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REVIEW

Abdominal Pain in the Emergency Department: How to Select the Correct Imaging for Diagnosis

Carmen Wolfe[1], Maglin Halsey-Nichols[2], Kathryn Ritter[3], Nicole McCoin[4]

[1]Department of Emergency Medicine, TriStar Skyline Medical Center, Nashville, TN, USA; [2]Department of Emergency Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA; [3]Department of Emergency Medicine, Oregon Health & Science University, Portland, OR, USA; [4]Department of Emergency Medicine, Ochsner Medical Center, New Orleans, LA, USA

Correspondence: Carmen Wolfe, Department of Emergency Medicine, TriStar Skyline Medical Center, 3443 Dickerson Pike, Suite 550, Nashville, TN, USA, Tel +1 615 426 4692, Fax +1 615 860 5229, Email Carmen.wolfe@hcahealthcare.com

Abstract: Abdominal pain is a common presenting complaint in the emergency department, and utilization of diagnostic imaging is often a key tool in determining its etiology. Plain radiography has limited utility in this population. Computed tomography (CT) is the imaging modality of choice for undifferentiated abdominal pain. Ultrasound and magnetic resonance imaging may be helpful in specific scenarios, primarily in pediatrics and pregnancy, and offer the benefit of eliminating ionizing radiation risk of CT. Guidance for imaging selection is determined by location of pain, special patient considerations, and specific suspected etiologies. Expert guidance is offered by the American College of Radiology Appropriateness Criteria® which outlines imaging options based on location of pain.

Keywords: computed tomography, ultrasound, radiograph, appendicitis

Introduction

Abdominal pain is one of the most common chief complaints for patients presenting to the emergency department (ED), accounting for nearly 7% of all ED visits in the United States and representing more than 3 million patient encounters.[1] Evaluation of abdominal pain requires consideration of a broad differential diagnosis, including pathology outside of the abdomen itself. In addition to gastrointestinal, gynecologic, urologic and vascular conditions, physicians should also consider cardiac, respiratory, and musculoskeletal conditions. A careful history, physical exam, and utilization of laboratory testing may identify a diagnosis, but in many cases imaging studies may be necessary.[2] Selecting the appropriate diagnostic imaging modalities in order to accurately rule in or out life-threatening pathology is paramount. The American College of Radiology Appropriateness Criteria® offers expert guidance on imaging selection based on location of pain.[3] This article will explore common imaging modalities utilized in the ED and offer specific considerations given special patient populations as well as suspected pathologies.

Common Imaging Modalities Utilized in the Emergency Department

Plain Radiograph

A radiograph is a static image generated by the passage of x-rays through a patient's body. While plain radiographs were commonly used in the past for evaluation of abdominal pain, the low diagnostic yield of this imaging modality has been recognized for many decades. In the 1970s, a study of 1000 consecutive patients presenting with abdominal pain reported that while 38% had an abdominal x-ray performed, in none of those cases was the clinical diagnosis changed by the x-ray findings.[4] Concerns regarding poor sensitivity and specificity limit the utility of plain radiographs. For example, in the diagnosis of small bowel obstruction, the sensitivity and specificity of plain radiographs are only 69% and 57%, respectively.[5] A large retrospective study found that information from radiographs is more likely to be incidental or inaccurate rather than helpful.[6]

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Utilization of plain radiographs should therefore be limited to very specific indications. In unstable patients with clinical criteria suggesting a perforated viscus, plain films may be able to confirm the diagnosis without necessitating transport of the patient to a radiology suite. Sensitivity of plain radiography in detecting pneumoperitoneum was found to be 89.2% in one prospective analysis utilizing exploratory laparotomy as a gold standard for diagnosis.[7] Plain films also demonstrate high sensitivity in the detection of inserted or ingested foreign bodies, provided that these objects are radiopaque. Objects that are not readily visualized with radiography include thin metal objects, glass, plastic, wood, and fish or chicken bones.[8]

Plain abdominal radiographs may have an expanded role in pediatrics, a population where reduction in radiation exposure is of interest. One prospective study suggested that only children with one of five high yield clinical criteria (prior abdominal surgery, foreign body ingestion, abnormal bowel sounds, abdominal distention, or peritoneal signs) should be considered for an abdominal radiograph. In this study, presence of one of these features led to radiographs that were 93% sensitive and 40% specific for detection of patients with major disease potentially requiring procedural intervention. Adherence to the suggested protocol would have reduced radiograph utilization by 38%.[9]

In the rare case that radiographs are felt to be clinically indicated, obtaining a supine abdominal view and erect chest radiograph may provide adequate information as compared to a traditional three film radiographic abdominal series that includes an erect abdominal view. In a small retrospective study of adult and pediatric patients presenting to a general ED, a combination of these two views diagnosed normality or abnormality in 98% of patients, with the third view rarely adding significant diagnostic information.[10]

Computed Tomography

Computed tomography (CT) is an imaging modality utilizing x-rays to create cross-sectional images of the body. Based on information from the National Hospital Ambulatory Medical Care Survey, surveys regarding utilization of CT among ED visits for abdominal pain reveal a drastic increase over the studied time period from 1997 to 2016. Proportions of CT utilization rose from 3.9% (95% CI 3.1–4.8) of visits for abdominal pain in 1997 to 37.8% (95% CI 35.5–41.0) of visits in 2016.[11]

The rise in utilization of CT underscores its utility in identifying a diagnosis and directing subsequent management of patients with abdominal pain. A prospective multi-center study revealed that CT changed the leading diagnosis in 51% of patients presenting to the ED with abdominal pain.[12] Obtaining a CT also led to a 25% increase in confidence of diagnosis, with the median post-CT confidence at 95%.[12] Another study showed an increase in mean level of certainty of diagnosis of 1.5 on a five-point scale after abdominal CT.[13] Management of patient care has also been shown to be dramatically impacted by CT, with studies reporting admission decisions changing in 25% of cases and alterations of the management plan present in 42% of cases.[12,14]

Diagnostic accuracy of CT may vary depending on the clinical entity being evaluated, scanner characteristics, and utilization of contrast agents. For the most commonly encountered pathologies in the emergency department, CT has been shown to perform well with adequate testing characteristics. For example, a large meta-analysis evaluating the utilization of CT for diagnosis of acute appendicitis reported a summary sensitivity of 0.95 (95% CI 0.92–0.95) and summary specificity of 0.94 (95% CI 0.92–0.95).[15] For evaluation of small bowel obstruction, a meta-analysis revealed a pooled sensitivity of 91% (95% CI 84–95) and pooled specificity of 89% (95% CI 81–94%).[16]

