Imaging and Laboratory Testing in Acute Abdominal Pain

Nova L. Panebianco, MD, MPH[a,*], Katherine Jahnes, MD[b], Angela M. Mills, MD[a]

KEYWORDS

• Abdominal pain • Computed tomography • Ultrasonography

As noted by almost every author in this issue, the diagnosis of emergency abdominal conditions involves the integration of information from the history, physical examination, laboratory testing, and imaging studies. Only rarely does the history or physical examination provide information that is conclusive or unequivocal, so that in most cases the clinician must resort to laboratory testing or imaging studies, which may themselves be equivocal or inaccurate. To prioritize and weight the information obtained from testing, it is important for the clinician to know the accuracy of the test being used. When discussing which laboratory tests or imaging to order in the setting of acute abdominal pain, it is convenient to organize information by disease process (eg, acute appendicitis, cholecystitis). Because studies on the accuracy of diagnostic tests are of necessity related to the presence or absence of specific diagnoses, and because clinicians frequently look to tests to help them rule in or rule out specific conditions, this article is organized by region of pain and common abdominal diagnoses. It focuses on the contributions that laboratory testing and imaging make in the emergency management of abdominal complaints as well as potential blind-spots and pitfalls that can arise if the tests are misapplied or misinterpreted.

OVERVIEW OF LABORATORY TESTING

Acute abdominal pain was the leading symptom-related cause for visiting an emergency department (ED), at 6.7% or 8 million visits, in 2006.[1] Laboratory work in the

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[a] Department of Emergency Medicine, University of Pennsylvania School of Medicine, 3400 Spruce Street, Ground Ravdin, Philadelphia, PA 19104, USA

[b] Department of Emergency Medicine, New York Methodist Hospital, 506 Sixth Street, Brooklyn, NY 11215, USA

* Corresponding author.

E-mail address: Nova.panebianco@uphs.upenn.edu

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patient with abdominal pain can serve to make a diagnosis, indicate the severity of disease, or direct attention toward coexisting medical problems. However, tests may result in incidental findings that may confound the clinical picture. For this reason, tests should be ordered with a specific clinical question in mind and, when possible, with a clear sense of the pretest probability and likelihood ratios engendered by a positive or negative outcome of the test.

Determining the value of an individual laboratory test for a patient with abdominal pain is difficult. In fact, the 1994 American College of Emergency Physicians (ACEP) policy statement recommends laboratory analysis for very few clinical diagnoses in patients with abdominal pain. However, clinical practice certainly varies significantly from this policy. Some studies have looked at the diagnostic importance of individual laboratory tests in the evaluation of specific conditions or suspected conditions (eg, suspicion of appendicitis). While review of data shows that individual laboratory studies taken in isolation infrequently “make” a diagnosis, results of laboratory studies do frequently affect disposition or treatment in the ED. In addition, many studies investigating laboratory testing in abdominal pain involve protocols in which laboratory tests are ordered for all patients and then tailored to the individual case after history and physical examination.[2–5] Most abdominal labs test general physiology, for example the complete blood count (CBC). Few tests are as specific as the lipase and urinalysis. In addition, even tests that are relatively specific, such as aspartate transaminase (AST) and alanine aminotransferase (ALT), may be abnormal in many different conditions.

The usefulness of a given test is often evaluated by its ability to rule in or out a given disease process. Using that as a starting point, intuitively it is clear that laboratory tests that give a more systemic glimpse at a patient’s physiology, for instance a CBC or electrolytes, will be perceived as less “useful” than laboratory tests that more directly measure injury to an organ that is diseased, for example, troponins in myocardial ischemia or lipase in pancreatitis. However, laboratory tests that give an indication of systemic illness are clinically important for patients with abdominal pain. The most common laboratory tests ordered in the ED by percentage of patient visits are CBC (34.0%), blood urea nitrogen (BUN)/creatinine (20.1%), electrolytes (19.1%), cardiac enzymes (19.0%), and liver function tests (11.5%). Urinalysis was ordered in 20.2% of ED visits.[1] A study of abdominal pain patients at an urban academic ED found that laboratory and imaging tests led to a change in diagnosis in 37% of subjects and in disposition in 41%.[4] The investigators reported the two most useful tests to be abdominal computed tomography (CT) and urinalysis.

Summary

1. Laboratory tests can narrow a differential diagnosis, confirm clinical suspicion of a disease process, and, occasionally confound the treating physician.
2. Labs should be obtained to answer a focused clinical question.

OVERVIEW OF DIAGNOSTIC IMAGING

Imaging plays an important role in the evaluation of patients with acute abdominal pain. In 2005, 44% of ED visits included imaging; 35% of visits included plain radiography, 11% had CT, 3% had ultrasonography (US), and 0.5% magnetic resonance imaging (MRI).[6] While these statistics are for all complaints, not just for abdominal pain, it reflects the reliance on ancillary testing in the ED. When evaluating a patient with acute abdominal pain, the decision to order an imaging study, just as with laboratory testing, should come from information gleaned from a comprehensive yet focused history and physical examination. It is important to remember that all diagnostic testing has significant false-positive and false-negative results, and in the setting of a high pretest suspicion for disease, a negative test does not rule out disease. In addition, radiographic imaging may carry risks such as contrast and radiation exposure, and as such it is important to consider risks and benefits of an imaging modality when evaluating a patient with acute abdominal pain.

