American College of Radiology
ACR Appropriateness Criteria®
Right Lower Quadrant Pain

Variant: 1 Right lower quadrant pain. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
US abdomen	May Be Appropriate	O
US pelvis	May Be Appropriate	O
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	O
MRI abdomen and pelvis without IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
WBC scan abdomen and pelvis	Usually Not Appropriate	☢☢☢☢

Variant: 2 Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢
US abdomen	May Be Appropriate	O
US pelvis	May Be Appropriate	O
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	O
MRI abdomen and pelvis without IV contrast	May Be Appropriate	O
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢
WBC scan abdomen and pelvis	Usually Not Appropriate	☢☢☢☢

Variant: 3 Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US abdomen	Usually Appropriate	O
MRI abdomen and pelvis without IV contrast	Usually Appropriate	O
US pelvis	May Be Appropriate	O
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
Fluoroscopy contrast enema	Usually Not Appropriate	☢☢☢
MRI abdomen and pelvis without and with IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢

| WBC scan abdomen and pelvis | Usually Not Appropriate | ☢☢☢☢ |

Panel Members

Avinash R. Kambadakone, MD[a]; Cynthia S. Santillan, MD[b]; David H. Kim, MD[c]; Kathryn J. Fowler, MD[d]; James H. Birkholz, MD[e]; Marc A. Camacho, MD, MS[f]; Brooks D. Cash, MD[g]; Bari Dane, MD[h]; Robin A. Felker, MD[i]; Eric J. Grossman, MD[j]; Elena K. Korngold, MD[k]; Peter S. Liu, MD[l]; Daniele Marin, MD[m]; Marion McCrary, MD[n]; Jason A. Pietryga, MD[o]; Stefanie Weinstein, MD[p]; Katherine Zukotynski, MD, PhD[q]; Laura R. Carucci, MD.[r]

Summary of Literature Review

Introduction/Background

Right lower quadrant (RLQ) abdominal pain accounts for nearly 50% of patients presenting to the emergency department with abdominal pain [1]. Appendicitis is the most common surgical pathology responsible for RLQ abdominal pain in the United States [1,2]. Other less frequent causes of RLQ pain include right colonic diverticulitis, ureteral stone, colitis, and intestinal obstruction [1,3,4]. Imaging remains the diagnostic mainstay in the workup of patients presenting with RLQ abdominal pain for evaluation of suspected appendicitis and diagnosis of other conditions. Buckius et al [2] reported an annual increase in the rate of acute appendicitis in the United States; however, Ferris et al [5], in a recent systematic review of population-based studies, showed that although the incidence of both perforated and nonperforated appendicitis is stable in North America, the incidence is rising in newly industrialized countries. Historically, the clinical determination of appendicitis has been poor, particularly in special patient populations, such as those at the extremes of age and pregnant women. The negative appendectomy rate (NAR) based on clinical determination alone without imaging is unacceptably high, as high as 25% [6]. Clinical decisions tools, such as the Alvarado score (AS), have not improved the outright diagnostic accuracy of the clinical examination [7] and demonstrate mixed results as an adjunct to help guide CT use [8,9]. The decrease in NAR with increased imaging utilization is not accompanied by an increase in perforations from any introduced delays [10,11].

The choice of imaging modality should be tailored for diagnosis of acute appendicitis in patients with a high degree of suspicion but should also allow diagnosis of other causes of RLQ pain to triage appropriate patient management. In patients with suspected appendicitis, modalities should demonstrate high accuracy, which allows for 1) the confident (and presumed early) diagnosis in positive cases, reducing delays in diagnosis and perforation with attendant morbidity and mortality; 2) the confident exclusion of the diagnosis in negative cases with a decrease in the NAR and the attendant potential surgical complications; and 3) the confident diagnosis of alternative diagnoses, in many cases.

This document refers to imaging appropriateness in diagnosis of adult patients who are >18 years of age. References including pediatric patient populations are identified where included. Suspected appendicitis in pediatric patients is covered in the ACR Appropriateness Criteria® topic on "Suspected Appendicitis-Child" [12].

Special Imaging Considerations

To increase the sensitivity or specificity of imaging modalities in diagnosing the cause of RLQ abdominal pain, investigators have sought alternative techniques, made possible by advances in technology and the expansion of known advanced imaging techniques to new applications and disease conditions. Research articles are particularly focused on enhancing diagnosis of appendicitis, and investigators are using sonographic elastography, diffusion-weighted imaging (DWI) via MRI to increase diagnostic performance and decrease the dependence on CT, modified low-dose CT (LDCT) protocols, and dual-energy CT. Abbreviated MR protocols are also being investigated to expedite patient turnaround times and reduce imaging costs in emergency department patients with RLQ pain and suspected appendicitis [13].

