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Introduction and Epidemiology

Abdominal pain is one of the most common reasons for visits to the emergency room, comprising 7 % of all visits [1]. Although for the majority of patients, symptoms are benign and self-limited, a subset will be diagnosed with an “acute abdomen,” as a result of serious intra-abdominal pathology necessitating emergency intervention [2].

An expeditious workup and Epidemiology is necessary when evaluating patients presenting with acute abdominal pain to determine the most likely cause of their symptoms and determine whether or not emergent operative intervention is necessary. The most appropriate therapy should then be initiated with the patient’s clinical status optimized. The workup should first include a thorough but efficient acquisition of the patient’s history and physical examination followed by the judicious use of laboratory and radiologic studies. The evaluation of patients with acute abdominal pain can pose a diagnostic challenge for physicians as patients may present with atypical symptoms that interfere with the usual pattern recognition that often guides decision making. These atypical presentations may help account for the over 25 % of abdominal pain cases labeled as “nonspecific” or “undifferentiated” [2].

Additionally, physicians must take into account the patient’s age, gender, and comorbidities as conditions associated with the acute abdomen may vary accordingly. Specifically, gastroenteritis, acute appendicitis, and abdominal trauma are common causes of the acute abdomen in children and young adults [3], whereas biliary disease, intestinal obstruction, diverticulitis, and appendicitis are among the most common causes in middle-aged adults and the elderly [4]. Furthermore, pelvic pathology accounts for

approximately 12 % of acute abdominal pain presentations and should therefore be considered when evaluating female patients [2].

Finally, there are a variety of nonsurgical causes of abdominal pain that are cardiovascular, metabolic, and toxic in origin that should be considered when evaluating these patients.

Clinical Presentation

A thorough, yet expeditiously obtained, history and physical exam is paramount to developing the differential diagnosis for patients presenting with an acute abdomen. Various laboratory and imaging studies may subsequently be used as adjuncts to help guide decision making.

History

When obtaining a patient history, the physician should avoid questions that are leading and should focus on details of the pain. This includes information on the onset, character, duration, and location of pain as well as the presence of radiation of pain.

Regarding onset, pain that develops suddenly may be suggestive of a perforated viscus or ruptured abdominal aortic aneurysm (AAA). Pain that gradually worsens over time may be the result of conditions characterized by the progressive development of infection and inflammation such as acute appendicitis and cholecystitis.

With regard to character, pain described as “burning” may implicate the pain of a perforated peptic ulcer while a “ripping” or “tearing” sensation typically represents the pain of an aortic dissection. Pain that is intermittent or colicky should be distinguished from pain that is continuous in nature. Colicky pain is typically associated with obstructive processes of the intestinal, hepatobiliary, or genitourinary tract, while pain that is continuous is usually the result of

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underlying ischemia or peritoneal inflammation. The latter may occur primarily or following an initial episode of colicky pain when an obstructive process is complicated by the development of ischemia. Examples of this include cases of biliary colic that progresses to acute cholecystitis or an incarcerated loop of intestine that becomes strangulated and ischemic.

The location of pain is important to consider as various pathologic conditions tend to occur in specific regions or quadrants of the abdomen (Fig. 2.1a, b). Therefore, if the physician is knowledgeable of the disease processes that cause pain in these areas, they may be able to significantly narrow down their differential. This holds true for those with the understanding that certain conditions may result in pain that radiates or is referred to an area beyond the site of disease due to shared innervation. Classic examples of this include biliary pain that is referred to the right subscapular region, the pain of acute pancreatitis that radiates to the back, and genitourinary pain that radiates from the flank down to the groin. Finally, it is important to note any chronological variation in the pain as this may provide helpful clues to the diagnosis. One of the best examples of this is in the case of acute appendicitis, in which pain is initially perceived in the periumbilical region before localizing to the right lower quadrant (RLQ). This phenomenon reflects the transition from visceral to parietal pain as appendiceal inflammation progresses to involve and irritate the peritoneal lining.

The majority of patients presenting with acute abdominal pain have associating symptoms (e.g., nausea, vomiting, diarrhea, constipation, hematochezia) that are often helpful in making a diagnosis. Chronology of nausea is important to consider as vomiting that occurs after the onset of abdominal pain is more likely to be surgical in nature as a result of medullary vomiting centers that are stimulated by pain impulses traveling via secondary visceral afferent fibers. Additionally, constipation or obstipation may point towards an intestinal obstruction, while diarrhea (especially if bloody) is associated with gastroenteritis, inflammatory bowel disease, and intestinal ischemia.

Aggravating or alleviating factors may also provide diagnostic clues. Depending on the underlying etiology, patients may maintain certain positions to help alleviate their pain. For example, patients with peritonitis may find some relief when lying still with their knees bent, while patients suffering from a bout of acute pancreatitis prefer to sit upright and lean forward. The effect of food is also important to consider as eating may alleviate the pain of a peptic ulcer while worsening the pain of an intestinal obstruction, acute cholecystitis, or acute pancreatitis [5, 6].

The patient's past medical and surgical histories may also help to narrow down the differential. A remote history of abdominal surgery may indicate that intestinal obstruction secondary to adhesive disease is the source of a patient's

complaints. Furthermore, it is important to consider the impact that coexistent medical conditions, such as diabetes, chronic obstructive pulmonary disease, and atherosclerosis, may have on patient outcomes. The fact that elderly patients are more likely to have significant comorbidities places them at increased risk for end organ damage incited by gastrointestinal emergencies [7].

Physicians should also take into account the effects of medication use. Anticoagulants may predispose to the development of rectus sheath hematomas and precipitate the gastrointestinal bleeding that is a component of the patient's underlying illness or complicating the patient's postoperative or posttreatment course. Chronic use of nonsteroidal anti-inflammatory drugs (NSAIDs) may also promote bleeding episodes along with the development of peptic ulcer disease (PUD) and its complications.