While CT has excellent diagnostic characteristics, utilization of computed tomography is not without risks. Major risks associated with CT include the risk of ionizing radiation as well as the risk of incidental findings and downstream testing.[11] Ionizing radiation removes orbital electrons from atoms or molecules, damaging DNA directly from an ejected electron or indirectly through the production of free radicals.[17] An increase in cancer incidence after exposure to radiation has been well documented in survivors of nuclear warfare as well as in retrospective reviews of children receiving CT scans in childhood.[18,19] Projections suggest that approximately 2% of all cancers diagnosed in the US may be related to previous CT exposure.[20] Incidental findings refer to abnormalities detected on a scan unrelated to the reason the test was ordered. This includes true-positive pathologic findings as well as false-positive findings that do not reflect true or clinically significant disease. Evaluation of these incidental findings leads to increased downstream testing, diagnostic procedures, and treatments, which may lead to increases in patient anxiety and iatrogenic harm.[21]

Utilization of Contrast Agents in Computed Tomography

Guidance regarding utilization of contrast agents in computed tomography can be gained from the American College of Radiology's Appropriateness Criteria®. For acute nonlocalized abdominal pain, these guidelines assign the highest appropriateness category to CT abdomen and pelvis with IV contrast, however they also note that it may be appropriate to perform with or without IV contrast, and with or without oral contrast.[3] Enteric and IV contrast may be more helpful in thin patients with a lower body mass index who lack sufficient mesenteric fat to demonstrate fat stranding associated with pathology.[22] Despite the availability of guidelines, a survey of physician leaders in academic EDs indicated that real-world application varies quite considerably.[23]

IV contrast agents contain iodine which serves to increase absorption and scattering of radiation during CT, thereby resulting in higher attenuation values, also called enhancement.[24] Utilization of IV contrast has been shown to increase sensitivity of CT for diagnosis of such entities as appendicitis and has the highest recommendation from the ACR Appropriateness Criteria.[15,25] While often helpful, IV contrast has its own downsides including possible anaphylactic or anaphylactoid reactions, contrast-induced nephropathy in susceptible patients, as well as cost.[22,26] Extravasation causing local skin and soft tissue injury is also a risk, though a large retrospective study found the rate to be only 0.34% and was more common when upper arm vessels were utilized.[27]

Enteric contrast may be administered orally or rectally. Utilization of rectal contrast is limited by patient discomfort and difficulty of administration.[22] The decision to utilize oral contrast may be influenced by the suspected etiology such as abnormalities of the gastrointestinal lumen or bowel wall such as fistulas, perforations, or abscesses. Local expert opinion through hospital protocols often guides this decision, as well as consideration for the patient's ability to safely tolerate contrast by mouth.[28] Downsides to utilization include that administration of oral contrast may delay scanning due to increased time for administration and bowel transit.[22] For evaluation of general acute nontraumatic abdominal pain, oral contrast appears to add little to radiological diagnostic performance.[29]

An ACEP clinical policy notes that while the addition of IV or oral contrast may increase the sensitivity of CT for diagnosis of appendicitis, the improvement in diagnostic accuracy is small. Given the increased sensitivity of modern multi-slice CT scanners, the need for contrast may eventually be shown to be unnecessary in many cases.[22]

Ultrasound

Ultrasound imaging utilizes a transducer to emit sound waves. These waves propagate through tissues with different acoustic characteristics, reflecting the sound and leading to the production of images that can be used for diagnostic purposes.[30] Benefits of ultrasound include the absence of any associated radiation risks, making it an ideal modality in the pediatric population. Pitfalls of ultrasound utilization involve inaccuracies that may be related to operator skill, patient factors such as obesity, or ultrasound machine variability.[31]

Optimal utilization of ultrasound depends on the suspected clinical diagnosis and location of pain. For nonlocalized abdominal pain, ultrasound is generally considered to be less sensitive and specific than computed tomography.[3] For right upper quadrant pain, ultrasound of the abdomen is the sole imaging modality assigned to the highest category of appropriateness.[32]

Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) utilizes magnetic fields to create three-dimensional images, without the use of ionizing radiation associated with CT.[33] Utilization of MRI in the ED has increased in recent years in both adult and pediatric populations, though still represents a small minority of advanced imaging studies ordered in the ED.[34–36] While MRI produces high-quality images, utilization in the ED is often limited due to high cost and availability. Access to MRI for evaluation of emergency department patients may be limited depending on hospital resources.[37] Additionally, there are very few instances in which MRI could yield diagnostic information that could not be obtained by CT for patients presenting with abdominal pain. Notable exceptions are in pediatric populations and pregnant women, both groups in which limiting ionizing radiation are of utmost importance.

Considerations for Special Populations

Pediatrics

Just as in adults, acute abdominal pain is one of the most common presenting pediatric chief complaints in the ED. As acute appendicitis represents the most common abdominal surgical emergency in this group, imaging choice is often driven by the need to rule out this diagnosis.[38] A large body of literature has been published to determine the best approach to the evaluation for potential appendicitis in children. The ACR Appropriateness Criteria discourage imaging of any type in low-risk presentations and identify ultrasound as the first choice in imaging modality for moderate risk presentations. In the event of a non-diagnostic ultrasound, recommendations are then equivocal for CT abdomen and pelvis with IV contrast, MRI abdomen and pelvis with IV contrast, and MRI abdomen and pelvis with and without IV contrast.[39] This stepwise approach utilizing ultrasound and subsequent CT or MRI has demonstrated high clinical accuracy in multiple studies.[40,41]

Utilization of MRI has been increasing rapidly primarily due to a desire to limit ionizing radiation exposure in this population, and may present an opportunity to utilize MRI as a primary imaging modality.[42] Studies of performance of MRI in pediatric appendicitis reveal high sensitivity, specificity, positive predictive value, and negative predictive value, with values similar to that of ultrasound.[43] MRI protocols have been implemented in many institutions, and studies of these protocols report high diagnostic accuracy, rapid image acquisition, and favorable clinical outcomes.[44] In fact, recent studies have suggested that MRI may potentially supplant ultrasound as a first-line imaging modality for evaluation of acute appendicitis in the pediatric population.[45] These studies additionally highlight the ability of MRI to provide an alternate diagnosis, which a systematic review found to be present in approximately 20% of cases.[42]

