acutely with cholecystectomy catheter drainage. Open cholecystectomy has been the traditional approach, but studies have shown that a laparoscopic approach is a safe alternative [27,28].

Cholangitis

Ascending cholangitis is a potentially lethal entity that occurs when the bile ducts become obstructed. Once bile flow is impeded, superinfection of the stagnant bile occurs. Pus builds up under pressure, which causes the infection to rapidly ascend into the liver and spread into the blood stream. Common pathogens include *Escherichia coli*, *Klebsiella* spp, *Bacteroides*, *Enterococcus*, and other enteric pathogens [29]. The most common cause of obstruction in the United States is choledocholithiasis, which accounts for approximately 85% of cases. Although the majority of cases resulting from choledocholithiasis are from gallbladder stones, the in situ formation of common duct stones (primary common bile duct stones) also may occur [30]. Benign biliary strictures, choledochal cysts, biliary parasites, and neoplasms are less common causes of cholangitis.

Symptoms and signs of cholangitis include fever, jaundice, and right upper quadrant pain. These findings are collectively referred to as Charcot's triad, which has a reported sensitivity for cholangitis as high as 75% [31]. As cholangitis progresses, mental obtundation and signs and symptoms of septicemia occur. The combination of Charcot's triad with these findings is known as Reynolds' pentad. Although the sensitivity of Reynolds' pentad is significantly lower than that of Charcot's triad, its presence is significant because it indicates a higher morbidity and mortality rate [15].

Laboratory findings of ascending cholangitis include leukocytosis with a left shift, elevated alkaline phosphatase, and elevation of transaminases. An elevation of pancreatic enzymes can be seen in approximately one third of patients, especially with concomitant gallstone pancreatitis [32]. Because the pathophysiology of this disorder involves common bile duct obstruction, conjugated hyperbilirubinemia is invariably present.

The diagnosis of cholangitis is often made clinically and should be confirmed with cholangiography. Although ultrasonography may suggest the presence of biliary obstruction, its sensitivity for choledocholithiasis is poor [9]. Therefore, when the clinical diagnosis of ascending cholangitis is suspected, patients should undergo cholangiography even in the setting of an unremarkable right upper quadrant ultrasonography.

Patients who are suspected of having acute cholangitis should be referred quickly to an emergency department or hospitalized because the clinical course can progress rapidly and be fatal if left untreated. The initial management should include intravenous fluid resuscitation, bowel rest, and the initiation of broad-spectrum antibiotics with adequate coverage against

common enteric pathogens. Patients who are suspected of having cholangitis should have blood drawn and cultured at presentation so that therapy can be directed toward the offending pathogen. Additionally, vitamin K should be administered to patients who have elevated prothrombin time because prolonged biliary obstruction can lead to vitamin K deficiency.

The definitive therapy for cholangitis is decompression of the obstructed biliary system. ERCP is the diagnostic and therapeutic procedure of choice and is successful in relieving the obstruction in more than 95% of cases [18]. This is typically accomplished by stone extraction or the placement of a plastic stent into the common bile duct. In cases in which therapeutic ERCP is not available or is unsuccessful, options include percutaneous transhepatic cholangiography or surgical decompression. If choledocholithiasis is the cause of ascending cholangitis, patients should undergo elective cholecystectomy once the infection resolves.

Pancreatitis

Acute pancreatitis is an inflammatory disease of the pancreas that may cause significant morbidity and carries a case fatality rate of 5% to 9% [33]. Gallstones and alcohol account for more than 80% of cases in the United States [18]. Other less common causes of pancreatitis include medications, trauma, hypercalcemia, severe hypertriglyceridemia ($\geq$1000 mg/dL), malignancy, sphincter of Oddi dysfunction, infections, iatrogenic causes (ERCP), and congenital abnormalities of the pancreas such as pancreas divisum. In some cases, the cause of pancreatitis is not determined and is termed idiopathic. As much as 75% of cases of idiopathic pancreatitis are actually caused by biliary sludge or microlithiasis [34]. Regardless of the cause, diffuse pancreatic inflammation and edema develop. In severe cases, necrosis of pancreatic and peripancreatic tissue occurs, and multiorgan failure may ensue. Necrotizing pancreatitis occurs in 25% of patients who have pancreatitis and has a mortality rate of 15% to 20% [33,35].