With increasing rates of diagnostic imaging, primarily CT, in patients presenting to emergency departments, the phenomenon of multiple imaging episodes has become of concern. This has led to attempts to develop LDCT techniques [4,14,15] including limited coverage CT alternatives [16-18].

Dual-energy CT is a CT technology that enables superior tissue characterization because of material decomposition achieved by using 2 photon spectra, through either source-based or detector-based technology. Elbanna et al [19], in a retrospective study of 209 patients with appendicitis including 44 patients with gangrenous appendicitis, evaluated the role of dual-energy CT performed with oral and intravenous (IV) contrast. They found that use of 40 keV monoenergetic and iodine overlay images had a high sensitivity (100%) and specificity (80%-81%) for diagnosing gangrenous appendicitis compared with 120 kVp simulated imaging.

Abbreviated MR protocols comprising T2 half-Fourier acquisition single-shot turbo spin echo (HASTE) and DWI images have been shown to reduce imaging and interpretation times in diagnosis of appendicitis in emergency department patients with comparable accuracy to full protocol [13]. DWI sequences are well established in stroke and tumor imaging, but observers are finding ever-increasing applications in abdominal conditions, in part because of echo planar imaging, which increases the speed of acquisition and reduces motion artifacts [20,21]. In adult patients with appendicitis, adding DWI sequences has been shown to have specificities and positive predictive values (PPVs) of 100% each and sensitivities and negative predictive values (NPVs) between 97% to 99% for qualitative findings made by 2 experienced observers in high agreement [22]. Avcu et al [21] found similar results for DWI, with a specificity and PPV of 100%, a sensitivity of 98%, and an NPV of 94%. Inoue et al [23] reported that a combination of DWI sequence and T2-weighted images provided higher accuracy for diagnosing appendicitis and that inflamed appendix had lower apparent diffusion coefficient (ADC) value than the normal appendix. Avcu et al [21] also found a cutoff ADC value that showed a sensitivity of 78% and specificity of 92% on receiver operator characteristics curve analysis for discriminating perforated from nonperforated appendicitis. DWI may increase the conspicuity of the appendix, increasing the reader's confidence of visualization [20,22].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered

to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Right lower quadrant pain. Initial imaging.

In this clinical scenario, the patient presents with RLQ pain and may have associated signs and symptoms. Although appendicitis is in the differential in this patient, it is not the leading consideration from the clinical presentation in which other etiologies such as nonappendiceal gastrointestinal, genitourinary, hepato-pancreatic, and gynecologic conditions remain equally possible diagnostic considerations. Imaging methods for initial evaluation in patients in this clinical variant should be able to detect or exclude acute appendicitis and these other alternate diagnoses. If appendicitis is a primary concern, Variant 2 or 3 may be more applicable. If gynecologic conditions are a primary concern, please refer to ACR Appropriateness Criteria® topic on "Acute Pelvic Pain in the Reproductive Age Group" [24]. If acute flank pain related to urinary stone disease (urolithiasis) is a primary concern, please refer to ACR Appropriateness Criteria® topic on "Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis)" [25].