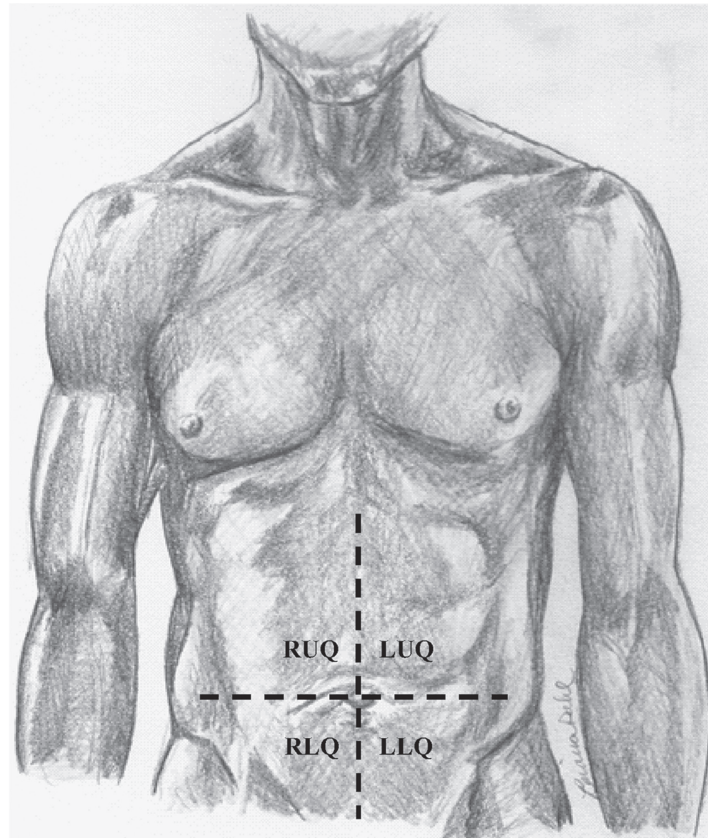
A detailed social history should also be obtained to determine if there is any significant history of tobacco, alcohol, or illicit drug use, as such behaviors can be a source of the patient's symptoms as well as complicate the patient's hospital course. Notably, a history of cocaine abuse may point towards a diagnosis of mesenteric ischemia as the underlying reason for the patient's symptoms.

The social history should consist of a detailed gynecologic history, including the date of the last menses, the presence of any vaginal bleeding or discharge, and any history of unprotected sexual activity or intercourse with multiple partners. Such information could indicate pregnancy complications, salpingitis or pelvic inflammatory disease, and other gynecologic conditions as the cause of the patient's acute abdominal complaints. Physicians should also take note of any history of recent travel to implicate infectious enterocolitis. Any exposure to environmental toxins should be determined, as lead and iron poisoning are two well-known, extra-abdominal sources of acute abdominal pain [5, 6].

Finally, the patient's family history may ascertain whether a patient's symptoms are hereditary in origin, as seen in the case of inherited hypercoagulable states, which can cause acute mesenteric ischemia secondary to mesenteric venous thrombosis.

Physical Examination

Examination of the patient presenting with acute abdominal pain should initially begin with overall appearance of the patient and vital signs. Patients who appear diaphoretic, pale, and anxious often suffer from a condition of vascular origin, including dissecting AAA, mesenteric ischemia, or atypical angina. The patient who is lying particularly still on the exam table often has peritonitis from perforated viscus or pancreatitis. Vital signs should always be interpreted knowing the status of the patient's pain, or the influence of any home

a**Right Upper Quadrant (RUQ)**

Cholecystitis
 Biliary Colic
 Cholangitis
 Hepatitis
 Hepatic Abscess
 Pancreatitis
 Peptic Ulcer
 Appendicitis (pregnancy)
 Intestinal Obstruction
 Inflammatory Bowel Disease
 Pneumonia

Left Upper Quadrant (LUQ)

Gastritis
 Peptic Ulcer
 Pancreatitis
 Splenomegaly
 Splenic Rupture
 Intestinal Obstruction
 Inflammatory Bowel Disease
 Diverticulitis (Splenic Flexure)
 Pneumonia
 Myocardial ischemia
 Pericarditis

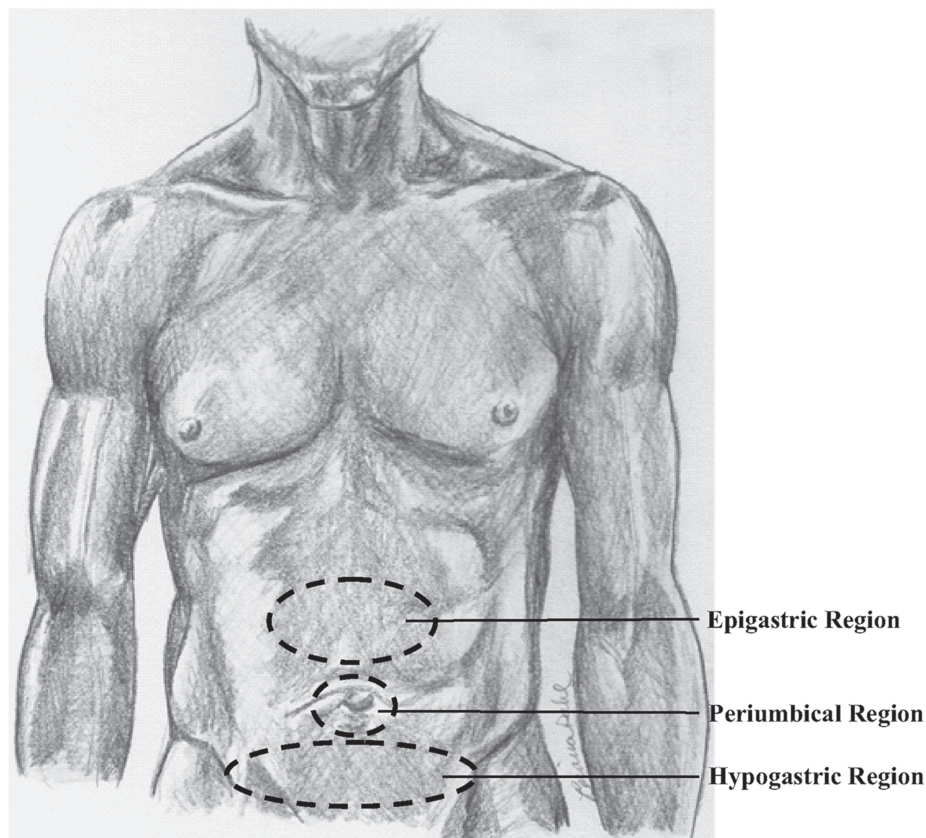
Right Lower Quadrant (RLQ)