The general approach to pediatric abdominal pain is not covered by the ACR Appropriateness Criteria. Imaging choice is guided by suspected diagnosis with a differential diagnosis largely driven by age category in conjunction with presenting symptoms. Intussusception is the most common abdominal emergency in early childhood, most frequently seen in children from 3 months to age 5.[46] As opposed to traditional radiography which carries a low sensitivity (48%) and specificity (21%) for this diagnosis, abdominal ultrasound represents the gold standard for initial study of choice with a sensitivity of 97.9% (95% CI 95–100) and specificity of 97.9% (95% CI 97–99%).[47] In very early childhood from the first week of life until six months, pyloric stenosis should be considered in children with non-bilious emesis.[46] The ACR Appropriateness Criteria for evaluation of vomiting infants indicates that ultrasound of the abdomen is the imaging modality of choice for this consideration.[48] Finally, malrotation or midgut volvulus represents another surgical emergency in early childhood, presenting anytime from birth to age 5 when the incidence begins to decrease.[46] While ultrasound might be effective in demonstrating findings suggestive of this diagnosis, the primary imaging modality of choice is a fluoroscopic upper gastrointestinal (GI) series.[49]

Trends in imaging of pediatric patients appear to have shifted in recent years. A retrospective cohort study determined that the odds of a pediatric patient having a CT in an ED visit increased during each year of the study from 1999 to 2007.[50] Of note, the odds were lower if the patient presented to a pediatric emergency department.[50] A recent cross-sectional study reviewed trends from 2009 to 2018 and revealed that while the rate of utilization of advanced imaging increased from 6.4% to 8.7%, this increase was driven by an increase in ultrasound (2.5% to 5.8%) and MRI (0.3% to 0.6%). CT utilization decreased over the time period from 3.9% to 2.9%, revealing a decreased dependency on imaging that utilizes potentially dangerous ionizing radiation.[35]

Women of Childbearing Age

For women of childbearing age, it is important to consider potential risks to the fetus when ordering abdominal imaging. A pregnancy test should be obtained in order to guide imaging decisions and appropriately counsel patients. The risks of contrast exposure and radiation should be weighed against the risks of missing a potentially life-threatening diagnosis.

For non-pregnant women of childbearing age, the American College of Radiology recommends different first-line imaging modalities depending on the clinician's most likely diagnosis on the differential. Ultrasound, either transvaginal or transabdominal, is the initial imaging test-of-choice when an obstetric or gynecologic diagnosis is suspected.[51] Ultrasound is widely available in the ED, and the use of ultrasound will not expose the patient to harmful ionizing

radiation. Typically, transvaginal ultrasound is utilized, but a transabdominal approach may be performed if a larger field of view is required. In clinical cases with a high suspicion for a urologic or gastrointestinal cause, CT should be performed.[51] MRI may be considered in order to minimize exposure to ionizing radiation, however this modality is typically reserved for patients with clear contraindications to CT.[51]

For pregnant patients, the risks of fetal contrast exposure should be considered when ordering abdominal imaging. Both Iodinated CT contrast and gadolinium-based MRI contrast media cross the placenta; therefore, concerns exist regarding administration in pregnancy. Previously, it was hypothesized that exposure to iodinated CT contrast dye could lead to fetal hypothyroidism.[52] However, Atwell et al performed a retrospective study and found that there were no adverse effects on thyroid function after in-utero exposure to iodinated CT contrast dye.[53] Gadolinium-based contrast has not been shown to cause any adverse effects on the fetus even though it does cross the placenta.[51] Nevertheless, it can accumulate in fetal tissues, and evidence about its use is limited. Therefore, it should still be reserved for rare cases in which gadolinium-based contrast could significantly affect the final diagnosis.[51]

For pregnant patients, MRI is typically preferred over CT for the evaluation of suspected gastrointestinal etiologies of abdominal pain in order to avoid ionizing radiation. It can be used to successfully diagnose multiple pathologies including appendicitis, intraabdominal abscess, Crohn's disease, or ulcerative colitis.[54] In addition, transabdominal ultrasound has been used to diagnose appendicitis in pregnant patients in the first or second trimesters, but these examinations are typically limited in the third trimester due to displacement of the appendix by the gravid uterus.[55] In fact, multiple studies have cited that 88–92% of ultrasounds performed on pregnant patients are indeterminate since the appendix cannot be visualized.[56–58] Thus, MRI is preferred since it has a sensitivity of 80–100% and specificity of 94–100%.[59]

Suspected urologic causes of abdominal pain in pregnancy may be evaluated using ultrasound, MRI, or CT if necessary. Urolithiasis can be challenging to diagnose in pregnancy since hydronephrosis in pregnancy may be physiologic.[51] Physiologic hydronephrosis and hydronephrosis due to ureteral obstruction appear similar on ultrasound. MRI urography can be used to diagnose urolithiasis, but it is less sensitive for identifying small calculi causing early ureteral obstruction.[51] If it is necessary to perform a CT during pregnancy to evaluate for urolithiasis, then a low-dose CT without contrast should be ordered.[51]

Geriatrics

The geriatric population has a high rate of serious disease when presenting with abdominal pain. On a retrospective review, patients with age greater than 65 required surgery for the pathology causing their presenting abdominal pain in 42% of cases.[60] A prospective observational study revealed that in patients aged 60 or older presenting to the ED with abdominal pain, 58% were hospitalized, 18% required surgery or an invasive procedure, and case fatality rate was 5%.[61] Furthermore, atypical presentations of disease are frequently described in this age group.[62] Imaging is especially important in this high-risk population to identify high-risk diagnoses which may or may not have been suspected prior to imaging. In one retrospective study, 43% of diagnoses, defined as actionable findings, were clinically unsuspected prior to CT.[63] CT of the abdomen is performed in the geriatric population at a higher rate than other diagnostic tests, and the impact of CT on diagnosis and disposition far outweighs the effect of all other diagnostic testing combined.[62]

Immunocompromised Patients

Immunocompromised patients represent a high-risk group and includes patients with congenital immunodeficiencies, malignancy, viral-induced immunodeficiency, and patients who have had solid organ transplant or hematopoietic stem cell transplant.[64] In the setting of neutropenia, cancer patients presenting with abdominal pain have a high mortality, up to 52% at 90 days; therefore, swift determination of etiology of symptoms along with careful management is prudent.[65] Neutropenic enterocolitis and intestinal mucositis should be specifically considered in this high-risk group.[64] Because classic symptoms of abdominal sepsis may be absent in these patients, CT should be utilized liberally in their evaluation in the ED.[66] The ACR Appropriateness Criteria lists CT abdomen and pelvis with IV contrast as its highest recommendation in neutropenic patients.[3]