Variant 1: Right lower quadrant pain. Initial imaging.
A. CT Abdomen and Pelvis

CT of the abdomen and pelvis is an excellent diagnostic imaging modality for the evaluation of patients with nonspecific RLQ pain because of its high diagnostic yield for detection of appendicitis as well as suggesting alternative diagnosis [1,26,27]. CT frequently identifies the cause of RLQ pain, and these conditions, including appendicitis and other etiologies, often require hospitalization and invasive treatment. Regarding appendicitis, Rud et al [28] reported the results of a meta-analysis of 71 study populations, which included studies with noncontrast CT and contrast-enhanced CT with rectal or oral contrast. They reported a summary sensitivity of 95% (95% confidence interval [CI]: 0.93-0.96) and summary specificity of 94% (95% CI: 0.92-0.95) for CT in the diagnosis of appendicitis. In contrast, Pooler et al [27] reported that in patients undergoing contrast-enhanced CT with oral contrast for RLQ pain with diagnosis other than appendicitis at CT, the CT diagnosis was concordant with clinical diagnosis in 94.3% of cases (383/406). In patients (n = 90/496) without a final clinical diagnosis, the most common CT diagnosis included benign adnexal mass, gastroenteritis, colitis, constipation, inflammatory bowel disease, and pelvic congestion syndrome [27]. In patients receiving nonappendiceal CT diagnosis, 41% were hospitalized, with 22% undergoing surgical or image-guided intervention [27]. In contrast, in patients without CT diagnosis, only 14% were hospitalized and 4% underwent surgical or image-guided intervention. Barksdale et al [29] prospectively evaluated the impact of CT on emergency department physician diagnosis and disposition plans in 547 adult patients (≥18 years of age). In the subgroup analysis of those suspected to have appendicitis (67 patients), the diagnosis was altered in 43 patients, decreasing the number to 24 patients (4.4%) of the population. Morley et al [1] reported that in patients with RLQ pain, right colonic diverticulitis and obstruction were seen in 8% and 3% of patients, respectively. Patients with infectious enterocolitis such as typhlitis, inflammatory terminal

ileitis, and ureteral stone can also present with RLQ pain.

In a recent study using the National Hospital Ambulatory Medical Care Survey, Wang et al [30] reported that CT use significantly increased from 3.9% in 1997 (95% CI: 3.1%-4.8%) to 37.8% (95% CI: 35.5%-41%) in 2016 for adults presenting to the emergency department for abdominal pain and appendicitis. A large number of studies investigating the role of imaging in patients with RLQ pain are tailored to the diagnosis of suspected appendicitis. Studies specific to patients with RLQ pain not specific to suspected appendicitis or with atypical presentation are limited, despite the fact that this represents approximately 50% of this patient population [27,31]. Three single-institution studies were identified [29,32,33], each evaluating patients presenting with nonspecific atraumatic abdominal pain. In a study of 257 adult patients who underwent appendectomy, including 10 pregnant patients, the patients were divided into 4 groups based on the AS (AS <5: low clinical suspicion for acute appendicitis and AS ≥5: high clinical suspicion for acute appendicitis) and the presence or absence of preoperative CT [33]. Negative appendectomy rate was determined for each group. The total negative appendectomy rate was 5.8%, ranging from 2.6% to 18.7% in the 4 groups. The highest negative appendectomy rate was observed in the low probability non-CT group with AS <5. The odds ratio (OR) of negative appendectomy rate for patients without a CT scan was 5.2 (95% CI: 1.2-27.7) for low clinical probability and 1.6 (95% CI: 0.2-14.2) for high clinical probability, respectively.

There are no studies comparing the utility of noncontrast CT versus contrast-enhanced CT and CT with and without IV contrast in the diagnosis of patients with RLQ pain due to any cause. In patients with suspected appendicitis, noncontrast CT has high diagnostic accuracy in detecting acute appendicitis. In a meta-analysis of 7 studies with 1,060 patients, Hlibczuk et al [34] reported that noncontrast CT had pooled sensitivity and specificity of 92.7% and 96.1%, respectively, for diagnosis of acute appendicitis. In a single-center, unblinded, parallel randomized controlled trial of noncontrast CT and ultrasound (US) in patients with atypical right iliac fossa pain, Jones et al [32] found that noncontrast CT had a diagnostic accuracy of 73%, a PPV of 100%, and an NPV of 100% for acute appendicitis. In addition to acute appendicitis, CT findings included diverticulitis and ileocecitis.

Variant 1: Right lower quadrant pain. Initial imaging.
B. Fluoroscopy Contrast Enema

There is no relevant literature supporting the use of contrast enema in the evaluation of RLQ pain.

Variant 1: Right lower quadrant pain. Initial imaging.
C. MRI Abdomen and Pelvis

Relevant articles from the literature search included 1 retrospective study, 5 prospective studies, and 1 meta-analysis for the topic of MRI in the evaluation of acute abdominal or RLQ pain particularly for the diagnosis of appendicitis and alternate diagnoses in adult patients, not limited to pregnant patients. Studies reporting utility of MRI with IV contrast should be interpreted as MRI performed without and with IV contrast because noncontrast MRI sequences such as T2-weighted images, DWIs, and precontrast T1-weighted images are integral to all contrast-enhanced MRI examinations.