Appendicitis
 Inflammatory Bowel Disease
 Diverticulitis (Cecal, Meckel's)
 Mesenteric Adenitis
 Intestinal Obstruction
 Hernia
 Ectopic Pregnancy
 Salpingitis
 Ovarian Torsion
 Ruptured Ovarian Cyst
 Mittelschmerz
 Nephrolithiasis
 Pyelonephritis

Left Lower Quadrant (LLQ)

Diverticulitis
 Appendicitis
 Intestinal Obstruction
 Inflammatory Bowel Disease
 Ischemic Colitis
 Hernia
 Ectopic Pregnancy
 Salpingitis
 Ovarian Torsion
 Ruptured Ovarian Cyst
 Mittelschmerz
 Nephrolithiasis
 Pyelonephritis

Fig. 2.1 (a) Common causes of the acute abdomen based on quadrant. (b) Common causes of the acute abdomen based on region. (Illustrations courtesy of Briana Dahl.)

b**EPIGASTRIC REGION**

Gastritis
 Peptic Ulcer
 Pancreatitis
 Cholecystitis
 Mesenteric Thrombosis/Ischemia
 Intestinal Obstruction
 Myocardial Ischemia
 Pericarditis

PERIUMBILICAL REGION

Appendicitis (Early)
 Enterocolitis
 Mesenteric Thrombosis/Ischemia
 Intestinal Obstruction
 Inflammatory Bowel Disease
 Ruptured Abdominal Aortic
 Aneurysm
 Hernia

HYPOGASTRIC REGION

Appendicitis
 Enterocolitis
 Diverticulitis
 Intestinal Obstruction
 Inflammatory Bowel Disease
 Hernia
 Ectopic Pregnancy
 Salpingitis
 Ovarian Torsion
 Ruptured Ovarian Cyst
 Cystitis

Fig. 2.1 (continued)

medications (beta blockers masking tachycardia, for example). Severity of systemic illness can be graded based on the degree of tachypnea, tachycardia, febrile or hypothermic response, and relative hypotension. Further examination of the lungs and heart could reveal signs representing primary cardiac disease or new-onset arrhythmias, which could lead to mesenteric embolic disease. The remainder of a complete physical examination should proceed expeditiously so that attention can be focused on the abdomen.

Examination of the abdomen should comprise four sequential components: inspection, auscultation, percussion, and palpation. The exam should include all areas of the abdomen, flanks, and groins.

Inspection

Inspection is the initial step of the abdominal examination and consists first of a general assessment of the patient's overall state followed by focus on the abdomen. Patients with peritonitis tend to lie still with their knees flexed as doing so provides some alleviation of their pain. Upon closer inspection of the abdomen, one should note the presence of prior surgical scars, abdominal distension or visible peristalsis, any obvious masses suggestive of an incarcerated hernia or tumor, or erythema or ecchymoses secondary to traumatic injury or hemorrhagic complications of acute pancreatitis. Caput medusa may indicate liver disease.

Auscultation of the abdomen should be performed next and involves listening for the presence or the absence of bowel sounds, for the characteristics of those sounds, and for the presence of bruits. Although this step may be the least valuable overall, as bowel sounds may be completely normal in patients with severe intra-abdominal pathology, it may nonetheless provide some information that assists the physician in making a diagnosis. For example, the absence of bowel sounds may point towards a paralytic ileus, while ones that are high pitched in nature or rushed may indicate the presence of a mechanical bowel obstruction. Finally, bruits that are detected on the abdominal exam suggest the presence of turbulent flow, which is often the case for arterial stenoses.

Percussion

Next, percussion is utilized to assess for any dull masses, pneumoperitoneum, peritonitis, and ascites. A largely tympanic abdomen may indicate the presence of underlying loops of gas-filled bowel typical of intestinal obstructions or a paralytic ileus. If findings of tympany extend to include the right upper quadrant (RUQ) however, it may be suggestive of free intraperitoneal air. Lastly, percussion can be used to detect ascites by the presence of shifting dullness or by the generation of a fluid wave. Percussion may be all that is necessary to elicit pain in the patient who has peritonitis, for whom further palpation should be deferred.

Palpation

Palpation is the final, critical step as it enables the physician to better define the location and severity of pain and confirm any findings made on other aspects of the physical exam. Palpation should always commence away from the area of greatest pain to prevent any voluntary guarding, which should be distinguished from the involuntary guarding that accompanies peritonitis. Palpation can produce various signs commonly associated with specific disease processes. These include Murphy's sign, characterized by an arrest in inspiration upon deep palpation of the RUQ in patients with acute cholecystitis, and Rovsing's sign, observed many times in patients with acute appendicitis in which pain is elicited at McBurney's point upon palpation of the left lower quadrant. Additionally, pain felt with hyperextension of the right hip, or iliopsoas sign, may indicate the presence of a retrocecal appendix, while a pelvic location of the appendix may be suspected in patients exhibiting Obturator sign, or pain created with internal rotation of a flexed right hip.

It is essential that all patients presenting with acute abdominal pain undergo a digital rectal exam as it may reveal the presence of a mass, the focal tenderness of

a periappendiceal or peridiverticular abscess, and the presence of gross or occult blood. Finally, a pelvic examination should be performed in female patients presenting with lower quadrant pain to discern whether their pain has a gynecologic or obstetric source like pelvic inflammatory disease or a ruptured ectopic pregnancy. On exam, one should take note of any vaginal bleeding or discharge and any adnexal or cervical motion tenderness [4, 5].

Diagnosis Including Use/Value of Pertinent Diagnostic Studies

Laboratory Studies

Various laboratory studies can be used as adjuncts to help narrow down the differential, or to confirm or rule out a diagnosis. A complete blood count (CBC) with differential, for example, may help detect or confirm the presence of an infectious or inflammatory process by the demonstration of leukocytosis and/or a left shift. The accompanying hematocrit is also of value as it can provide information about one's plasma volume, altered in cases of dehydration and hemorrhage. In addition, serum electrolytes, blood urea nitrogen (BUN), and serum creatinine may provide clues to the extent of any fluid losses resulting from emesis, diarrhea, and third-spacing as can lactic acid levels and arterial blood gases. The latter two tests may also help to confirm the presence of any intestinal ischemia or infarction as well.