Utilization of CT provides a high yield in cancer patients. In a retrospective review from an ED whose oncology population is more than 90%, abdominopelvic CT was positive for significant pathology in 49.0% of scans. Furthermore, an additional 14.5% of scans had an incidental positive finding that was not an initial diagnostic consideration, highlighting the utility of CT in identifying occult pathology and expanding a differential diagnosis.[67]

Patients with a History of Previous Bariatric Surgery

A thorough surgical history is an important factor in the evaluation of abdominal pain. Patients with a history of previous bariatric surgery who present to the ED with abdominal pain require careful evaluation given the expanded differential diagnosis specific to this population. Additional high-risk considerations in this population include internal hernia, intussusception, obstruction, perforation, and pouch-related disease such as ulcers, gastrogastric fistula, and stenosis.[68] Initial imaging strategy for undifferentiated pain includes CT, often augmented by upper gastrointestinal series or esophagogastroduodenoscopy (EGD) when necessary. Given the life threatening nature of many of these complications, severe abdominal pain in patients with a history of bariatric surgery may necessitate surgical exploration unless diagnostic testing is able to provide a clear diagnosis.[69]

Internal hernia is potentially lethal and relatively common after bariatric surgery with incidence reported between 1% and 5%.[68,70–72] The recommended initial imaging strategy is CT as this examination is typically widely and rapidly available. However, sensitivity of CT for this finding has been reported as low as 28.6% in one study, therefore further imaging and even exploratory laparotomy may be indicated.[73]

Evaluation of Specific Pathology

Female Pelvic Pathology

When evaluating a female patient with abdominopelvic pain, it is crucial to consider obstetrical and gynecologic pathologies. The differential diagnosis may include ovarian torsion, ruptured ovarian cyst, pelvic inflammatory disease, tubo-ovarian abscess, fibroids, endometriosis, pelvic mass, ectopic pregnancy, spontaneous abortion, or other complications of pregnancy. The ACR recommends ultrasound as the initial imaging test-of-choice for these obstetrical and gynecologic diagnoses.[51] Nevertheless, these diagnoses may also be discovered on CT or MRI. One prospective study found no significant differences between the sensitivity and specificity of ultrasound, CT, and MRI to diagnose five key pelvic pathologies including ovarian cyst, ovarian torsion, tubo-ovarian abscess, oophoritis/salpingitis, and endometrial/uterine mass.[74]

Ovarian torsion is a crucial and time-sensitive ED diagnosis given that delay can lead to tissue necrosis and adverse effects on fertility. Ultrasonography with Doppler can be used to examine the vascular flow to the ovaries.[51] Absence of flow or abnormal flow in the ovarian vein is the most sensitive finding for diagnosing ovarian torsion with a sensitivity of 100%.[75] Other ultrasound findings of ovarian torsion include tissue edema, absence of intra-ovarian vascularity, and absence of arterial flow.[75] However, these findings all have a lower sensitivity compared to absence of flow or abnormal flow in the ovarian vein.[75] Therefore, clinicians should not be falsely reassured by presence of arterial flow on ultrasound if ovarian torsion is suspected. In some clinical scenarios, a CT might have initially been performed instead of an ultrasound for a patient with nonspecific abdominal pain, so it is important to also be able to recognize CT findings suggesting torsion. The most common imaging finding is asymmetric ovarian enlargement greater than 5 cm, but this finding is not specific.[76,77] Other CT findings include decreased adnexal enhancement after IV contrast administration, a twisted vascular pedicle, pelvic free fluid, inflammatory fat stranding adjacent to the ovary, and uterine deviation towards the affected side.[76]

Although many sources cite ultrasound as the preferred imaging modality to diagnose tubo-ovarian abscess, the sensitivity of ultrasound is actually lower than typically quoted in the emergency medicine literature.[78] While earlier retrospective studies demonstrated a 93% sensitivity in the diagnosis of tubo-ovarian abscess, a later prospective study found that transvaginal ultrasound only demonstrated a sensitivity of 56%.[79–81] MRI performs much better with a sensitivity of 100%. It is important to keep this limited sensitivity in mind if an ultrasound is performed first for a patient with a high clinical suspicion of a tubo-ovarian abscess. In this setting, it may be necessary to proceed with CT or MRI if the initial ultrasound is negative.

Biliary Pathology

Abdominal ultrasound is the primary modality of choice when biliary disease is suspected in the ED setting.[32] In the event of a negative or equivocal ultrasound, the workup may require additional imaging with CT, MRI or nuclear medicine scans to either continue to search for biliary pathology or to establish the diagnosis of other intra abdominal pathology that may be contributing to the patient's presenting complaints.[32]

Cholescintigraphy, also known as a hepatobiliary iminodiacetic acid (HIDA) scan, also has utility in the diagnosis of biliary pathology and carries a higher sensitivity than ultrasound in the evaluation of acute cholecystitis.[82] Despite this, limited availability of equipment or personnel, longer acquisition times, and limited ability to identify or exclude alternative diagnoses continue to limit the scope of cholescintigraphy in the emergency setting.[83] A retrospective review of the ED patients in whom cholescintigraphy was utilized after a negative ultrasound revealed very limited utility. Operative diagnosis more often agreed with ultrasound (80%, 95% CI 62–98%) rather than cholescintigraphy when discordance was present, and only 42% of patients with acute cholecystitis on cholescintigraphy who went to the OR had a concordant operative diagnosis.[83]

Nephrolithiasis

Nephrolithiasis can be diagnosed by multiple different imaging studies, providing an opportunity for the clinician to choose the most appropriate study for the clinical scenario. Noncontrasted CT scans have historically been the gold standard, but a CT scan with contrast can effectively rule out obstructive urolithiasis with the additional benefit of showing other findings of obstructive uropathy not seen on a noncontrasted study such as delayed nephrogram.[84] Additionally, the contrasted CT is more useful for identifying other abdominopelvic pathology. Ultrasound is also capable of identifying signs of ureteral obstruction including hydronephrosis and can sometimes visualize stones. This imaging study carries the added benefit of the absence of radiation exposure and may be effectively completed by the emergency medicine physician in a more timely manner. Still, a negative ultrasound does not completely rule out nephrolithiasis.[85] A multispecialty consensus has provided further recommendations on clinical scenarios where each imaging modality may be best. In a younger patient with a classic presentation for nephrolithiasis or a middle-aged patient with a known history of nephrolithiasis, ultrasound can be utilized first. Ultrasound is also useful as a first-line imaging modality in pregnant patients and patients with renal stents. CT imaging should be used for patients who are older, have atypical presentations, or have uncontrolled pain.[86] While a common emergency medicine teaching has been to obtain a CT for first time kidney stones, one study showed no associated increase in high-risk diagnoses, no increase in serious adverse events, and no increase in return ED visits or hospitalizations when ultrasound was used as the initial imaging modality.[87]