Patients with pancreatitis present typically with the acute onset of abdominal pain, nausea, and vomiting. The pain is steady and is usually located in the epigastrum, but it may also be appreciated in the right or left upper quadrants of the abdomen. Pain is often described as a boring sensation that radiates into the back. Patients are often unable to get comfortable when lying supinely, and they will lean forward in an attempt to find relief. Because of marked fluid shifts, intravascular volume may become markedly depleted. As a result, tachycardia and hypotension with orthostatic changes may develop. Other vital sign abnormalities include low-grade fever and tachypnea. The latter is a poor prognostic sign and may herald the development of acute respiratory distress syndrome. The abdominal examination may reveal diminished or absent bowel sounds secondary to the development of a paralytic ileus. Abdominal distension may also occur. With palpation, the abdomen may be diffusely tender, but focal

tenderness in the epigastrum is more common. Depending on the severity of the pancreatitis, voluntary guarding and rebound tenderness may also be appreciated. Signs of hemorrhagic pancreatitis such as Gray-Turner's sign (flank ecchymosis), Cullen's sign (periumbilical ecchymosis), or Fox's sign (inguinal ecchymosis) are seen in less than 1% of cases. Other rare physical findings of acute pancreatitis include subcutaneous nodules and synovitis, which result from subcutaneous fat necrosis. When acute pancreatitis is suspected clinically, levels of serum amylase or lipase should be determined. In the setting of suspected acute pancreatitis, levels greater than three times the normal values have a high specificity for acute pancreatitis. Serum lipase remains elevated for a longer duration than serum amylase and is more specific for acute pancreatitis [36]. The magnitude of elevation of the serum amylase and lipase does not correlate well with disease severity. As a result of the marked intravascular volume depletion that occurs, the hematocrit is often elevated in acute pancreatitis secondary to hemoconcentration. Hematocrit levels higher than 44% are associated with a worse prognosis [37]. An elevation of ALT to greater than 150 mg/dL suggests gallstones as the cause of the pancreatitis [38]. Hyperbilirubinemia and elevations of the alkaline phosphatase also point to a biliary cause. A bilirubin level greater than 5 mg/dL that does not fall after 6 to 12 hours suggests the presence of an impacted stone in the ampulla of Vater. Because of marked fluid shifts that occur with acute pancreatitis, blood-urea-nitrogen, creatinine, and serum electrolyte levels, including calcium, should be assessed.

Imaging of the pancreas with CT can confirm the diagnosis of acute pancreatitis but is not necessary in all cases. The present authors believe that CT scanning should be reserved for patients in whom the diagnosis is in question, cases of suspected pancreatic necrosis, or in cases of clinical deterioration despite adequate medical therapy. The use of intravenous contrast is highly recommended, and CT should ideally be deferred until the patient has received adequate volume resuscitation to prevent nephrotoxicity.

The care of patients who have acute pancreatitis is complicated by the difficulty in determining whether a patient's course will be mild or severe. Several scoring systems have been developed to assess the severity in acute pancreatitis and to determine prognosis. The most well known of all these criteria is Ranson's criterion, which was originally developed for alcoholic pancreatitis and later modified and validated for gallstone pancreatitis. Ranson's criterion has limited clinical value because it takes 48 hours to determine. The Imrie-Glasgow criteria and the acute physiology and chronic health evaluation II score are two other prospective systems, but both are cumbersome to perform. A prognostic CT scoring system, known as the Balthazar criteria, has been validated for predicting severity in acute pancreatitis. The score is weighted heavily on the presence of pancreatic necrosis [39]. A CT scan can also be used when the diagnosis is in question, but is not necessary in all cases of acute pancreatitis. Specifically, the role

of an abdominal CT without intravenous contrast in a dehydrated patient at presentation is miniscule. These authors believe that CT scanning should be reserved for patients in whom the diagnosis is in question, cases of suspected pancreatic necrosis, or in cases of clinical deterioration despite adequate medical therapy. Intravenous contrast is mandatory, and CT should ideally be deferred until the patient has received adequate volume resuscitation.