Plain Abdominal Radiography

Plain radiography has historically been the initial imaging modality used for the evaluation of abdominal pain, due to its ease of acquisition and cost. With the increased availability and technological advances of other imaging modalities such as CT and US, the usefulness of plain radiographs has diminished. With alternative imaging readily available, the usefulness of abdominal radiographs in the nontraumatic patient is controversial. In a recent study of patients whose abdominal radiograph was interpreted as normal or nonspecific, the majority (81%) had positive findings on CT, US, or upper gastrointestinal imaging.[7] The investigators found that plain radiographs led to a change in management in only 4% of patients. In another study, when compared with unenhanced helical CT, 3-view abdominal radiographs yielded only an overall sensitivity of 30%, specificity of 88%, and accuracy of 56% (95% confidence interval 0.46–0.66), with a negative predictive value of 51%.[8] Given the poor performance, added cost, and increased radiation dose, plain radiographs are indicated only in specific, limited settings.

Some have suggested that abdominal radiography be used solely to identify bowel obstruction, perforation, foreign body ingestion, or localization of catheter placement.[9] However, in obstruction, abdominal radiography alone does not provide the exact location or extent of the obstruction (partial, complete, or intermittent) and often requires further imaging such as CT.[10] Thus, a patient may be subjected to multiple tests with ionizing radiation. Pneumoperitoneum can be seen on an abdominal series radiograph; however, is often better visualized on an upright chest radiograph, which subjects the patient to shorter exposure times, less radiographic penetration, and more tangential alignment of the x-ray beam to the diaphragm (**Fig. 1**).[11] Abdominal radiography for the identification and localization of a foreign body or catheter may be the strongest indication for this imaging modality.

Summary

1. Plain abdominal radiography is of limited value and may only increase cost of care and a patient's total exposure to ionizing radiation.
2. Indications for the use of abdominal radiographs include suspicion for pneumoperitoneum or small bowel obstruction in the setting of limited or delayed availability of CT, localization of an ingested foreign body, and the localization of catheters.

Abdominal Computed Tomography

The use of CT for medical imaging is a relatively recent phenomenon, with the first commercially available CT scanner publicly announced in 1972. The benefits of CT include high-contrast resolution of images, multiplanar reformatted imaging, and rapid high-accuracy diagnosis. CT is often the test of choice when multiple diagnoses are being entertained, and greatly increases clinician diagnostic confidence. The disadvantages of CT include exposure to ionizing radiation, increased cost, increased personnel requirements, lack of repeatability, intravenous dye load and contrast allergies, and the risks of removing a patient out of the emergency treatment area.

In the United States the use of CT has increased dramatically in the past few decades, with more than 70 million CT scans performed in 2007.[12,13] Although CT

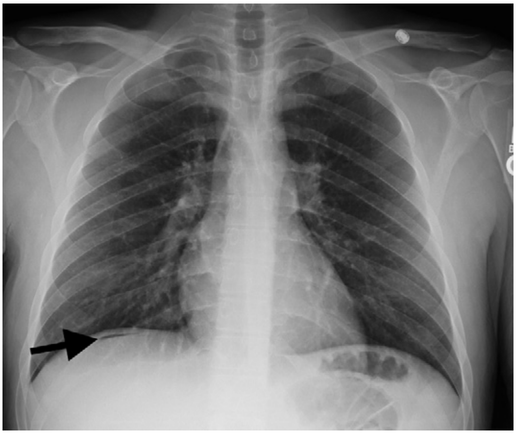

Fig. 1. A small stripe of free air (*arrow*) is seen in this upright chest radiograph. The thin pointy shape of the free air should be contrasted with the "roundy" shape of intraluminal of gas seen under the left hemidiaphragm. (*Courtesy of* Anthony J. Dean, MD, University of Pennsylvania, Philadelphia, PA.)

accounts for only 15% of radiological imaging, it accounts for approximately half of the collective medical radiation performed in the United States.[14,15] The median effective radiation dose for abdomen and pelvis CT ranges from 15 to 31 millisieverts (mSv), in comparison with the chest radiograph, which is 0.1 mSv.[16] In a study by Sodickson and colleagues,[15] cumulative CT radiation exposure added incrementally to baseline cancer risk. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a single abdominal CT in a 1-year-old is 0.18%.[17] Brenner and Hall[18] predicted that 1.5% to 2% of all United States population cancers may be caused by CT radiation exposure. In particular, patients with chronic or recurrent medical conditions have the greatest exposure risk.

There are two groups in whom the cost, delay, and risk of abdominal CT may outweigh the benefits.[19] Those patients with (1) a high index of suspicion for the need for immediate surgical intervention (eg, unstable, obvious peritonitis) and (2) those in whom there is high confidence of a nonsurgical diagnosis based on history, physical examination, and/or other laboratory tests, yielding a low index of suspicion of serious abdominal pathology.[20] For those patients that fall between these two groups, abdominal CT can be invaluable.

An abdominal CT can be performed with or without intravenous (IV) iodinated contrast medium, and with or without oral/rectal contrast. In a prospective study of 100 ED patients with abdominal pain, patients were initially scanned without oral contrast and then again 90 minutes after oral contrast with identical scanning parameters. The investigators concluded that oral contrast takes at least 90 minutes to adequately opacify the bowel, increases length of stay in the ED by almost double that amount of time, but adds little, if anything, to the accuracy of diagnosis in patients with nontraumatic abdominal pain.[21] Similarly, in a study of noncontrast enhanced versus oral-contrast enhanced CTs, there was a 241-minute increase in time until disposition with the use of oral contrast.[22]

Summary

1. CT offers high-contrast resolution of images, multiplanar reformatted imaging, rapid high-accuracy diagnosis, and is often the test of choice when multiple diagnoses are

being considered. However, it may expose the patient to ionizing radiation, contrast dye, higher incurred cost, and removal from the ED treatment area.