Aortic Pathology

While a ruptured abdominal aortic aneurysm (AAA) is not a common ED diagnosis, it carries very high mortality, anywhere from 50% to 90% in prior studies.[88] Time to diagnosis is also associated with improved outcomes, making it paramount to pursue the best imaging study early.[88,89] CTA is most effective at identifying rupture, but ultrasound is very sensitive and specific for identifying the aneurysm itself.[88] While it is not adequate for ruling out a rupture, in a patient with symptoms concerning for rupture, ultrasound may provide information needed to expedite diagnosis and treatment. Ultrasounds completed by Emergency Medicine physicians are very sensitive (97.5% to 100%) and specific (94.1%) for AAA, while historical features including abdominal pain, back pain and syncope and physical exam findings including hypotension and pulsatile mass have very poor sensitivity and specificity.[88,89] Symptoms of ruptured AAA have been noted to be misdiagnosed as renal colic, myocardial infarction, colonic inflammation, and gastrointestinal perforation.[90] Ultrasound is a quick and accessible way for the EM clinician to effectively evaluate for presence of an AAA and determine if ruptured AAA is a possible cause of a patient's symptoms.

Inflammatory Bowel Disease

Patients with symptoms indicating a new diagnosis of inflammatory bowel disease (IBD) or complications of IBD typically present with acute non-localized abdominal pain. Utilization of CT with an oral contrast is key for evaluation, as

a non-contrasted CT is not sensitive in detecting mucosal abnormalities in these patients. Without oral contrast, the bowel may collapse or peristalsis may be present, obscuring or mimicking key pathology.[91] CT enterography (CTE), a thin-cut CT utilizing neutral oral contrast and IV contrast, is the preferred modality.[92] Rather than utilizing a standard barium solution, a neutral contrast distends the small bowel to allow for enhanced evaluation and can better detect obstruction, fistulas, and abscesses.[91,93]

Conclusion

Patients presenting to the ED with abdominal pain need rapid and accurate diagnosis to prevent morbidity and mortality. When the diagnosis is unclear after a thorough history, physical exam, evaluation of laboratory tests, diagnostic imaging is prudent. The ACR Appropriateness Criteria® offer a robust guide for selecting an appropriate imaging modality and is an appropriate reference tool for use in the ED setting. Utilization of these guidelines must be done in conjunction with determination of the location of the patient's pain and must take into account unique characteristics such as age, gender, immune function, and previous surgical history. The evaluations for specific etiologies such as female pelvic pathology, biliary pathology, nephrolithiasis, aortic pathology, and IBD may also include unique imaging approaches tailored to the most likely diagnosis.

Disclosure

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References

1. Kocher KE, Meurer WJ, Fazel R, Scott PA, Krumholz HM, Nallamothu BK. National trends in use of computed tomography in the emergency department. *Ann Emerg Med*. 2011;58(5):452–62.e3. doi:10.1016/j.annemergmed.2011.05.020
2. Cartwright SL, Knudson MP. Evaluation of acute abdominal pain in adults. *Am Fam Physician*. 2008;77(7):971–978.
3. Scheirey CD, Fowler KJ, Therrien JA, et al. ACR appropriateness criteria® acute nonlocalized abdominal pain. *J Am Coll Radiol*. 2018;15(11S): S217–S231. doi:10.1016/j.jacr.2018.09.010
4. Brewer BJ, Golden GT, Hitch DC, Rudolf LE, Wangensteen SL. Abdominal pain. An analysis of 1000 consecutive cases in a University Hospital emergency room. *Am J Surg*. 1976;131(2):219–223. doi:10.1016/0002-9610(76)90101-X
5. Maglinte DD, Reyes BL, Harmon BH, et al. Reliability and role of plain film radiography and CT in the diagnosis of small-bowel obstruction. *AJR Am J Roentgenol*. 1996;167(6):1451–1455. doi:10.2214/ajr.167.6.8956576
6. Campbell JP, Gunn AA. Plain abdominal radiographs and acute abdominal pain. *Br J Surg*. 1988;75(6):554–556. doi:10.1002/bjs.1800750616
7. Bansal J, Jenaw RK, Rao J, Kankaria J, Agrawal NN. Effectiveness of plain radiography in diagnosing hollow viscus perforation: study of 1723 patients of perforation peritonitis. *Emerg Radiol*. 2012;19(2):115–119. doi:10.1007/s10140-011-1007-y
8. Ikenberry SO, Jue TL, Anderson MA, et al. Management of ingested foreign bodies and food impactions. *Gastrointest Endosc*. 2011;73 (6):1085–1091. doi:10.1016/j.gie.2010.11.010
9. Rothrock SG, Green SM, Hummel CB. Plain abdominal radiography in the detection of major disease in children: a prospective analysis. *Ann Emerg Med*. 1992;21(12):1423–1429. doi:10.1016/S0196-0644(05)80053-8
10. Mirvis SE, Young JW, Keramati B, McCrea ES, Tarr R. Plain film evaluation of patients with abdominal pain: are three radiographs necessary? *AJR Am J Roentgenol*. 1986;147(3):501–503. doi:10.2214/ajr.147.3.501
11. Wang RC, Kornblith AE, Grupp-Phelan J, Smith-Bindman R, Kao LS, Fahimi J. Trends in use of diagnostic imaging for abdominal pain in U.S. emergency departments. *AJR Am J Roentgenol*. 2021;216:200–208. doi:10.2214/AJR.19.22667
12. Pandharipande PV, Reisner AT, Binder WD, et al. CT in the emergency department: a real-time study of changes in physician decision making. *Radiology*. 2016;278(3):812–821. doi:10.1148/radiol.2015150473
13. Rosen MP, Sands DZ, Longmaid HE 3rd, Reynolds KF, Wagner M, Raptopoulos V. Impact of abdominal CT on the management of patients presenting to the emergency department with acute abdominal pain. *AJR Am J Roentgenol*. 2000;174(5):1391–1396. doi:10.2214/ajr.174.5.1741391
14. Abujudeh HH, Kaewlai R, McMahon PM, et al. Abdominopelvic CT increases diagnostic certainty and guides management decisions: a prospective investigation of 584 patients in a large academic medical center. *AJR Am J Roentgenol*. 2011;196(2):238–243. doi:10.2214/AJR.10.4467
15. Rud B, Vejborg TS, Rappeport ED, Reitsma JB, Wille-Jørgensen P. Computed tomography for diagnosis of acute appendicitis in adults. *Cochrane Database Syst Rev*. 2019;2019(11):CD009977.
16. Li Z, Zhang L, Liu X, Yuan F, Song B. Diagnostic utility of CT for small bowel obstruction: systematic review and meta-analysis. *PLoS One*. 2019;14(12):e0226740. doi:10.1371/journal.pone.0226740
17. Albert JM. Radiation risk from CT: implications for cancer screening. *AJR Am J Roentgenol*. 2013;201(1):W81–W87. doi:10.2214/AJR.12.9226
18. Preston DL, Ron E, Tokuoka S, et al. Solid cancer incidence in atomic bomb survivors: 1958–1998. *Radiat Res*. 2007;168(1):1–64. doi:10.1667/RR0763.1

19. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *JSLS*. 2017;21(4):e2017.00054.
20. Berrington de González A, Mahesh M, Kim KP, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. *Arch Intern Med*. 2009;169(22):2071–2077. doi:10.1001/archinternmed.2009.440
21. Smith-Bindman R. Use of advanced imaging tests and the not-so-incidental harms of incidental findings. *JAMA Intern Med*. 2018;178(2):227–228. doi:10.1001/jamainternmed.2017.7557
22. Howell JM, Eddy OL, Lukens TW, et al. Clinical policy: critical issues in the evaluation and management of emergency department patients with suspected appendicitis. *Ann Emerg Med*. 2010;55(1):71–116. doi:10.1016/j.annemergmed.2009.10.004
23. Broder JS, Hamedani AG, Liu SW, Emerman CL. Emergency department contrast practices for abdominal/pelvic computed tomography-A national survey and comparison with the American college of radiology appropriateness criteria(®). *J Emerg Med*. 2013;44(2):423–433. doi:10.1016/j.jemermed.2012.08.027
24. Purysko CP, Renapurkar R, Bolen MA. When does chest CT require contrast enhancement? *Cleve Clin J Med*. 2016;83(6):423–426. doi:10.3949/ccjm.83a.15037
25. Garcia EM, Camacho MA, Karolyi DR, et al. ACR appropriateness criteria® right lower quadrant pain-suspected appendicitis. *J Am Coll Radiol*. 2018;15(11S):S373–S387. doi:10.1016/j.jacr.2018.09.033
26. Pasternak JJ, Williamson EE. Clinical pharmacology, uses, and adverse reactions of iodinated contrast agents: a primer for the non-radiologist. *Mayo Clin Proc*. 2012;87(4):390–402. doi:10.1016/j.mayocp.2012.01.012
27. Stowell JR, Rigdon D, Colglazier R, et al. Risk of contrast extravasation with vascular access in computed tomography. *Emerg Radiol*. 2020;27(3):253–258. doi:10.1007/s10140-020-01752-x
28. Radetic M, DeVita R, Haaga J. When is contrast needed for abdominal and pelvic CT? *Cleve Clin J Med*. 2020;87(10):595–598.
29. Kessner R, Barnes S, Halpern P, Makrin V, Blachar A. CT for acute nontraumatic abdominal pain-is oral contrast really required? *Acad Radiol*. 2017;24(7):840–845. doi:10.1016/j.acra.2017.01.013
30. Coltrera MD. Ultrasound physics in a nutshell. *Otolaryngol Clin North Am*. 2010;43(6):1149–v. doi:10.1016/j.otc.2010.08.004
31. Abu-Zidan FM. Point-of-care ultrasound in critically ill patients: where do we stand? *J Emerg Trauma Shock*. 2012;5(1):70–71. doi:10.4103/0974-2700.93120
32. Peterson CM, McNamara MM, Kamel IR, et al. ACR appropriateness criteria® right upper quadrant pain. *J Am Coll Radiol*. 2019;16(5S):S235–S243. doi:10.1016/j.jacr.2019.02.013
33. Berger A. Magnetic resonance imaging. *BMJ*. 2002;324(7328):35. doi:10.1136/bmj.324.7328.35
34. Selvarajan SK, Levin DC, Parker L. The increasing use of emergency department imaging in the United States: is it appropriate? *AJR Am J Roentgenol*. 2019;213(4):W180–W184. doi:10.2214/AJR.19.21386
35. Marin JR, Rodean J, Hall M, et al. Trends in use of advanced imaging in pediatric emergency departments, 2009–2018. *JAMA Pediatr*. 2020;174(9):e202209. doi:10.1001/jamapediatrics.2020.2209
36. Scheinfeld MH, Moon JY, Fagan MJ, Davoudzadeh R, Wang D, Taragin BH. MRI usage in a pediatric emergency department: an analysis of usage and usage trends over 5 years. *Pediatr Radiol*. 2017;47(3):327–332. doi:10.1007/s00247-016-3764-y
37. Brian JM, Moore MM. Unenhanced MRI for abdominal pain in the pediatric emergency department: counterpoint-choice should consider access, patient, and cost. *AJR Am J Roentgenol*. 2021;216(4):876–877. doi:10.2214/AJR.20.24310
38. Glass CC, Rangel SJ. Overview and diagnosis of acute appendicitis in children. *Semin Pediatr Surg*. 2016;25(4):198–203. doi:10.1053/j.sempedsurg.2016.05.001
39. Koberlein GC, Trout AT, Rigsby CK, et al. ACR appropriateness criteria® suspected appendicitis-child. *J Am Coll Radiol*. 2019;16(5S):S252–S263. doi:10.1016/j.jacr.2019.02.022
40. Ramarajan N, Krishnamoorthi R, Barth R, et al. An interdisciplinary initiative to reduce radiation exposure: evaluation of appendicitis in a pediatric emergency department with clinical assessment supported by a staged ultrasound and computed tomography pathway. *Acad Emerg Med*. 2009;16(11):1258–1265. doi:10.1111/j.1553-2712.2009.00511.x
41. Krishnamoorthi R, Ramarajan N, Wang NE, et al. Effectiveness of a staged US and CT protocol for the diagnosis of pediatric appendicitis: reducing radiation exposure in the age of ALARA. *Radiology*. 2011;259(1):231–239. doi:10.1148/radiol.10100984
42. Moore MM, Kulaylat AN, Hollenbeak CS, Engbrecht BW, Dillman JR, Methratta ST. Magnetic resonance imaging in pediatric appendicitis: a systematic review. *Pediatr Radiol*. 2016;46(6):928–939. doi:10.1007/s00247-016-3557-3
43. Orth RC, Guillerman RP, Zhang W, Masand P, Bisset GS 3rd. Prospective comparison of MR imaging and US for the diagnosis of pediatric appendicitis [published correction appears in Radiology. *Radiology*. 2014;272(1):233–240. doi:10.1148/radiol.14132206
44. Kulaylat AN, Moore MM, Engbrecht BW, et al. An implemented MRI program to eliminate radiation from the evaluation of pediatric appendicitis. *J Pediatr Surg*. 2015;50(8):1359–1363. doi:10.1016/j.jpedsurg.2014.12.012
45. Mushtaq R, Desoky SM, Morello F, et al. First-line diagnostic evaluation with MRI of children suspected of having acute appendicitis. *Radiology*. 2019;291(1):170–177. doi:10.1148/radiol.2019181959
46. Naffaa L, Barakat A, Baassiri A, Atweh LA. Imaging acute non-traumatic abdominal pathologies in pediatric patients: a pictorial review. *J Radiol Case Rep*. 2019;13(7):29–43. doi:10.3941/jrcr.v13i7.3443
47. Carroll AG, Kavanagh RG, Ni Leidhin C, Cullinan NM, Lavelle LP, Malone DE. Comparative effectiveness of imaging modalities for the diagnosis and treatment of intussusception: a critically appraised topic. *Acad Radiol*. 2017;24(5):521–529. doi:10.1016/j.acra.2017.01.002
48. Alazraki AL, Rigsby CK, Iyer RS, et al. ACR appropriateness criteria® vomiting in infants. *J Am Coll Radiol*. 2020;17(11S):S505–S515. doi:10.1016/j.jacr.2020.09.002
49. Applegate KE, Anderson JM, Klatte EC. Intestinal malrotation in children: a problem-solving approach to the upper gastrointestinal series. *Radiographics*. 2006;26(5):1485–1500. doi:10.1148/rg.265055167
50. Hryhorczuk AL, Mannix RC, Taylor GA. Pediatric abdominal pain: use of imaging in the emergency department in the United States from 1999 to 2007. *Radiology*. 2012;263(3):778–785. doi:10.1148/radiol.12111726
51. Bhosale PR, Javitt MC, Atri M, et al. ACR appropriateness criteria® acute pelvic pain in the reproductive age group. *Ultrasound Q*. 2016;32(2):108–115. doi:10.1097/RUQ.0000000000000200