The cornerstone of therapy in acute pancreatitis is the prevention of pancreatic stimulation. Patients should take nothing orally (NPO) and therefore require a hospital setting for treatment. Both solid food and liquids can stimulate pancreatic secretion; thus, a clear liquid diet is not appropriate until the pain resolves. Aggressive intravenous fluid repletion is necessary to maintain intravascular volume and allow adequate perfusion of the pancreas and extrapancreatic organs such as the kidneys. Other supportive measures include adequate analgesia and the use of nasogastric tubes in patients who experience vomiting secondary to an ileus. Although a clear decline in mortality rate has not been demonstrated with prophylactic antibiotics, the present authors believe that antibiotics should be administered to patients who have necrotizing pancreatitis because they decrease the incidence of septic complications [40]. In patients who are unlikely to resume oral feeding within a few days, enteral nutrition through a nasojejunal tube is preferable to TPN [41–43]. In most cases, supportive care is all that is needed because nearly 90% of patients who have acute pancreatitis will respond to medical management [18]. Patients with gallstone pancreatitis and evidence of ongoing biliary obstruction should undergo ERCP and biliary decompression [44–46].

Appendicitis

Appendicitis is the most common abdominal surgical emergency in the United States, with over 250,000 appendectomies performed annually [47]. Most cases of appendicitis are believed to result from an obstruction of the appendicular lumen by fecaliths. After obstruction, increased intraluminal pressure causes local ischemia, leading to transluminal inflammation. Secondary bacterial infection occurs, and gangrene and perforation of the appendix may result.

A thorough history and physical examination are all that are required to clinically diagnose appendicitis. As a result of appendicular hypertension and distension, a visceral-type pain is felt initially in the periumbilical region. Patients often describe it as crampy in quality. There is often associated nausea, vomiting, and fever. As the inflammatory process progresses and directly irritates the parietal peritoneum, the quality of the pain becomes sharp and shifts to the right lower quadrant (RLQ). Almost all patients who have appendicitis will lose their appetite; in fact, if a patient is hungry, the clinical diagnosis of appendicitis should be questioned.

Auscultation of the abdomen reveals diminished or absent bowel sounds. Classically, the examination of patients who have appendicitis reveals tenderness to palpation at McBurney's point, anatomically located one third of the way from an imaginary line drawn from the anterior superior iliac spine to the umbilicus. Guarding, rigidity, and rebound tenderness may be present from peritoneal irritation. Rovsing's sign may be present, which is the elicitation of RLQ pain on left lower quadrant palpation. The obturator and iliopsoas signs can be elicited by internal rotation of the right hip and extension of the right hip, respectively. These findings occur as the result of the inflammatory process irritating the respective muscles during movement.

Patients who present with acute abdominal pain migrating from the umbilicus to the right lower quadrant and in whom the right lower quadrant is tender to the examiner's touch should undergo emergent appendectomy. The accuracy of the clinical diagnosis in this situation has been estimated to be nearly 95% [48]. However, the classic presentation of appendicitis described above occurs only in an estimated 66% of patients [49]. Atypical presentations account for the remainder, which result from either anomalous appendiceal anatomy or appear in certain populations of patients who are more prone to atypical presentations of common diseases, such as elderly, immunocompromised, or pregnant patients. For example, a retrocecal appendix that becomes inflamed may produce right flank rather than abdominal pain. Patients older than 55 years of age may present with vague symptoms and more subtle examination findings, which cause a delay in the diagnosis. This delay results in a higher rate of perforation compared with their younger counterparts [49]. Finally, misdiagnosis is more common in premenopausal women owing to a broadened gynecologic differential diagnosis and confusing presentations [50].

Leukocytosis is highly sensitive but not specific for the diagnosis of appendicitis [51]. Pyuria, bacteriuria, or hematuria may be seen in up to 40% of presenting patients, making the differentiation problematic between acute appendicitis and urologic infections [52]. In any woman of childbearing age, pregnancy should be ruled out with a serum or urinary β-human chorionic gonadotropin test.

Classic appendicitis is a clinical diagnosis that does not require imaging for confirmation. However, if the diagnosis is uncertain, especially with atypical presentations, imaging can be useful. Plain radiographs are neither sensitive nor specific for the diagnosis of acute appendicitis and should not be ordered [48]. In direct comparison studies, CT has been shown to have a greater sensitivity, accuracy, and negative predictive value than ultrasonography for the diagnosis of acute appendicitis. Ultrasonography has a sensitivity of 75% to 90%, a specificity of 86% to 100%, a PPV of 89% to 93%, and an overall accuracy rate for acute appendicitis of 90% to 94% [53–57]. CT has a sensitivity of 90% to 100%, a specificity of 91% to 99%, a PPV of 95% to 97%, and an overall accuracy rate of 90% to 98% [54,58,59].