2. CT is particularly useful in stable patients without overt surgical pathology but whose differential diagnosis includes significant abdominal pathology.
3. Radiation exposure may have consequences for the patient years to come, and the decision to perform the imaging examination should be taken in context of patients' current complaint and the future of their disease.
4. Oral contrast increases length of stay in the ED and may not add additional information.

Ultrasonography

US of the abdomen can produce anatomic, functional, and dynamic information during a real-time interaction between the examiner and the patient. The examiner may control the image plane, interrogate an area of tenderness, or watch for changes in image over time. US of the abdomen allows for rapid evaluation of an unstable patient, efficient narrowing of the differential diagnosis, repeatability throughout the resuscitation process, and the lack of known adverse biologic effects. The main drawbacks with US are that image acquisition and interpretation is operator dependent, and patient factors including body habitus and bowel gas may limit the examination.

Abdominal ultrasound images are traditionally obtained by technicians, interpreted later by radiologists, and then results are reported to clinicians. With the advent of smaller, more portable, higher-resolution machines, US is currently being used directly by clinicians. For more than a decade emergency physicians (EPs) have been using bedside US, and the ACEP has formally endorsed and supports bedside US by EPs for multiple applications, research, and education.[23] Emergency medicine residents are now required to receive training in point-of-care goal-directed US, and there are currently more than 50 ultrasound fellowships in the United States.

US has proved to be particularly useful in the early evaluation of the unstable patient. Appropriately trained nonradiologist clinician-performed bedside US can reliably detect intraperitoneal free fluid, the presence of an abdominal aortic aneurysm (**Fig. 2**), and ruptured ectopic pregnancy, and can assess the morphology and collapsibility of the inferior vena cava for volume status.[24–27] In a study by Jones and colleagues,[28] the investigators examined a physician-performed, goal-directed ultrasound protocol for the ED management of patients presenting with nontraumatic, symptomatic, undifferentiated hypotension. It was demonstrated that immediate goal-directed US in the evaluation of patients reduces the number of viable diagnostic possibilities and allows the physician to come to a more accurate final diagnosis.

Summary

1. Clinician-performed US is a repeatable examination that can provide vital diagnostic information at the bedside without exposing a patient to ionizing radiation.
2. In the unstable patient, a goal-directed ultrasound examination may be the most efficient way to narrow a diagnosis.
3. US is limited by patient factors including habitus, wound bandages, abdominal tenderness, and subcutaneous emphysema.

INTEGRATION OF LABORATORY TESTS AND IMAGING STUDIES BASED ON LOCATION OF PAIN AND DISEASE PROCESS

Evaluation of Generalized Abdominal Pain

Generalized abdominal pain can be secondary to infectious, mechanical, vascular, inflammatory, malignant, or traumatic processes ranging from benign to life-threatening

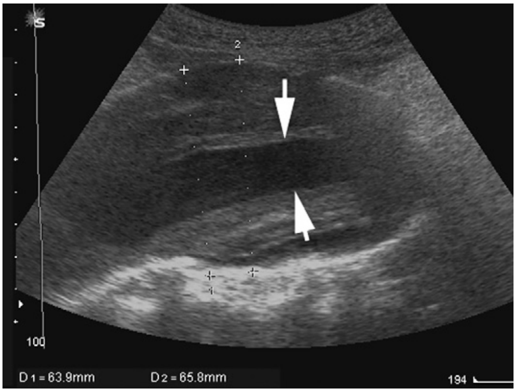

Fig. 2. Longitudinal ultrasound image of an abdominal aortic aneurysm. A thick layer of thrombus has formed within the walls of the aneurysm, creating a "pseudolumen" (*arrows*). Improper gain settings can result in the walls of the pseudolumen being mistaken for the walls of the aorta. (*Courtesy of* Anthony J. Dean, MD, University of Pennsylvania, Philadelphia, PA.)

in etiology. Some causes of generalized abdominal pain include bowel obstruction, abdominal aortic aneurysm (AAA), mesenteric ischemia, peritonitis, narcotic withdrawal, sickle cell crisis, irritable bowel syndrome, and heavy metal poisoning.[29] A workup for generalized abdominal pain will depend on a multitude of clinical factors, including history and physical examination, age, comorbidities, and vital signs, to avoid missing a serious condition. Several studies have shown that CT has an advantage over other imaging modalities in patients with nontraumatic generalized abdominal pain, and can alter disposition decisions in about a quarter of patients.[19,30,31]

A study of 100 young women (age 15–45 years) who presented to the ED with a chief complaint of lower abdominal pain attempted to examine the effects of CBC result on clinical decision making.[32] All patients in this study with appendicitis, as well as the one patient with an ectopic pregnancy, were appropriately diagnosed without the CBC result. In addition, of the 73 patients not admitted or diagnosed with an infectious disease, 17 were found to have an elevated white blood cell (WBC) count. While often ordered, the CBC in this study was found to have limited additional value in the workup of this patient population.

In the critically ill patient, lactate levels, although not specific to abdominal pain, can be a useful adjunct in the evaluation. In a prospective cohort study involving 1278 consecutive patients admitted to the hospital from an urban academic ED with a clinically significant infection (regardless of source), lactate levels were found to be useful as a risk stratification tool for inpatient mortality.[2] Primary end point was 28-day in-hospital mortality with a secondary outcome of "early death" within 3 days of hospitalization. Patients were divided into 3 groups by lactate levels defined as low (<2.5), medium (2.5–3.99), and high ($\geq$4). For the 3 groups, 28-day in-hospital mortality was 4.9%, 9.0%, and 28.4%, respectively, and early mortality was 1.5%, 4.5%, and 22.4%, respectively. Lactate levels greater than 4 were 55% specific and 91% sensitive for early death (positive likelihood ratio [LR+] 1.4, negative likelihood ratio [LR−] 0.22, authors' calculation), and 36% specific and 92% sensitive for 28-day death (LR+ 2.02, LR− 0.16, authors' calculation). The investigators surmise that lactate levels may be helpful in identifying patients who should be targeted for aggressive early therapy.