52. Tirada N, Dreizin D, Khati NJ, Akin EA, Zeman RK. Imaging Pregnant and Lactating Patients. *Radiographics*. 2015;35(6):1751–1765. doi:10.1148/rg.2015150031
53. Atwell TD, Lteif AN, Brown DL, McCann M, Townsend JE, Leroy AJ. Neonatal thyroid function after administration of IV iodinated contrast agent to 21 pregnant patients. *AJR Am J Roentgenol*. 2008;191(1):268–271. doi:10.2214/AJR.07.3336
54. Birchard KR, Brown MA, Hyslop WB, Firat Z, Semelka RC. MRI of acute abdominal and pelvic pain in pregnant patients. *AJR Am J Roentgenol*. 2005;184(2):452–458. doi:10.2214/ajr.184.2.01840452
55. Barloon TJ, Brown BP, Abu-Yousef MM, Warnock N, Berbaum KS. Sonography of acute appendicitis in pregnancy. *Abdom Imaging*. 1995;20(2):149–151. doi:10.1007/BF00201525
56. Israel GM, Malguria N, McCarthy S, Copel J, Weinreb J. MRI vs. ultrasound for suspected appendicitis during pregnancy. *J Magn Reson Imaging*. 2008;28(2):428–433. doi:10.1002/jmri.21456
57. Pedrosa I, Levine D, Eyvazzadeh AD, Siewert B, Ngo L, Rofsky NM. MR imaging evaluation of acute appendicitis in pregnancy. *Radiology*. 2006;238(3):891–899. doi:10.1148/radiol.2383050146
58. Cobben LP, Groot I, Haans L, Blickman JG, Puylaert J. MRI for clinically suspected appendicitis during pregnancy. *AJR Am J Roentgenol*. 2004;183(3):671–675. doi:10.2214/ajr.183.3.1830671
59. Long SS, Long C, Lai H, Macura KJ. Imaging strategies for right lower quadrant pain in pregnancy. *AJR Am J Roentgenol*. 2011;196(1):4–12. doi:10.2214/AJR.10.4323
60. Bugliosi TF, Meloy TD, Vukov LF. Acute abdominal pain in the elderly. *Ann Emerg Med*. 1990;19(12):1383–1386. doi:10.1016/S0196-0644(05)82602-2
61. Lewis LM, Banet GA, Blanda M, Hustey FM, Meldon SW, Gerson LW. Etiology and clinical course of abdominal pain in senior patients: a prospective, multicenter study. *J Gerontol a Biol Sci Med Sci*. 2005;60(8):1071–1076. doi:10.1093/gerona/60.8.1071
62. Lewis LM, Klippel AP, Bavolek RA, Ross LM, Scherer TM, Banet GA. Quantifying the usefulness of CT in evaluating seniors with abdominal pain. *Eur J Radiol*. 2007;61(2):290–296. doi:10.1016/j.ejrad.2006.09.014
63. Gardner CS, Jaffe TA, Nelson RC. Impact of CT in elderly patients presenting to the emergency department with acute abdominal pain. *Abdom Imaging*. 2015;40(7):2877–2882. doi:10.1007/s00261-015-0419-7
64. Wolfe C, McCoin N. Abdominal pain in the immunocompromised patient. *Emerg Med Clin North Am*. 2021;39(4):807–820. doi:10.1016/j.emc.2021.07.002
65. Badgwell BD, Cormier JN, Wray CJ, et al. Challenges in surgical management of abdominal pain in the neutropenic cancer patient. *Ann Surg*. 2008;248(1):104–109. doi:10.1097/SLA.0b013e3181724fe5
66. Spencer SP, Power N, Reznek RH. Multidetector computed tomography of the acute abdomen in the immunocompromised host: a pictorial review. *Curr Probl Diagn Radiol*. 2009;38(4):145–155. doi:10.1067/j.cpradiol.2007.11.001
67. Otoni JC, Noschang J, Okamoto TY, et al. Role of computed tomography at a cancer center emergency department. *Emerg Radiol*. 2017;24(2):113–117. doi:10.1007/s10140-016-1449-3
68. Greenstein AJ, O'Rourke RW. Abdominal pain after gastric bypass: suspects and solutions. *Am J Surg*. 2011;201(6):819–827. doi:10.1016/j.amjsurg.2010.05.007
69. Lanzetta MM, Masserelli A, Addeo G, et al. Internal hernias: a difficult diagnostic challenge. Review of CT signs and clinical findings. *Acta Biomed*. 2019;90(5–S):20–37. doi:10.23750/abm.v90i5-S.8344
70. Higa KD, Ho T, Boone KB. Internal hernias after laparoscopic Roux-en-Y gastric bypass: incidence, treatment and prevention. *Obes Surg*. 2003;13(3):350–354. doi:10.1381/096089203765887642
71. Garza E Jr, Kuhn J, Arnold D, Nicholson W, Reddy S, McCarty T. Internal hernias after laparoscopic Roux-en-Y gastric bypass. *Am J Surg*. 2004;188(6):796–800. doi:10.1016/j.amjsurg.2004.08.049
72. Paroz A, Calmes JM, Giusti V, Suter M. Internal hernia after laparoscopic Roux-en-Y gastric bypass for morbid obesity: a continuous challenge in bariatric surgery. *Obes Surg*. 2006;16(11):1482–1487. doi:10.1381/096089206778870102
73. Farukhi MA, Mattingly MS, Clapp B, Tyroch AH, Scan CT. Reliability in detecting internal hernia after gastric bypass. *JSLS*. 2017;21(4):e2017.00054. doi:10.4293/JSLS.2017.00054
74. Harringa JB, Bracken RL, Markhardt BK, et al. Magnetic resonance imaging versus computed tomography and ultrasound for the diagnosis of female pelvic pathology. *Emerg Radiol*. 2021;28(4):789–796. doi:10.1007/s10140-021-01923-4
75. Nizar K, Deutsch M, Filmer S, Weizman B, Beloosesky R, Weiner Z. Doppler studies of the ovarian venous blood flow in the diagnosis of adnexal torsion. *J Clin Ultrasound*. 2009;37(8):436–439. doi:10.1002/jcu.20621
76. Lourenco AP, Swenson D, Tubbs RJ, Lazarus E. Ovarian and tubal torsion: imaging findings on US, CT, and MRI. *Emerg Radiol*. 2014;21(2):179–187. doi:10.1007/s10140-013-1163-3
77. Duigenan S, Oliva E, Lee SI. Ovarian torsion: diagnostic features on CT and MRI with pathologic correlation. *AJR Am J Roentgenol*. 2012;198(2):W122–W131. doi:10.2214/AJR.10.7293
78. Lee DC, Swaminathan AK. Sensitivity of ultrasound for the diagnosis of tubo-ovarian abscess: a case report and literature review. *J Emerg Med*. 2011;40(2):170–175. doi:10.1016/j.jemermed.2010.02.033
79. Taylor KW, Graaff C, Wasson JM, Rosenfield AT, Andriole VT. Accuracy of grey-scale ultrasound diagnosis of abdominal and pelvic abscesses in 220 patients. *Lancet*. 1978;311(8055):83–84. doi:10.1016/S0140-6736(78)90016-8
80. Landers DV, Sweet RL. Tubo-ovarian abscess: contemporary approach to management. *Rev Infect Dis*. 1983;5(5):876–884. doi:10.1093/clinids/5.5.876
81. Tukeva TA, Aronen HJ, Karjalainen PT, Molander P, Paavonen T, Paavonen J. MR imaging in pelvic inflammatory disease: comparison with laparoscopy and US. *Radiology*. 1999;210(1):209–216. doi:10.1148/radiology.210.1.r99ja04209
82. Kalimi R, Gecelter GR, Caplin D, et al. Diagnosis of acute cholecystitis: sensitivity of sonography, cholescintigraphy, and combined sonography-cholescintigraphy. *J Am Coll Surg*. 2001;193(6):609–613. doi:10.1016/S1072-7515(01)01092-4
83. Blaivas M, Adhikari S. Diagnostic utility of cholescintigraphy in emergency department patients with suspected acute cholecystitis: comparison with bedside RUQ ultrasonography. *J Emerg Med*. 2007;33(1):47–52. doi:10.1016/j.jemermed.2007.02.044
84. Lei B, Harfouch N, Scheiner J, Demissie S, Hayim M. Can obstructive urolithiasis be safely excluded on contrast CT? A retrospective analysis of contrast-enhanced and noncontrast CT. *Am J Emerg Med*. 2021;47:70–73. doi:10.1016/j.ajem.2021.03.059