Liver function tests (LFTs) can help in determining whether conditions of the hepatobiliary tract are the source of the patient's symptoms, while measurements of serum amylase and lipase may implicate acute pancreatitis or its complications as the cause. Physicians should be mindful of the fact, however, that serum amylase levels may also be elevated in a variety of other acute abdominal conditions including intestinal obstruction, mesenteric thrombosis, ruptured ectopic pregnancy, and perforated PUD to name a few [8].

Finally, with respect to serologic tests, there has been recent interest in measurement of inflammatory markers, such as procalcitonin and C-reactive protein (CRP), to aid in the diagnosis of intra-abdominal pathology. However, at this point in time, the markers are insufficiently sensitive and/or specific to be routinely useful [9, 10]. Urinary tests, namely, urinalysis, should be obtained in patients presenting with hematuria, dysuria, or flank pain to determine if their symptoms are genitourinary in origin. Urine samples can also be used to perform toxicology screens in those whose abdominal pain is thought to be the result of long-standing illegal drug use, as seen in the case of mesenteric ischemia that occurs with chronic cocaine abuse. Finally, human chorionic gonadotropin (Hcg) levels can help in determining whether complications of pregnancy, such as a ruptured ectopic pregnancy,

are to blame. Regardless of whether or not it is the source of the patient's symptoms, Hcg levels should be obtained in all women of childbearing age as it may affect decision making, especially if additional studies or surgical intervention are deemed necessary [5]. Finally, depending on the clinical situation, blood may be obtained for typing and crossmatching.

Radiologic Studies

Radiologic imaging plays a key role in the evaluation and management of the acute abdomen (Table 2.1). Plain films, ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) are the most common imaging modalities employed in the diagnostic workup of these patients.

Plain radiographs are often the initial imaging study performed in patients presenting with acute abdominal pain. The advantages of their use include their rapidity and universal availability. Although patients are subject to ionizing radiation exposure, the dose is significantly lower than that of CT scans [11]. Plain films can be of great utility in patients suspected of a perforated viscus by the detection of a pneumoperitoneum by demonstrating dilated loops of bowel and air-fluid levels consistent with obstruction, or by visualization of a foreign body.

The advantages of abdominal US include the lower cost and the lack of ionizing radiation exposure [12], which is advantageous for the pediatric population and pregnant women. In addition, abdominal US is the imaging modality of choice for those patients presenting with suspected hepatobiliary pathology, with a sensitivity of 88 % and specificity of 80 % in the diagnosis of acute cholecystitis [13]. Features suggestive of acute cholecystitis on US include the presence of gallstones, gallbladder wall thickening, pericholecystic fluid, and an elicited Murphy's sign (Fig. 2.2).

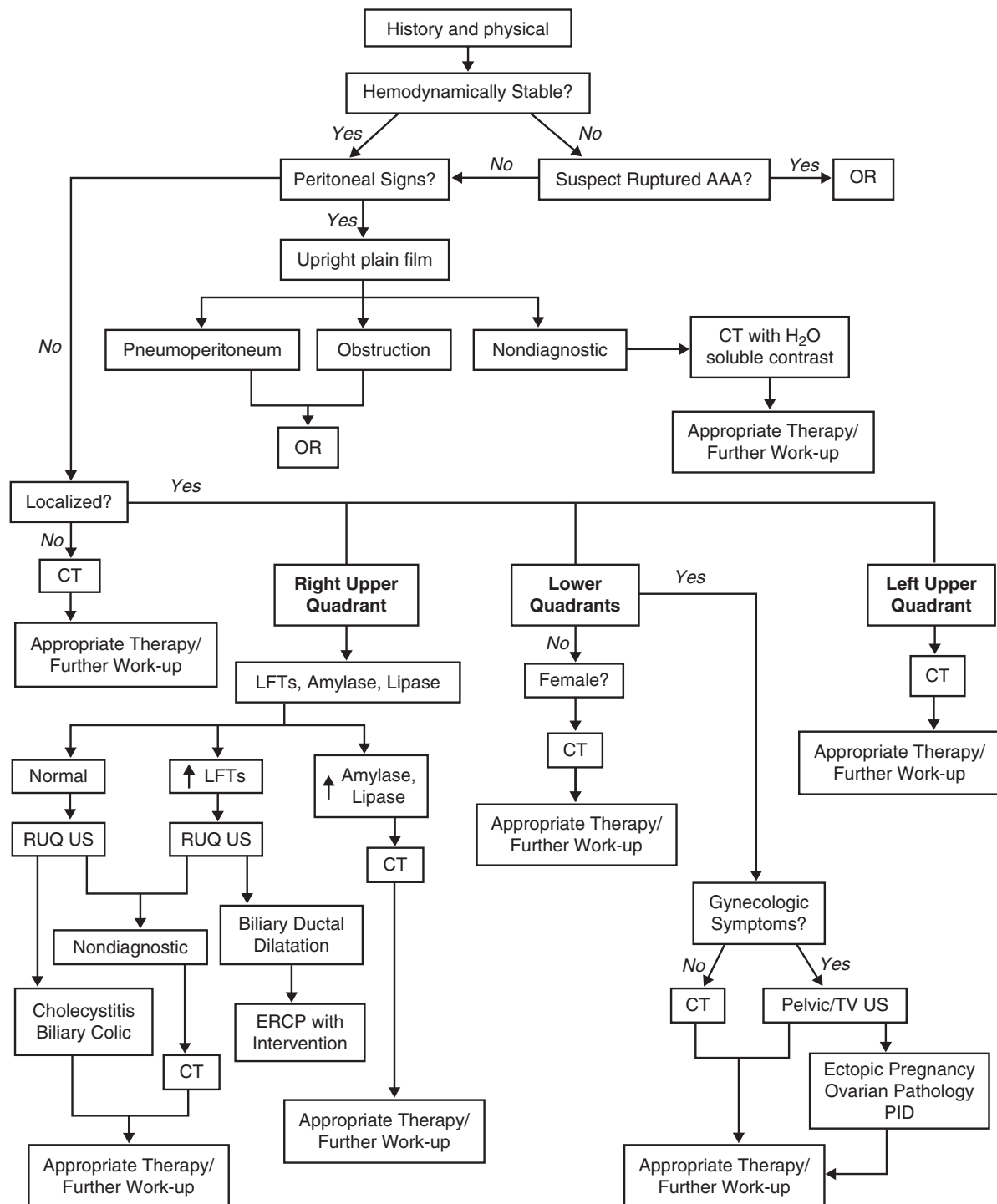
If an obstetrical or gynecologic condition is suspected as the source of a patient's acute abdominal pain, pelvic and transvaginal US are the preferred imaging modalities to assess the uterus and adnexal structures. The presence of free fluid and an empty uterus on US in the setting of a positive pregnancy test is strongly suggestive of a ruptured ectopic pregnancy [14] while an enlarged and edematous ovary with an absence of blood flow is characteristic of a torsed ovary.