Mesenteric ischemia is one of the most feared diagnoses for an ED physician with its unfortunate triad of frequent lack of history, unreliable physical examination, and lethality. The identification of laboratory markers to improve the diagnosis has so far proven elusive; however, a few potential markers have been identified. In a systematic review of the literature, 20 articles were identified that investigated serologic markers for intestinal ischemia in a combined 978 patients.[33] The prevalence of intestinal ischemia was 28% and included patients from a variety of settings. Of the multiple serologic markers investigated, 3 offered potential for improved diagnostic accuracy, including D-lactate, glutathione *S*-transferase (GST), and intestinal fatty acid binding protein (i-FABP). D-Lactate is produced by bacterial organisms and is thought to be a marker for bacterial translocation, as may follow ischemic (or other) mucosal injury. The investigators calculated a pooled positive LR of 2.64 in patients presenting with acute abdomen and a negative LR of 0.23. Physiologically, GST is a less specific marker, as it is released during oxidative stress from both the liver and the intestines; however, the analysis showed a positive LR of 3.28 and a negative LR of 0.23 in patients with acute abdomen. Intestinal fatty acid binding proteins are found in the cytoplasm of enterocytes at the tips of villi, the area most vulnerable to ischemia, thus making i-FABP an interesting candidate for a serologic marker of ischemia. In the analysis, the positive LR was 4.5 and the negative LR was 0.52. All of these markers require further research before becoming routine in the evaluation of ED patients presenting with acute abdominal pain.

As clinical examination and laboratory tests tend to have limited ability to predict the presence of mesenteric ischemia, imaging tests are often needed. Angiography of the mesenteric arteries traditionally has been the gold-standard diagnostic test for mesenteric ischemia. This test is limited by its invasiveness, dye load, and inability to visualize surrounding structures other than the vessel lumen. With the advent of multidetector-row CT and MRI, angiography is no longer a first-choice procedure. CT has many advantages over angiography in that it is minimally invasive, can detect ischemic changes in the affected areas (bowel wall thickening, fat stranding, pneumatosis), and image reformatting can allow for angiographic reconstructions that often eliminate the need for traditional angiography in the case of high clinical suspicion and negative CT (**Fig. 3**).[34] The limitations of CT include high radiation dose and risk of nephrotoxicity secondary to contrast dye. In a review article by Biolato and colleagues,[35] they report that CT with IV contrast has a sensitivity and specificity for acute mesenteric ischemia of 64% and 92%, respectively. Multidetector-row CT with 3-dimensional reformats increases sensitivity and specificity to 96% and 94%, respectively. MR angiography can obtain high-resolution angiograms in 85% to 90% of superior mesenteric arteries, 75% to 90% of celiac arteries, and 25% of inferior mesenteric arteries (lower because of its anatomic location). The superior mesenteric and celiac arteries are clearly visualized using duplex US in more than 90% and 80% of cases, respectively. As with MR, US cannot reliably visualize the inferior mesenteric artery because of its anatomic location.[35]

Summary

1. In the setting of generalized abdominal pain, CT is often the test of choice for evaluating patients with a significant clinical risk of an acute intra-abdominal process.
2. Lactate levels, although not specific to abdominal pain, can be a useful adjunct in the evaluation of patients who may be critically ill.
3. Multidetector-row CT, MRI, and duplex US may replace angiography as the first-line test for mesenteric ischemia.

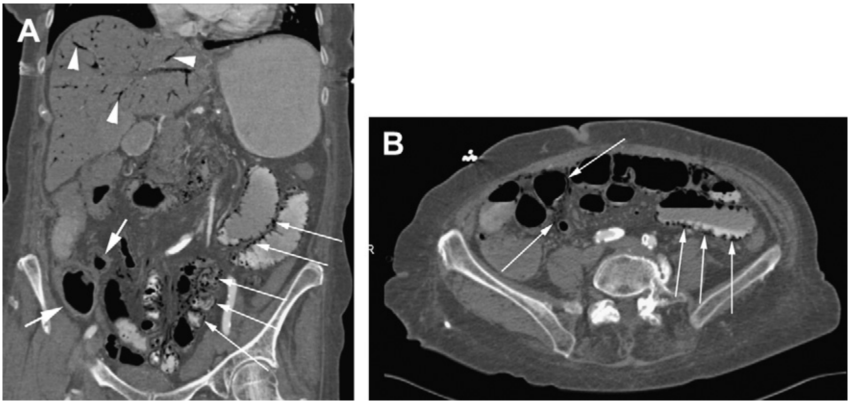

Fig. 3. Coronal (*A*) and axial (*B*) CT images of a patient with mesenteric ischemia demonstrating extensive portal venous gas (*arrowheads*), bowel wall edema (*short arrows*), and marked intestinal pneumatosis (*long arrows*). (*Courtesy of* William W. Boonn, MD, University of Pennsylvania, Philadelphia, PA.)