In patients with RLQ pain, MRI allows accurate diagnosis of appendicitis as well as suggesting alternative diagnosis [3]. In a prospective study of 52 patients, gadolinium-enhanced MRI provided an alternative diagnosis in 52% of patients, which included diverticulitis, ileitis, colitis, ischemia,

small bowel adhesions, pancreatitis, inguinal hernia, Crohn's disease, choledocholithiasis, and ileus [3]. A prospective multicenter diagnostic accuracy study performed to determine the accuracy and interobserver agreement between MR-expert and MR-nonexpert radiologists identified alternative urgent diagnoses including diverticulitis, urgent gynecological disorders, urgent urinary tract disorders, bowel obstruction, and pneumonia. The sensitivity for detecting all urgent diagnoses for nonexpert radiologists was 84% (95% CI: 78%-88%) compared with expert radiologists with 95% (95% CI: 90%-98%). The specificity for detecting all urgent diagnoses for nonexpert radiologists was 71% (95% CI: 62%-79%) compared with expert radiologists at 100% (95% CI: 76%-100%). Interobserver agreement expressed as Cohen's κ was 0.63 (95% CI: 0.55-0.70), consistent with good (but not excellent) agreement [35]. For this document, it is assumed that the procedure is performed and interpreted by an expert. A single-institution retrospective study of 403 patients (3 to 49 years of age) undergoing noncontrast MRI without oral or IV contrast identified both urgent and nonurgent alternative diagnoses in 336 patients. These conditions included gastrointestinal, gynecologic, urinary tract, musculoskeletal, inflammatory, neoplastic, and congenital conditions [36].

Regarding simple acute appendicitis, MRI for experienced readers had a sensitivity of 85% to 98% [3,37], a specificity of 93% to 99.4% (95% CI: 97.9%-99.9%) [35,36], a PPV of 94% (95% CI: 88%-97%), an NPV of 100% [21,35], and an accuracy of 93.75% to 96% [21,35]. Values for less-experienced readers had a sensitivity of 77% to 89% (95% CI: 77%-88%) [3,35], a specificity of 79% to 83% (95% CI: 77%-88%) [3,35], a PPV of 86% (95% CI: 81%-90%), and an NPV of 88% (95% CI: 82%-91%) [35]. For this document, it is assumed that the procedure is performed and interpreted by an expert.

MRI performance for diagnosis of perforated appendicitis was published in 2 studies [21,38] and was demonstrated to be less robust with sensitivities and specificities of 57% (95% CI: 39%-73%) and 86% (95% CI: 77%-91%) and 77.8% and 91.7%, respectively. Subgroup analyses of pediatric, pregnant, male, and female patients were performed in 2 studies without reaching statistical significance in either [36,39]. This finding was also not significantly different when compared with US with conditional CT diagnostic strategy [38]. Specific variations in technique were evaluated prospectively in 2 studies. Diagnostic performance to assess T2 HASTE imaging in 468 patients (7-59 years of age) yielded a sensitivity and specificity of 98% (95% CI) and 92% (95% CI), respectively [37]. Evaluation of DWI and ADC demonstrated mean ADC value for patients with appendicitis were significantly lower compared with controls. The sensitivity, specificity, NPV, and PPV for detecting appendicitis were reported as 97.5%, 100%, 93.75%, and 100%, respectively [21]. The protocol [39] also included DWI with procedure sensitivity and specificity of 97% and 93%, respectively. Combined diagnostic performance of 1.5T and 3.0T systems demonstrated a sensitivity and specificity of 97.0% (95% CI: 89.6%-99.6%) and 99.4% (95% CI: 97.9%-99.9%), respectively, and an absence of statistically significant differences between the 2 field strengths [36].

A meta-analysis performed from 30 studies from 1997 through 2015 contained a total of 2,665 patients that included pediatric, adult, and pregnant patients. The sensitivity and specificity for MRI detection of appendicitis were 96% (95% CI: 95%-97%) and 96% (95% CI: 95%-97%), respectively. This study did not find a statistically significant difference for the diagnostic accuracy of appendicitis between studies that were performed without IV contrast and those performed with IV contrast [40]. One study reported sensitivity and specificity for MRI detection of perforated

appendicitis as 57% and 86%, respectively. This finding was not significantly different when compared with US with conditional CT [38].