Furthermore, compared with ultrasonography, CT is superior in the accurate detection of not only appendicitis but alternative and concomitant abdominal pathology as well [60–62].

Patients with suspected appendicitis should be NPO and started on intravenous fluids. The prophylactic use of antibiotics is not supported by the literature and should be used only in cases of suspected perforation. Because of the potential perforation risk, patients who have a clinical diagnosis of appendicitis should undergo emergent surgical intervention. Historically, a 20% presurgical false-positive rate has been considered acceptable. In patients in whom the clinical diagnosis is uncertain, imaging studies and observation admissions for serial abdominal examinations may decrease this false-positive rate.

Ischemic bowel disease

Depending on the location, degree, and acuity of the vascular compromise, ischemic bowel disease is classified into three distinct syndromes: acute mesenteric ischemia, chronic mesenteric ischemia, and colonic ischemia. Acute mesenteric ischemia results from the rapid loss of blood supply to the portion of the intestines supplied by the celiac, superior mesenteric, or inferior mesenteric arteries. The cause is most commonly thromboembolic disease. The consequences of acute mesenteric ischemia are severe and include bowel necrosis, infarction, and death. Chronic mesenteric ischemia results from the gradual loss of blood supply to the portion of the intestines supplied by the celiac, superior mesenteric, or inferior mesenteric arteries. The cause is usually atherosclerosis. Patients with chronic mesenteric ischemia present with chronic postprandial abdominal pain, called intestinal angina. Because the pain is worsened by eating, patients develop sitophobia (fear of eating), and significant weight loss may occur. Colonic ischemia, also known as ischemic colitis, is the most commonly encountered intestinal vascular disorder [63]. Colonic ischemia occurs when there is a decrease in colonic mucosal oxygenation. In the vast majority of patients, colonic ischemia does not result from an occlusive vascular process, but rather occurs when the oxygen requirements to a specific portion of the colon are not met by the vascular supply. Colonic ischemia occurs in the portions of the colon where blood flow is least redundant, the watershed areas between the superior and inferior mesenteric artery supply, the splenic flexure, and rectosigmoid junction. Lower gastrointestinal bleeding, rather than abdominal pain, is the most common presenting symptom. The disorder is self-limited in most cases, and the prognosis is good. Of the three ischemic bowel syndromes, acute mesenteric ischemia is the disease that presents with acute abdominal pain and will be discussed further below.

The acute interruption of blood supply in the mesenteric vasculature results from either thromboembolic disease or vasospasm. The major risk factors include older age, hypercoagulability, vascular disease, and heart

disorders such as atrial fibrillation or valvular disease. Once the blood supply to the mesenteric vascular is interrupted, acute ischemia ensues. If the vascular compromise persists, bowel infarction, necrosis, and perforation may occur. Patients with acute mesenteric ischemia present with an acute onset of severe periumbilical abdominal pain. Early in the disease course, the pain is often out of proportion to the tenderness produced during the physical examination. If the patient presents after bowel infarction has already occurred, peritoneal signs may develop. The stool may be positive for occult blood, but hematochezia is uncommon with acute mesenteric ischemia.

Common laboratory test abnormalities seen with acute mesenteric ischemia include leukocytosis and an elevated hematocrit from hemoconcentration. A low level of serum bicarbonate, metabolic acidosis, and an elevated lactate level are seen once bowel infarction has already occurred. Retrospective studies evaluating the role of elevated plasma D-dimer levels in the diagnosis of early mesenteric ischemia have shown initial promise, although subsequent prospective evaluations have shown D-dimer to be less helpful [64,65].

Several imaging modalities, including plain films, Doppler ultrasonography, conventional CT, and MRI have been studied for the diagnosis of acute mesenteric ischemia. Unfortunately, these imaging techniques lack sensitivity and specificity for an accurate diagnosis [66]. Mesenteric angiography is the gold standard test for diagnosing occlusive arterial mesenteric ischemia. Its sensitivity and specificity are 75% to 100% and 100%, respectively [63]. In addition to its diagnostic capabilities, angiography offers the potential for treatment. Several studies demonstrate a decreased mortality in patients who undergo routine angiography for suspected occlusive mesenteric arterial ischemia [67,68].