Of all the available diagnostic radiologic, the CT scan has emerged as the tool of choice, due to its sensitivity, specificity, and ability to improve work flow and decrease unnecessary hospital admissions [15, 16]. The CT scan has sensitivity of 96 % overall for diagnosing most causes of the acute abdomen, compared to a 30 % sensitivity for plain films [11]. CT scanning has had a significant impact on the diagnosis of acute appendicitis as it has decreased the negative appendectomy

Table 2.1 Diagnostic imaging strategies and treatment options for common causes of acute abdominal pain based on age and gender

	Imaging strategy	Treatment options
Children/young adults		
Acute appendicitis	US, CT	Appendectomy (laparoscopic or open); percutaneous abscess drainage
Gastroenteritis	None	Supportive care
Functional constipation	XR	Manual or pharmacologic fecal disimpaction
Intussusception	XR, US, contrast enema	Contrast enema; operative reduction; resection of ischemic or perforated bowel
Abdominal trauma	FAST, DPL, CT	Exploratory laparotomy; IR
Older adults/elderly		
Acute cholecystitis	US	Cholecystectomy (laparoscopic or open); percutaneous cholecystostomy
Intestinal obstruction	XR, CT	Supportive care; exploratory laparotomy with adhesiolysis, resection of ischemic bowel
Perforated peptic ulcer	XR, CT, or UGI with H ₂ O soluble contrast	Patch closure with <i>Helicobacter pylori</i> treatment if hemodynamic instability
Diverticulitis	CT	Supportive care; percutaneous abscess drainage; resection of involved bowel
Acute appendicitis	CT	Appendectomy (laparoscopic or open); percutaneous abscess drainage
Acute pancreatitis	US, CT	Supportive care; IR or operative pseudocyst drainage; debridement of infected necrosis
Mesenteric ischemia	CTA, MRA	Supportive care; IR; operative bypass, thrombectomy, resection of ischemic bowel
Women		
Acute appendicitis in pregnancy	US, CT, MRI	Appendectomy (laparoscopic or open)
Acute cholecystitis in pregnancy	US	Cholecystectomy (laparoscopic or open)
Ectopic pregnancy	US	Linear salpingostomy or salpingectomy (laparoscopic or open)
Ovarian torsion	US	Ovarian detorsion, possible oophorectomy (laparoscopic or open)
Pelvic inflammatory disease	US, MRI, CT	Supportive care; percutaneous or operative drainage of abscess

US ultrasound, CT computerized tomography, XR plain radiography, FAST focused abdominal sonography for trauma, DPL diagnostic peritoneal lavage, UGI upper gastrointestinal series, IR interventional radiology, CTA, CT computerized tomographic angiography, MRA magnetic resonance angiography, MRI magnetic resonance imaging



AAA, Abdominal Aortic Aneurysm; CT, Computerized Tomography; LFTs, Liver Function Tests; ERCP, Endoscopic Retrograde Cholangiopancreatography; RUQ, Right Upper Quadrant; US, Ultrasound; TV, Transvaginal; PID, Pelvic Inflammatory Disease.

Fig. 2.2 Algorithm for the treatment of the acute abdomen

rate from 24 to 3% [17]. Findings diagnostic of appendicitis on CT scan include an enlarged, nonopacified appendix, appendicoliths, and adjacent fat stranding while the presence of an abscess, phlegmon, and extraluminal gas points towards appendiceal perforation (see Fig. 2.2).

Although MRIs provide excellent visualization of the intraabdominal organs without the need for ionizing radiation, their cost and lack of universal availability make them less ideal for use in the evaluation of the acute abdomen [18]. In addition, some patients have contraindications to undergoing

an MRI or are simply unable to tolerate the test because of claustrophobia. MRI, however, may be of utility for pregnant women in the setting of acute abdominal pain, and has been increasingly been used in diagnostic algorithms with the goal of reducing fetal radiation exposure while still optimizing speedy evaluation and treatment [19, 20].

Diagnostic Laparoscopy

Diagnostic laparoscopy may be of utility in the evaluation of acute abdominal pain, especially in situations in which the underlying etiology remains unclear despite a thorough clinical evaluation and radiologic imaging. The advantages of diagnostic laparoscopy include its ability to make a definitive diagnosis in 90–98 % of cases and determine whether further intervention is necessary [21, 22]. A resultant decrease in the negative laparotomy rate—and the fact that if further treatment is indicated that many acute abdominal conditions can be treated laparoscopically—equates to a decrease in morbidity and mortality, a shorter length of stay, and decreased hospital costs [21]. As experience and skill with advanced laparoscopic techniques increase among surgeons, surgical conditions such as infected pancreatic necrosis, bowel obstructions caused by one or two adhesive bands, and perforated peptic ulcer are now being both diagnosed and treated laparoscopically, with favorable results reported in the literature [23].