Right Upper Quadrant

Pain in the right upper quadrant (RUQ) may relate to disorders of the hepatobiliary system, right kidney, pancreas, bowel, pleura/lung, and musculoskeletal system. In a retrospective study of 100 patients with suspected acute cholecystitis who underwent a hepatobiliary scan, Singer and colleagues[36] investigated whether the presence or absence of various clinical or laboratory parameters (including WBC count, total bilirubin, AST, ALT, alkaline phosphatase, and amylase) would identify patients at high risk for having a positive hepatobiliary scan. In fact, none of the laboratory values evaluated in this study were predictive of having a positive hepatobiliary scan. A study of 311 patients admitted with suspected acute cholecystitis described the relationship between elevated liver function tests (LFTs) (specifically bilirubin, ALT, and alkaline phosphatase) and acute cholecystitis.[37] The incidence of confirmed acute cholecystitis was 73.6%, and though LFT abnormalities were statistically more frequent in patients with acute cholecystitis than without acute cholecystitis, these results were not clinically useful because of the broad overlap of values in those with other conditions. Furthermore, normal LFTs did not exclude cholecystitis. Laboratory testing is an adjunct to the workup of patients with suspected acute cholecystitis, but ultimately clinical suspicion and imaging studies are needed for diagnosis.

It is estimated that 20 million persons in the United States have gallstones.[38] Although radionuclide imaging is sensitive for acute cholecystitis, it is expensive, time consuming, and does not assess structures outside of the biliary tract. Thus, RUQ US is considered the test of choice for evaluation of the gallbladder and biliary tree.[39] Multiple studies have shown that EPs can detect cholelithiasis by US, with good sensitivity and specificity.[40,41] Acute cholecystitis is characterized on ultrasound images by the presence of gallstones (particularly if in the neck of the gallbladder), thickened wall, pericholecystic fluid, and the presence of a sonographic Murphy sign (**Fig. 4**). One study of EPs' ability to detect gallstones by bedside US found a sensitivity and specificity of 91% and 66%, respectively.[42] The low specificity may have been secondary to the use of a single criterion in the diagnosis of acute inflammation, a sonographic Murphy sign.

In the setting of acute jaundice, US may be used to detect the presence of biliary stasis, localize the level of ductal obstruction, and identify the cause of obstruction.

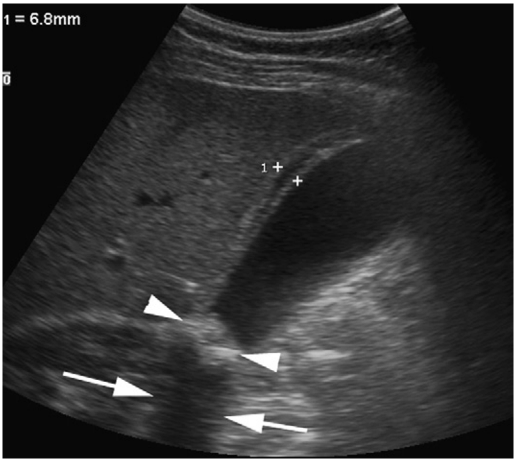

Fig. 4. Longitudinal ultrasound view showing stones (*arrowheads*) impacted in the gallbladder neck with posterior shadowing (*arrows*). In this case of cholecystitis, the wall is thickened with a dark layer of intramural edema. (*Courtesy of* Anthony J. Dean, MD, University of Pennsylvania, Philadelphia, PA.)

The ability of US to detect common bile duct stones is limited, with some studies reporting a sensitivity of less than 70%; however, the diagnosis of intrahepatic calculi by US may be more accurate than that of CT because these stones lack sufficient calcium to make them radio-opaque.[43,44] US may be useful to rule in disease, but not significantly sensitive to rule it out. In this setting, LFTs including total bilirubin, AST, ALT, and γ-glutamyl transpeptidase (GGT) may be useful.

Other causes of pain in the RUQ include pneumonia, hepatitis, renal colic, musculoskeletal pain, and herpes zoster. RUQ pain secondary to lung infection can often be determined by physical examination and chest radiography. Pain due to renal colic may be identified by the history and physical examination. Urinalysis may contain red blood cells; however, lack of hematuria does not rule out nephrolithiasis. In a study using helical CT as the reference standard for ureterolithiasis, the sensitivity and specificity for a patient with any degree of microscopic hematuria were 89% and 29%, respectively.[45] Imaging may include plain radiography, unenhanced CT, intravenous urography (IVU), and US. A kidney-ureter-bladder (KUB) radiograph can be used to determine the location and size of a kidney stone, and is often used to track the progress of a known stone. The sensitivity and specificity of KUB for nephrolithiasis is 44% to 77% and 80% to 87% respectively.[46] In a study by Wang and colleagues,[47] unenhanced CT was determined to be more effective and efficient than IVU and was recommended to replace IVU as the first-line diagnostic tool for ureteral stone detection in the ED. In a review by Heidenreich and colleagues,[46] the investigators write that "unenhanced helical CT has been demonstrated to be superior (in diagnosing ureteral stones) since (1) it detects ureteral stones with a sensitivity and specificity from 98% to 100% regardless of size, location and chemical composition, (2) it identifies extra-urinary causes of flank pain in about one third of all patients presenting with acute flank pain, (3) it does not need contrast agent, and (4) it is a time saving imaging technique being performed within 5 minutes." Renal US is commonly used in the evaluation of acute flank pain and may reveal hydronephrosis, and occasionally a stone is seen in the ureterovesicular junction. US is appealing, as it is fast, painless, repeatable, does not expose the patient to ionizing radiation, and may be able to rule out obstruction with the presence of ureteral jets. US may be particularly useful in a patient with a history of nephrolithiasis and low risk for alternative diagnosis, in order to avoid a CT scan.

Summary

1. There is no single blood test that predicts the presence or absence of acute cholecystitis.
2. RUQ US is the test of choice in the evaluation of biliary disease.
3. Unenhanced CT of the abdomen has excellent sensitivity and specificity for ureterolithiasis, and can point to an alternative diagnosis if no stones are identified.