The mortality rate for patients who have acute mesenteric ischemia that has not been diagnosed before the onset of bowel infarction is reportedly as high as 90% [63]; therefore, early diagnosis is crucial. Because laboratory findings may be nonspecific early in the disease course, a high index of suspicion based on predisposing risk factors and clinical presentation are required. Patients presenting with suspected acute mesenteric ischemia should promptly undergo angiography and surgical evaluation [69].

Diverticulitis

Diverticular disease of the colon is common and increases with age. Nearly one third of patients over the age of 50 and two thirds by the age of 80 have diverticular disease [70]. Diverticulitis, a complication caused by the perforation of a diverticulum, affects up to 25% of patients who have diverticular disease [71]. Inspissated food, stool, and increased intraluminal pressure are believed to be involved in the pathogenesis of diverticular perforation. The clinical presentation of patients who have

diverticulitis depends on the extent of the perforation. Small perforations are walled off by surrounding mesentery and pericolonic fat, whereas larger perforations can result in extensive intraperitoneal abscess formation and frank peritonitis.

The location of abdominal pain in patients who have diverticulitis depends on the location of the perforated diverticulum. Because diverticular disease most commonly affects the sigmoid colon, patients most often present with crampy left lower quadrant abdominal pain. However, right lower quadrant abdominal pain may occur in patients who have a redundant sigmoid colon or diverticular disease involving the right colon [72]. Nausea, vomiting, fever, and anorexia are associated symptoms. Physical examination often reveals tenderness over the inflamed area, and an inflammatory mass may be palpable. In patients who have free perforation, diffuse peritoneal signs such as rebound, guarding, and rigidity may be present.

Although diverticulitis often can be diagnosed on clinical grounds alone, an imaging study should be performed during a patient's initial presentation to confirm the presence of the diverticulae. A CT of the abdomen and pelvis with intravenous, oral, and optional rectal contrast is the diagnostic modality of choice, with a reported sensitivity as high as 98% [73]. Colonoscopy should not be performed in patients who are suspected of having diverticulitis because perforation is a contraindication for the procedure.

Mild, uncomplicated diverticulitis can be managed on an outpatient basis and consists of a clear liquid diet and the administration of oral antibiotics that cover typical gastrointestinal pathogens. Complicated diverticulitis occurs when patients develop intra-abdominal abscesses, fistulas, free perforations, or intestinal obstructions and require hospitalization. Enteral feedings should be held, and patients are started on intravenous antibiotics. Intra-abdominal abscesses can often be managed with percutaneous drainage catheters, but surgery is sometimes required [74]. Free perforation or intestinal obstruction usually mandates emergent surgery.

Obstruction

Bowel obstruction occurs when the normal flow of intestinal contents is interrupted by a mechanical blockage. Approximately 75% of cases of small bowel obstruction (SBO) is the result of adhesive peritoneal bands in patients who have a history of abdominal surgery [75,76]. In fact, up to 15% of patients who undergo laparotomy will be readmitted within 2 years with SBO from adhesions, and up to 3% will require operative intervention as a result [77]. Furthermore, it is estimated that the 10-year risk of developing recurrent SBO from adhesions is approximately 40% [78]. Hernias are the second most common cause of SBO and account for up to 25% of cases [79]. The remaining cases of SBO result from a number of causes, including Crohn's disease, volvulus, neoplasm, intussusception, gallstones, and ischemia.

Once the bowel is obstructed, the segment of bowel proximal to the obstruction becomes increasingly distended by swallowed air, gas from bacterial fermentation, and luminal secretions. Bacterial overgrowth, bowel edema, and the loss of absorptive function follow. If the obstruction is not treated promptly, ischemia, necrosis, and perforation may occur.

The pain caused by small bowel obstruction is a colicky, diffuse pain, which waxes and wanes over 5-minute intervals. Nausea, vomiting, distention, and obstipation are associated with the pain. The emesis is often feculent because of bacterial overgrowth. The passage of stool and flatus do not eliminate SBO from the differential diagnosis because luminal contents distal to the blockage can still pass. Physical examination reveals a distended, diffusely tender abdomen with either hyperactive high-pitched or hypoactive bowel sounds. Rushes of luminal fluid can often be heard. Findings of rigidity, rebound tenderness, or guarding suggest peritonitis. A ventral, inguinal, or periumbilical hernia should be sought as a potential cause. Patients will often exhibit physical signs of dehydration. Laboratory analysis is usually nonspecific, but common abnormalities include hemoconcentration, leukocytosis, and electrolyte imbalances.