Therapeutic Options

In the evaluation of patients presenting with acute abdominal pain, the physician must first determine whether operative intervention is necessary, and if so, whether it should be pursued on an immediate or emergent basis versus urgently or within a few hours of a patient's arrival. Treatment algorithms are beneficial in helping to make such decisions (see Fig. 2.2). In some cases, a short delay to fully correct any fluid and electrolyte abnormalities may prove to be beneficial, whereas in others, immediate operative intervention is necessary for stabilization of a patient's condition. This holds true in the presence of peritonitis, a pneumoperitoneum, intestinal ischemia or infarction, and continued hemodynamic instability despite aggressive resuscitative measures.

Specific treatment strategies for the acute abdomen are largely dependent upon the underlying etiology (see Table 2.1). In the case of acute appendicitis, patients should receive antibiotics and undergo urgent removal of their appendix through either an open or laparoscopic approach, unless their condition is complicated by a perforation with an associated abscess or phlegmon, for which initial nonoperative therapy with interval appendectomy is employed.

For those presenting with acute pancreatitis, however, treatment is largely supportive and includes bowel rest, aggressive fluid and electrolyte repletion, pain control, antibiotic therapy, and nutritional support. Surgery is reserved for the management of complications that may occur subsequently, including the development of infected pancreatic necrosis and large, symptomatic pseudocysts.

Lastly, for patients whose conditions do not warrant emergent surgery, but in whom the underlying etiology remains uncertain, treatment options include diagnostic laparoscopy as previously discussed or observation with frequent monitoring of their hemodynamic status and serial abdominal examinations. Studies have demonstrated that observation in properly selected patients is safe without an increased risk of complications [24].

Special Patient Populations

The Acute Abdomen in the Extremes of Age

Abdominal pain is one of the most common complaints among elderly patients presenting to the emergency department [25]. As the presentation is often different than what is seen in younger patients, the ability to accurately diagnose the underlying cause of their abdominal complaints can be challenging. Elderly patients may lack the febrile response, leukocytosis, and severity of pain expected in those suffering from serious intra-abdominal pathology as a result of the age-dependent decline in immune function [26] along with a well-documented delay in pain perception [27].

The atypical presentation commonly seen in these patients may also be attributed to the effects of other, coexisting medical conditions and medications. For example, beta blockers may blunt the normal tachycardic response to acute abdominal processes while nonsteroidal agents and acetaminophen may prevent the development of a fever. Finally, diagnostic accuracy may be difficult to achieve because of the inability to obtain an adequate history from elderly patients with memory and hearing deficits. Combined, these factors contribute to the increased incidence of complications and increased morbidity and mortality observed in elderly patients presenting with acute abdominal pain. For example, although the incidence of acute appendicitis is lower in this population compared to their younger counterparts, the rate of perforation is significantly higher, reaching almost 70 % in some series [28]. Furthermore, complications of acute cholecystitis occur in more than 50 % of patients aged 65 or older [29].

Although on the opposite end of the age spectrum, the diagnosis of the acute abdomen in children can be equally as challenging, particularly in children who are preverbal or uncooperative. Further adding to the difficulty is the fact that

the etiologies of abdominal pain in children can range from trivial (e.g., constipation) to potentially life-threatening (e.g., malrotation with midgut volvulus) with little to no difference in their presentation [30]. As a result, there are higher rates of misdiagnosis and complications in the pediatric population as well. In fact, the rate of perforation in childhood cases of acute appendicitis is 30–65 %, which is significantly higher than what is reported for adults [31].

Overall, physicians should be mindful of the potential challenges posed to them in the evaluation of acute abdominal pain in these extremes of age and adjust their diagnostic approach accordingly.

The Acute Abdomen in Immunocompromised Patients

The ability to make the diagnosis of an acute abdomen is often challenging for those patients who are immunocompromised as a result of conditions such as cancer requiring chemotherapy, transplantation, human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS), renal failure, diabetes, and malnourishment to name a few. As a result of their body's inability to launch a full inflammatory response, these patients may have a delayed onset of fever and other typical symptoms, experience less pain, and have an underwhelming leukocytosis [5]. As a result, a diagnosis may not be made until the development of overwhelming sepsis, multisystem organ failure, and death.

It is also important to consider that these patients may suffer from a variety of atypical infections—including ones that are viral (in particular, cytomegalovirus and Epstein–Barr virus infections), mycobacterial, fungal, and protozoal in origin—that may affect the pancreas and hepatobiliary, and gastrointestinal tracts. Furthermore, neutropenic enterocolitis is a common source of acute abdominal pain in patients with bone marrow suppression secondary to chemotherapy [32]. As a result of these challenges unique to this subset of patients, physicians should have a high index of suspicion for an acute abdominal process if such patients present with persistent abdominal complaints even if seemingly mild in intensity. These patients should undergo prompt diagnostic imaging and the possibility of operative intervention should be considered early.

The Acute Abdomen in the Critically Ill

The acute abdomen in the critically ill presents a diagnostic challenge as even the history and physical exam is often unattainable or unhelpful, especially in those patients who are obtunded, sedated, or intubated. Physicians should therefore have a high index of suspicion and develop a strategy

that will allow them to diagnose and treat acute abdominal illnesses in a timely fashion.

Physicians should initially take note of any recent abdominal surgery, the sudden onset of abdominal pain or distension, as well as any changes in laboratory studies or hemodynamic status as indicated by changes in vital signs, an increase in volume requirements, and the need for pressors.

If not contraindicated because of hemodynamic instability or physical constraints, radiologic imaging should be obtained to search for evidence of an acute abdominal process. As is the case for patients who are not critically ill, the sensitivity and specificity for diagnosing certain conditions may vary amongst imaging modalities.

If contraindicated, however, but clinical suspicion is high, then emergent laparotomy is indicated. If there are still doubts however, a less invasive technique such as diagnostic peritoneal lavage (DPL) may be used to assist in decision making. The advantages of DPL include the ability to perform the test at the bedside and the fact that it prevented unnecessary laparotomy in more than 60 % of patients in a small series [33, 34]. Overall however, CT is the imaging modality of choice for most intra-abdominal processes, unless a biliary process is suspected for which US is the most sensitive and specific [13].

An acute abdominal condition of the biliary tract more commonly observed in the critically ill is that of acute acalculous cholecystitis. Although the exact etiology is unclear, biliary stasis and gallbladder ischemia with resultant bacterial colonization have been implicated in its development [35]. Such a scenario is common in critically ill patients who are typically not enterally fed and who are hemodynamically unstable.