85. Wong C, Teitge B, Ross M, Young P, Robertson HL, Lang E. The accuracy and prognostic value of point-of-care ultrasound for nephrolithiasis in the emergency department: a systematic review and meta-analysis. *Acad Emerg Med*. 2018;25(6):684–698. doi:10.1111/acem.13388
86. Moore CL, Carpenter CR, Heilbrun ML, et al. Imaging in suspected renal colic: systematic review of the literature and multispecialty consensus. *J Urol*. 2019;202(3):475–483. doi:10.1097/JU.0000000000000342
87. Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med*. 2014;371(12):1100–1110. doi:10.1056/NEJMoa1404446
88. Fernando SM, Tran A, Cheng W, et al. Accuracy of presenting symptoms, physical examination, and imaging for diagnosis of ruptured abdominal aortic aneurysm: systematic review and meta-analysis. *Acad Emerg Med*. 2022;29(4):486–496. doi:10.1111/acem.14475
89. Rubano E, Mehta N, Caputo W, Paladino L, Sinert R. Systematic review: emergency department bedside ultrasonography for diagnosing suspected abdominal aortic aneurysm. *Acad Emerg Med*. 2013;20(2):128–138. doi:10.1111/acem.12080
90. Azhar B, Patel SR, Holt PJ, Hinchliffe RJ, Thompson MM, Karthikesalingam A. Misdiagnosis of ruptured abdominal aortic aneurysm: systematic review and meta-analysis. *J Endovasc Ther*. 2014;21(4):568–575. doi:10.1583/13-4626MR.1
91. Fletcher JG, Fidler JL, Bruining DH, Huprich JE. New concepts in intestinal imaging for inflammatory bowel diseases. *Gastroenterology*. 2011;140(6):1795–1806. doi:10.1053/j.gastro.2011.02.013
92. Huprich JE, Rosen MP, Fidler JL, et al. ACR appropriateness criteria on Crohn's disease. *J Am Coll Radiol*. 2010;7(2):94–102. doi:10.1016/j.jacr.2009.10.009
93. Morris MS, Chu DI. Imaging for inflammatory bowel disease. *Surg Clin North Am*. 2015;95(6):1143–v. doi:10.1016/j.suc.2015.07.007