Epigastric

Amylase and lipase are the two serologic markers used to diagnose acute pancreatitis. In a retrospective study of 10,931 patients, serum amylase and lipase measurements were compared with discharge diagnosis of acute pancreatitis using radiographic evidence for confirmation of diagnosis.[48] The investigators demonstrated an improved diagnostic accuracy for lipase over amylase, with sensitivity and specificity of 90.3% and 93.0%, respectively for lipase and 78.7% and 92.6%, respectively for amylase. The level of pancreatic enzyme elevation has not been shown to correlate with severity of disease, nor can daily measurement of enzymes be used to assess clinical progress or prognosis.[49]

Enhanced CT of the abdomen is the radiologic test of choice to evaluate for pancreatic necrosis. Abdominal plain radiography typically offers little information in the evaluation of acute pancreatitis. Abdominal US may yield information about the pancreas; however, it may be limited by patient habitus and bowel gas. US may play a role in the assessment of pancreatitis by identifying gallstones as the cause. Patients with necrotizing pancreatitis have been found to have a mortality of 10% to 23% compared with a mortality of less than 1% in those with interstitial pancreatitis.[50] As CT grade of severity increases, so does the rate of complications and mortality. Not all patients with pancreatitis must undergo abdominal CT. For those with a known history of pancreatitis, stable labs, and vital signs, CT may not be of additional value.[51] CT is often used to exclude other sources of pain and to assess the severity of disease, especially in patients with continued symptoms who are not improving.

Summary

1. Elevated lipase is more specific than amylase in the detection of acute pancreatitis.
2. Contrast-enhanced CT can be used to determine the extent of pancreatic injury and identify alternative causes of acute epigastric abdominal pain.

Right Lower Quadrant

Pain in the right lower quadrant (RLQ) may be caused by appendicitis, ovarian pathology, ectopic pregnancy, hernia, intestinal pathology, and renal colic. In the 2009 ACEP clinical policy with regard to the evaluation and management of ED patients with suspected appendicitis, the subcommittee gave a level B recommendation to the use of clinical findings to risk-stratify patients and guide further testing and management. The subcommittee also concluded that WBC alone is not a consistent predictor of appendicitis, as it may frequently be normal especially in the setting of early presentation.[52] A meta-analysis by Andersson[53] of clinical signs and symptoms and laboratory values in suspected appendicitis found individual components to be “of weak discriminatory and predictive capacity.” The study reports, however, that a WBC greater than 10 ($\times 10^9$/L) had a positive LR of 2.47 for appendicitis, and

C-reactive protein (CRP) greater than 10 (mg/L) had a positive LR of 1.97. Andersson also calculated LRs for granulocyte counts and proportion of polymorphonuclear neutrophil (PMN) cells, and found appendicitis to be more likely in patients with high granulocyte counts and PMN percentages greater than 75. Appendicitis was unlikely in cases where both WBC and CRP were less than 10. Andersson concluded that “contrary to common opinion, simple and easily performed laboratory tests of the inflammatory response appear to be at least as important as discriminators as the clinical descriptions of peritoneal irritation, especially in advanced appendicitis.”

Abdominal radiography has a limited role in the evaluation of the patient with acute RLQ pain. US and CT are often used to evaluate patients for acute appendicitis. CT is more accurate than US in the evaluation of appendicitis (particularly in obese patients), often provides an alternative diagnosis when negative for acute appendicitis, and should be considered in any clinically stable older patient (**Fig. 5**).[54,55] In a study by Balthazar and colleagues,[56] 100 patients had both CT and US evaluation for acute appendicitis. Fifty-four patients had acute appendicitis and 46 did not. Of the 54 patients with appendicitis, analysis of the data for CT versus US revealed sensitivity of 96% versus 76%, respectively, and specificity of 89% versus 91%. In the 46 patients without appendicitis, an alternative diagnosis was made by CT in 22 patients and by US in 15. CT scans showed abscesses and/or phlegmons in 28% of patients with appendicitis versus only 17% using US. Thus, CT was more accurate than US in the diagnosis of acute appendicitis, and offered an alternative diagnosis more often when the patient did not have acute appendicitis.

There are certain populations where CT in the evaluation for acute appendicitis may be contraindicated. Acute appendicitis is the most common cause of surgical abdominal pain in children, and they are most at risk for lifelong effects of ionizing radiation. Children are also less often obese, a common limitation of US for acute appendicitis. Given the risk of ionizing radiation, the advantage of a pediatric physique, and specificities as high as 88% to 99%, it may be best to perform US first in these patients (**Fig. 6**).[55,57] A positive study requires no further testing, and a negative or equivocal study could be followed by CT or observation with serial examinations. A similar argument can be made for pregnant patients in whom ionizing radiation may put the fetus at risk. In these patients, US or MRI may be the initial imaging test of choice. In a small study by Israel and colleagues,[58] when the appendix was visualized on MRI the

Fig. 5. CT scan showing the appendix (*arrows*) to be very enlarged and unfilled with contrast (compare with bowel). Fat stranding is demonstrated even in this thin patient, where the fat posterior to the appendix is of much higher radiodensity than that on the other side of the abdomen. (*Courtesy of* Nova L. Panebianco, MD, University of Pennsylvania, Philadelphia, PA.)

Fig. 6. Ultrasonogram of an inflamed appendix in short-axis plane (outlined by *narrow white arrows*). In real time it is found to be a blind-ending tubular structure that lacks peristalsis and is typically located at the point of maximal tenderness. When viewed in short axis it is often described as a “target” sign. (*Courtesy of* Nova L. Panebianco, MD, University of Pennsylvania, Philadelphia, PA.)

sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the diagnosis of appendicitis was 100% for all parameters. When the appendix was visualized by US, the sensitivity, specificity, PPV, and NPV for the diagnosis of appendicitis was 50%, 100%, 100%, and 66%, respectively.