An abdominal plain film series should be the initial diagnostic imaging test in patients who are suspected of having obstruction. Typical findings include air-fluid levels, small bowel distention, and a paucity of air in the rectal vault. In addition, evidence of complications such as intraperitoneal free air can be seen. Although most cases can be diagnosed clinically, with the comfirmatory assistance of plain films, there are instances in which plain films are not sufficient. In these instances, CT may be helpful for both diagnosing SBO and determining the cause, with a reported sensitivity of 100% and accuracy of 90% [80,81].

The clinical presentation of large bowel obstruction (LBO) is very similar to that of SBO. Nearly 60% of cases of LBO are the result of malignancy, with colon cancer being the most common. Other causes include diverticular strictures and colonic volvulus [82]. The cecum and the sigmoid colon are the most common locations of colonic volvulus [83].

Patients with bowel obstructions are initially managed with strict restriction of oral intake, nasogastric tube decompression, intravenous fluids, and electrolyte repletion. Early surgical evaluation is mandatory. The philosophy that ''the sun should never rise nor set on a small bowel obstruction'' remains true today.

Peptic ulcer disease

Peptic ulcer disease (PUD) is a common condition that has a significant impact on quality of life. In 1989, more than $5 billion was spent on the care of patients who had PUD [84]. The most common cause of PUD is infection by *Helicobacter pylori*. *H pylori* infection has been associated with 75% to 95% of duodenal ulcers and 65% to 95% of gastric ulcers [85–87].

Nonsteroidal anti-inflammatory medications (NSAIDs) are the second most common cause of PUD, with an estimated yearly incidence of clinically significant gastric or duodenal ulceration of approximately 1.5% [88]. The use of NSAIDs presents a particular challenge because up to 40% of patients will not report the use of NSAIDs [89]. Acid hypersecretory syndromes such as Zollinger-Ellison syndrome account for the majority of the remaining cases.

The clinical presentation of PUD depends on the location of the ulcer and whether complications develop from the ulcer. Patients who have uncomplicated peptic ulcers may be asymptomatic or they may present with upper abdominal pain [90,91]. The pain is typically described as a burning or gnawing pain but may occasionally be crampy in nature. Nausea and vomiting may also be seen. In patients who have gastric ulcers, the pain is often made worse by eating, whereas patients who have duodenal ulcers often feel better with eating.

Complications of PUD include bleeding, obstruction, perforation and penetration into adjacent structures. Bleeding from PUD may present with melena, hematochezia, and hematemesis with or without hemodynamic compromise. Bleeding can generally be managed medically with IV fluid, blood transfusions, antisecretory therapy, and endoscopic therapy. Endoscopy is also useful to determine the risk for recurrent bleeding [92]. Surgical or angiographic intervention is reserved for bleeding refractory to endoscopic therapies. Pyloric channel and duodenal bulb ulcers may cause gastric outlet obstruction. In addition to epigastric pain, patients may present nausea, projectile vomiting, early satiety, anorexia and weight loss. Conservative measures are often successful in resolution, though many patients will require surgery or endoscopic dilatation therapy [93,94]. Most ulcers that perforate are located in the duodenal bulb, and are often associated with NSAID use [95,96]. Patients present with the sudden onset of epigastric pain which quickly becomes diffuse as generalized peritonitis ensues. Patients can sometimes develop paradoxical improvement in their pain following perforation despite a markedly rigid and diffusely tender abdomen. Plain films are usually adequate to confirm the diagnosis of ulcer perforation. Perforations require immediate surgical evaluation. Ulcer penetration into adjacent structures occurs in up to 20% of cases of PUD, but only a small proportion become clinically apparent [97]. The most common sites of ulcer penetration include the pancreas, omentum, hepatobiliary system, colon, and adjacent vasculature. Patient presentation reflects the structure that is involved, and the therapy is site-specific.

Summary

Because there are many causes of acute abdominal pain, a systematic approach by the evaluating physician is necessary to narrow the differential

diagnosis. It is vital that the physician have an understanding of the mechanisms of pain generation and be familiar with the presentations of common diseases that cause abdominal pain. Recognizing the red flags in the history and physical examination and the initial imaging and laboratory findings helps to determine which patients may have a serious underlying disease process, and therefore warrant more expedited evaluation and treatment.

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