Acalculous cholecystitis tends to have a more fulminant course and is therefore characterized by increased rates of gallbladder perforation and gangrene [35]. While cholecystectomy is the treatment of choice for this condition, for patients who are critically ill and unable to undergo surgery, percutaneous cholecystostomy is therapeutic until the patient is able to undergo cholecystectomy at a later time. Approximately 90 % of patients experience significant improvement after percutaneous cholecystostomy [36].

Another acute abdominal process more prevalent in the critically ill population is that of abdominal compartment syndrome (ACS), which often occurs in the setting of abdominal sepsis coupled with aggressive fluid resuscitation [37]. Characterized by an increased intra-abdominal pressure (IAP) of 20 mmHg or higher, ACS can progress to hemodynamic compromise (due to impaired venous return), difficulties with ventilation and oxygenation (a result of elevated airway pressures), and oliguria (secondary to impaired venous return and renal vein compression) [38]. Treatment involves emergent abdominal fascial decompression.

The Acute Abdomen in the Morbidly Obese

It is often more challenging to diagnose the acute abdomen in morbidly obese patients as a result of the subtle changes in vital signs, atypical symptoms, and underwhelming physical exam findings these patients often present with. A mildly elevated heart rate, fever, nausea, and malaise may be the only indications to the presence of a serious intra-abdominal process. This is further complicated by the constraints created by an obese body habitus that make performing a physical exam and interpreting any exam findings more difficult. By the time the patient is found to have peritonitis, it is often a late finding with the patient at significant risk for the subsequent development of abdominal sepsis, multisystem organ failure, and death [39].

Physicians should also be aware of the fact that an obese body habitus may result in imaging studies being unattainable or more difficult to interpret. Weight limits may render some morbidly obese patients from being eligible to undergo CT or MRI scanning and large amounts of subcutaneous fat can result in poor radiographic and sonographic image quality [40]. As a result of these challenges, a high index of suspicion should be employed when making treatment decisions, in particular, whether to operate or not. Note that with the advent of laparoscopy and the development of bariatric laparoscopic ports and instruments less invasive measures may be taken to both diagnose and treat the source of the patient's symptoms [41].

The Acute Abdomen in Pregnant Patients

When evaluating a pregnant patient who presents with abdominal pain, one must keep in mind that delays in diagnosis and subsequent intervention can result in an increased risk of morbidity and mortality for both the patient and her unborn fetus.

Delays in presentation, diagnosis, and treatment may occur because many of the presenting signs and symptoms may mimic those normally observed in pregnancy, including abdominal pain, nausea, vomiting, and anorexia. In addition, vital signs and laboratory findings may be more difficult to interpret as they are routinely altered in pregnancy. There is notably a "physiologic anemia" in pregnancy in addition to mild leukocytosis. Additionally, there is typically a 10–15 bpm increase in pulse rate as well as relative hypotension as a result of hormone-mediated vasodilation [42].

The examining physician must also take into account that the presentation of certain disease processes and physical exam findings may differ in the pregnant patient as a result of the upward displacement of the gravid uterus. A classic example of this is seen in the case of acute appendicitis, in which tenderness may be palpated in the RUQ. Appendicitis

is the most common nonobstetrical cause of the acute abdomen, complicating 1 in 1500 births [43]. Although the overall incidence is similar to that of nonpregnant patients, the rate of perforation is higher at approximately 25 %, presumably due to delays in diagnosis and intervention. If and when perforation occurs, the risk of both fetal and maternal mortality increases significantly [44].

Delays may occur because of hesitancy on the part of the physician to obtain certain radiologic studies like that of plain films or CT scans due to the concerns of the radiation exposure associated with these modalities. Ultrasound is therefore used as the initial imaging study in most evaluations of the pregnant acute abdomen [45]. In addition to fetal evaluation, ultrasound is the imaging study of choice for assessment of the biliary tract, pancreas, kidneys, and adnexa. In addition, multiple studies have shown that when paired with graded compression, ultrasound has a sensitivity between 67 and 100 % and a specificity between 83 and 96 % for diagnosing acute appendicitis in pregnancy [46].

If the diagnosis remains uncertain, CT scan is an acceptable alternative means of imaging the pregnant abdomen if used judiciously in order to minimize ionizing radiation exposure [47]. Although the estimated conceptus dose from a single CT acquisition is 25 mGy [48], as per the 1995 American College of Obstetricians and Gynecologists (ACOG) consensus statement, "Women should be counseled that X-ray exposure from a single diagnostic procedure does not result in harmful fetal effects. Specifically, exposure to less than 5 rad (50 mGy) has not been associated with an increase in fetal anomalies or pregnancy loss" [49]. Ultimately, the use of CT scans as a secondary imaging tool in pregnancy can lead to a more timely diagnosis of acute appendicitis resulting in decreased rates of perforation. This along with the decreased rate of negative appendectomies observed in expectant women undergoing US followed by CT scan [50] likely reduces the risk of mortality for both the mother and fetus significantly.

MRI, which uses magnets instead of ionizing radiation, has also been shown recently to be of use in evaluating abdominal pain during pregnancy when ultrasonography was deemed inconclusive [15, 20]. Despite this however, MRI is not always readily available for emergent evaluations; this plus cost and lack of experienced radiologists to read the studies contribute to barriers to its routine use [51].

Once diagnosed, patients should undergo appendectomy. Despite initial concerns of the safety of such an approach, laparoscopy has been accepted as safe with the same advantages afforded for nonpregnant patients, including shorter hospitalizations and less narcotic medication needs [52]. Of course certain precautions should be taken to ensure safety, including using an open Hasson approach to enter the abdomen, a left tilted position, maintaining a CO₂ insufflation of 10–15 mmHg, and monitoring fetal heart tones during the procedure [53].