In the female patient with right (or left) lower quadrant pain, ruptured ovarian cysts, ovarian torsion, tubo-ovarian abscess (TOA), and ectopic pregnancy should be considered. Any woman of child-bearing age with acute abdominal pain should have a urine pregnancy test as part of their initial ED evaluation. Urine pregnancy tests can detect human chorionic gonadotropin (hCG) hormone in concentrations as low as 25 mIU/mL. A double decidual sac can be visualized consistently using transabdominal sonography, with a B-hCG of 6500 mIU/mL and 1500 mIU/mL using transvaginal US. Identification of a yolk sac or fetal pole within the uterus effectively rules out ectopic pregnancy in patients who did not undergo assisted reproductive technologies. Although the B-hCG level should not determine whether US should be performed for the evaluation of ectopic pregnancy, it may assist in interpreting the US results.[59]

According to the Centers for Disease Control and Prevention (CDC), the incidence of *Chlamydia*, gonorrhea, and syphilis reported from 1996 to 2008 was 170 in 100,000.[60] Sexually transmitted diseases are associated with pelvic inflammatory disease (PID), TOA, ectopic pregnancy, and decreased fertility. A ruptured TOA has a mortality rate as high as 8.6%.[61] Patients are often tested for *Chlamydia*, gonorrhea, and syphilis while in the ED; however, the results of these tests may not be available for several days. Although the results do not assist the ED physician at the point of care, they are important in public health implications and may be useful in subsequent clinical encounters. There is no single laboratory test to reliably confirm or refute the diagnosis of TOA. An elevated WBC is a nonspecific finding. In a 2007 review article, Blenning and colleagues[62] report that elevated erythrocyte sedimentation rate (ESR) and CRP along with an elevated WBC count may be helpful in diagnosing PID, particularly in mild cases.

The diagnoses of ruptured ovarian cyst, ovarian torsion, TOA, and ectopic pregnancy can be made with US (**Fig. 7**). Pelvic US has a sensitivity of 93% and a specificity of 98% in the diagnosis of TOA.[63] In a study by Lee and colleagues[64] examining ovarian torsion, the twisted vascular pedicle was detected preoperatively by US in 28 of 32 patients with surgically proven torsion, showing a diagnostic accuracy of 87%. In a study by Pascual and colleagues,[65] the sensitivity and specificity of color Doppler transvaginal sonography to detect functional ovarian cysts were 84.6% and 99.2%, respectively, with positive and NPVs of 98% and 93.5%.

Summary

1. CT is more accurate than US in the diagnosis of acute appendicitis; however, in certain populations where the risk of ionizing radiation is great, US or MRI may be the better initial imaging strategy. A positive ultrasonogram rules in the diagnosis, but a negative study does not rule it out.
2. A urine pregnancy test is almost invariably needed in the evaluation of acute abdominal pain in any female patient of child-bearing age.
3. Pelvic US, in most situations, should be the first imaging study in a young woman with acute pelvic pain.

Left Upper Quadrant

Emergent causes of abdominal pain in the left upper quadrant (LUQ) are rare. Diagnoses to consider include disorders of the stomach including gastritis and its related conditions, disorders of the spleen including splenomegaly, splenic infarct or abscess, and pancreatitis, and disorders of the kidney including renal colic and pyelonephritis. Other conditions to consider in the patient with LUQ abdominal pain include herpes

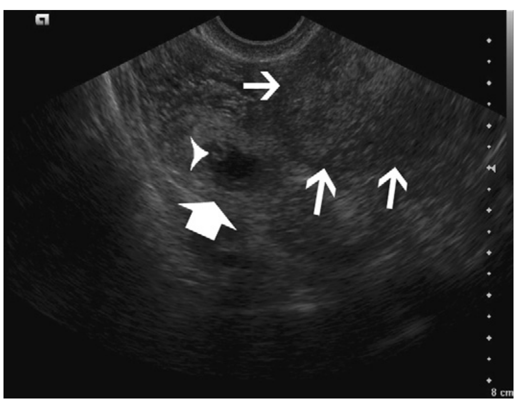

Fig. 7. Ultrasound image shows an empty uterus (outlined by *narrow white arrows*) with a right adnexal ectopic mass (*thick white arrow*). A yolk sac is visualized within the cystic ectopic mass (*arrowhead*). (*Courtesy of* Nova L. Panebianco, MD, University of Pennsylvania, Philadelphia, PA.)

zoster and conditions of the chest such as pneumonia, pleurisy, myocardial infarction, and pericarditis.

Similar to laboratory testing, there is no specific radiologic test for the LUQ. A chest radiograph may reveal pneumonia. If the patient's history and physical examination suggest esophageal or gastric origin, then symptomatic therapy and endoscopy is recommended. If renal colic is suspected then US or CT, as described earlier, may corroborate the diagnosis. CT scan can reveal pancreatitis, splenic infarct or abscess, gastric malignancy, pyelonephritis, and inflammation of the bowel. In the setting of blunt trauma, US may detect free fluid in the abdomen as a surrogate marker for acute splenic trauma (**Fig. 8**). The decision to image, and what imaging modality to use, must be made on a case-by-case basis.

Summary

1. There is limited literature on the usefulness of laboratory and radiologic imaging in the evaluation of acute LUQ abdominal pain, and clinical features should guide testing.
2. US and CT imaging may be used to narrow or make the diagnosis when there is high clinical suspicion for an acute abdominal process, particularly in the elderly, immunosuppressed, or trauma patient.

Left Lower Quadrant

Important diagnoses in patients with acute left lower quadrant (LLQ) pain include diverticulitis and colitis (including Crohn disease, ulcerative colitis, and *Clostridium difficile* colitis) as well as the complications of these conditions. As for patients with RLQ pain, LLQ pain can be secondary to renal colic, ovarian pathology, ectopic pregnancy, and hernia. Laboratory testing and imaging for these conditions is described in the section on RLQ.

Acute diverticulitis is a common cause of LLQ pain. The prevalence of diverticular disease is age dependent, increasing from less than 5% at age 40, to 30% by age 60, to 65% by age 85 years.[66] The patient may have leukocytosis, but in one study 45% of patients had a normal WBC count.[67] LFTs are usually normal. Amylase may be normal or elevated. Urinalysis may reveal sterile pyuria secondary to inflammation adjacent to the bladder. CT with oral and IV contrast is very sensitive for the detection of acute diverticulitis (79%–98%) and can help distinguish this from other causes of

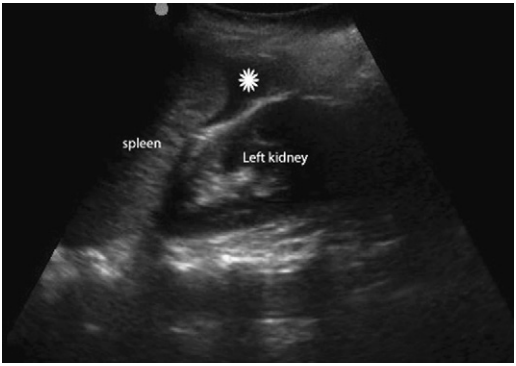

Fig. 8. Longitudinal ultrasound view of the left upper quadrant. Free fluid (*white star*) outlines the lower pole of the spleen and tracts into the splenorenal space. (*Courtesy of* Nova L. Panebianco, MD, University of Pennsylvania, Philadelphia, PA.)

acute LLQ pain (**Fig. 9**).[19] In a study by Rao and colleagues,[68] the sensitivity and specificity of helical CT (with colonic contrast only) was determined to be 97% and 100%, respectively. CT is also useful for identifying complications of acute diverticulitis such as perforation and abscess formation, and allows for an assessment of the severity of the disease. US for the detection of acute diverticulitis has also been studied. In a prospective study of 123 patients with clinical signs of acute intestinal inflammation, the sensitivity of US in comparison with abdominal CT in diagnosing acute colonic diverticulitis was 84.6%, and the specificity 80.3%.[69] US may be less sensitive than CT in detecting abscesses and microperforation.

Summary

1. Acute diverticulitis is a common cause of LLQ pain.
2. CT with oral or rectal, and IV contrast, is very sensitive for this disease.

Suprapubic

Disorders of the bladder and surrounding structures often cause suprapubic abdominal pain. Little and colleagues[70] evaluated the accuracy of urinalysis dipsticks versus a clinical decision rule for diagnosis of urinary tract infection (UTI), and found favorable diagnostic accuracy with dipsticks. In 427 women with suspected UTI, nitrite, leukocyte esterase (+ or greater), and blood (trace hemolyzed or greater) on dipstick analysis were all independently predictive of UTI with adjusted odds ratios of 6.36, 4.52, and 2.23, respectively. The investigators found a PPV of 92% for dipstick-positive nitrite and either blood or leukocyte esterase. In a study by Jou and Powers,[71] urine microscopy prompted a management change in only 9 of 166 patients (5%) after the initial urine dip. Six changes resulted in therapy for UTI, 1 resulted in withholding of therapy for UTI, and 2 resulted in cancellation of plans for diagnostic imaging. It was concluded that primary use of dipstick urinalysis, with microscopy in selected cases, would likely result in considerable cost savings and time saving without compromising patient care. The dipstick-only approach may not be appropriate in elderly patients, children, or any patient in whom urosepsis is suspected, as these patients require adequate sampling for culture.

Acute urinary retention may be secondary to benign prostatic hypertrophy (BPH), a bladder mass, blood clot, medication, or bladder injury. US of the bladder to assess

Fig. 9. CT scan of the pelvis showing a loop of bowel with markedly thickened walls (demonstrated by location of intraluminal contrast, *black arrows*), multiple diverticuli (*white arrowheads*), and a large area of intensive stranding anteriorly (*white arrows*). (*Courtesy of* Anthony J. Dean, MD, University of Pennsylvania, Philadelphia, PA.)

for the etiology of acute urinary retention can assist the ED physician. Bladder stones will have a highly reflective surface and a brightly reflective posterior. Clotted blood in the bladder tends to settle down into the most dependent areas and layers out. An enlarged prostate can be seen on transabdominal sonography. US can also be used to confirm Foley placement in a patient who is anuric. If the US is negative for acute pathology then one may consider a CT with or without contrast.

Summary

1. Urine dip is as good as urinary microanalysis at revealing the presence or abscess of a UTI.
2. US can be used to assess bladder volumes. This is important in patients with acute urinary retention whether secondary to bladder pathology (BPH, blood clot), medication induced, or secondary to trauma.

SUMMARY

The evaluation of acute abdominal pain in the ED is challenging. Often laboratory testing and radiologic imaging are needed to supplement the history and physical examination to confirm or exclude a diagnosis. Unfortunately, all diagnostic tests have false-negative and false-positive rates. A negative test does not rule out disease, and in the setting of a high pretest probability of disease, it is prudent to consider reassessment and a short course of observation for serial abdominal examinations for disease progression or resolution. Careful selection of laboratory and imaging studies should be made to efficiently and safely manage patient care.

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