After appendicitis, the next most common nonobstetric causes of acute abdominal pain are disorders of the biliary tract, notably acute cholecystitis and gallstone pancreatitis. The incidence of acute cholecystitis ranges from 1 in 6000 to 1 in 10,000 births [42]. Presenting symptoms, diagnostic workup, and treatment are similar to their nonpregnant counterparts. As previously stated, laboratory values may be more difficult to interpret, especially in the case of acute cholecystitis as white blood cell counts and alkaline phosphatase levels are normally elevated during pregnancy [42]. As is the case in nonpregnant patients, acute cholecystitis is usually treated conservatively early on with intravenous fluid hydration, bowel rest, pain control, and antibiotics. If the patient fails to respond to medical management, then surgery is indicated. Failing to operate on these patients in a timely fashion significantly increases the risk of preterm labor and fetal loss [54].

Regardless of whether patients respond appropriately to conservative management, the majority of surgeons still recommend surgery during pregnancy to prevent any recurrence or any complications that may pose a threat to the fetus [54]. In fact, the rate of fetal demise with gallstone pancreatitis has been reported to be as high as 60% [55]. As is the case with acute appendicitis, laparoscopic cholecystectomy has been deemed safe to perform during pregnancy without any increased risk of morbidity or mortality to the mother or fetus [56].

The Acute Abdomen from a Global Perspective

The acute abdomen can be especially concerning from a global health perspective. In 2010, nearly 900,000 people lost their lives to emergency general surgical conditions, such as peptic ulcer disease, bowel obstruction, and appendicitis, diseases which are widely viewed as treatable and survivable in higher resourced countries [57].

The low density of adequately trained physicians and quality treatment facilities in developing countries means long delays between symptom onset and treatment, resulting in worse outcomes [58, 59]. Proper management of the acute abdomen in these regions may be further complicated by the lack of modern radiographic and other diagnostic modalities, which may render contemporary treatment algorithms unusable. As a result, increased emphasis should be placed on careful history taking and physical exam skills. Findings of abdominal distension, abdominal masses, deranged vital signs, guarding, and a positive vaginal/rectal examination have been associated with worse outcomes in these regions, warranting further investigation [60]. In areas where advanced clinicians are unavailable, a standardized questionnaire may help in establishing a differential diagnosis in patients presenting with acute abdominal pain.

In addition to common causes of abdominal pain, physicians in developing countries must consider other exotic causes of acute abdominal pain, including typhoid enteritis, abdominal tuberculosis, and parasitic infections, which can themselves cause acute intestinal obstructions, appendicitis, cholangitis, and liver abscesses [61]. Typhoid, which usually presents with high fever, abdominal distension, and delirium, remains endemic in impoverished parts of the world [62]. Caused by the bacterium *Salmonella typhi*, typhoid fever is transmitted through fecal contamination of food or water supplies. If not identified and treated in a timely fashion with the appropriate antibiotics, typhoid can result in intestinal hemorrhage or perforation—two potentially fatal causes of an acute abdomen requiring surgical intervention [63]. In one series, typhoid fever complicated by ileal perforation was diagnosed in 16% of patients in a region of West Africa, making it the second most common cause of the acute abdomen [64].

A large number of acute abdominal cases in developing countries are caused by parasitic infections, which like that of typhoid fever are typically acquired through fecal–oral transmission. In one study originating from West Africa, some 4% of acute abdominal cases necessitating emergency surgery were attributable to parasites [65]. The majority of these were secondary to infections with members of the amoeba family, which can cause colitis and hepatic abscesses, or *Ascaris lumbricoides*, a species of roundworms that can invade and overwhelm the gastrointestinal and hepatobiliary systems, resulting in intestinal obstruction, appendicitis, pancreatitis, and cholecystitis [66]. In addition to emergent surgical intervention, patients should be treated with antiparasitic medications to ensure complete eradication of disease.

Overall, the acute abdomen poses diagnostic challenges unique to the developing world given the limited access to resources and personnel required to sufficiently treat patients with potentially life-threatening abdominal conditions. Compounding this are the other exotic causes of acute abdominal pain prevalent in these regions that one must consider in their workup. Therefore, in addition to enhancing access to healthcare, health education, and sanitation, attention should be placed on the development of adequate history taking and physical exam skills to improve the outcomes of patients presenting with an acute abdomen in these regions of the world.

Potential Complications

The outcomes of patients presenting with an acute abdomen are influenced by the underlying etiology of their symptoms, age, comorbid conditions, and the time to diagnosis and treatment. In terms of etiology, one could assume that a

patient with a noncontained hollow viscus perforation is likely to have higher rates of morbidity and mortality in the peri- and postoperative period compared to a patient presenting with acute, nonperforated appendicitis. With regard to age and health status, diminished physiologic reserve and an increased incidence of comorbidities place elderly patients at an elevated risk of complications and death compared to their younger counterparts. For example, the age-related decline in pulmonary function is associated with a prolonged need for mechanical ventilation and an increased risk of developing ventilator-associated pneumonias [67]. These issues are compounded by the fact that elderly patients tend to have delays in diagnosis and treatment, further contributing to their increased rates of morbidity and mortality. In the case of perforated PUD, older patients who underwent surgery more than 24 h after perforation were 8 times more likely to die compared to those who were operated on within 4 h [68].

Morbidly obese patients with an acute abdomen are also at an increased risk of poor outcomes due to atypical presentations and the challenges posed by their body habitus that result in treatment delays [39]. Even in cases where surgery is indicated and performed in a timely manner, higher rates of postoperative complications including surgical wound infections and multisystem organ failure are experienced by morbidly obese patients [69].

In pregnant patients, the acute abdomen poses significant risks to both the mother and fetus. Atypical presentations and the inability to distinguish some acute abdominal symptoms from those normally experienced during pregnancy can result in treatment delays and an increased susceptibility for preterm labor and fetal loss [56].

Outcomes

Evaluating outcomes after treatment for an emergent intra-abdominal disease process has been challenged by the lack of risk-stratified data. The American College of Surgeons National Surgical Quality Improvement Project (ACS NSQIP) deliberately focused on elective surgical cases, though there is currently a multi-center pilot project underway that should begin to address this issue. Recently published grading scales which standardize the approach to anatomic severity of disease in emergency surgery should help with risk stratification and, ultimately, comparative analysis of outcomes [70, 71].

In general, regardless of age or health status, patients presenting with an acute abdomen should undergo a thorough yet expeditious evaluation to help establish a diagnosis and initiate the therapeutic interventions necessary to help ensure positive outcomes for these patients.

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