Variant 1: Right lower quadrant pain. Initial imaging.
D. Radiography Abdomen

With the shift to cross-sectional imaging modalities for evaluation of patients with RLQ pain, there is little current literature on radiographic signs. A prospective single-institution study [41] of the fecal loading sign, cecum distended with stool containing innumerable punctate lucencies, evaluated 470 adult and pediatric patients with acute abdominal pain. Patients were divided into 4 groups, with the appendicitis group subdivided into patients with preoperative only and both preoperative and postoperative abdominal radiographs. The fecal loading sign had a sensitivity, specificity, PPV, and NPV of 97.05%, 85.33%, 78.94%, and 98%, respectively. Fecal loading in the cecum was associated with all stages of appendicitis and disappeared after appendectomy. This sign was uncommon in other acute inflammatory diseases of the right side of the abdomen evaluated, which includes right nephrolithiasis (19%), right pelvic inflammatory disease (12%), and acute cholecystitis (13%).

Variant 1: Right lower quadrant pain. Initial imaging.
E. US Abdomen

US research articles did not consistently differentiate abdominal from pelvic US protocols. The methods sections were reviewed, and, where specified, articles were separated into abdomen or pelvis. Studies of the right iliac fossa were designated pelvis. Articles referring to graded compression US technique [42], those that specified abdomen, and unspecified studies are included in this section. Graded compression grayscale US is a modification to abdominal US, taking advantage of patient respiratory motion by deepening abdominal compression using the transducer and both of the operator's hands upon exhalation to displace intervening organs and simulate clinical deep abdominal palpation [42]. This technique has moderate performance characteristics for diagnosing appendicitis, exacerbated in North America by the decreased visualization rate of the appendix [43-47] in comparison with Europe and Asia because of due to perceived limitation related to patient body habitus.

Two studies, one retrospective and the second prospective, of US evaluation specifically of patients with atypical presentation of appendicitis, atypical lab results [48], or nonspecific abdominal pain [49] were identified in the current literature. The first study demonstrated US sensitivity, specificity, PPV, NPV, and accuracy of 71.4%, 78.5%, 94.8%, 33.3%, and 72.5%, respectively. Subgroup analysis of performance of emergency physicians with FAST experience plus training, 1 day didactic and 1 day practical course for abdominal US examination performance, and radiologists in US diagnosis yielded statistically significant differences: emergency physicians identified 33.3% (9 of 27) of patients with appendicitis, and radiologists identified 59.2% (16 of 27) ($P = .001$). For this document, it is assumed that the procedure is performed and interpreted by an expert.

Variant 1: Right lower quadrant pain. Initial imaging.
F. US Pelvis

US research articles did not consistently differentiate abdominal from pelvic US protocols. The methods sections were reviewed, and, where specified, articles were separated into abdomen or pelvis. Studies of the right iliac fossa were designated pelvis. Two multi-institution retrospective studies were identified, which included all patients who had undergone US before appendectomy [50,51]. D'Souza et al [51], in a review of 573 adult and pediatric patients (>6 years of age), yielded

mean sensitivity and specificity in patients with visualization of the appendix of 81.7% and 53.9% and total patient population mean values of 51.8% and 81.4%. NAR in all patients evaluated with US was 38.4%. The rate for patients with appendix visualization and positive results was 18.3%. The appendix was not visualized in 45% of the patients. A review of 620 patients with US performed [50] yielded a nonvisualization rate of 27.7%. Evaluation of indirect signs of appendicitis in the nonvisualization subgroup yielded a sensitivity of 31.8% to 83.9%, a specificity of 56.7% to 96.7%, a PPV of 25% to 95.8%, and an NPV of 57.2% to 83.3%, depending on presence and combination of the evaluated indirect signs, pain, hypertrophic periappendiceal fat, and diminished periappendiceal peristalsis. In patients where gynecological conditions are a primary concern, please refer to the ACR Appropriateness Criteria® topic on "Acute Pelvic Pain in the Reproductive Age Group" [24].

Variant 1: Right lower quadrant pain. Initial imaging.
G. WBC Scan Abdomen and Pelvis

There is no recent literature regarding the use of Tc-99m white blood cell (WBC) scan abdomen and pelvis in the evaluation of RLQ pain. However, in a blinded prospective study of 30 patients with suspected appendicitis, Foley et al [52] showed that the Tc-99m WBC scan achieved a sensitivity of 81%, a specificity of 100%, and an accuracy of 89%. Because delayed imaging, up to 4 hours post injection, may be required for diagnosis with this procedure, utility may be in the identification of alternate diagnoses of abdominal pain other than appendicitis, especially given the diagnostic performance and rapidity of CT.

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.

In this clinical scenario, the patient presents with RLQ pain in which the leading clinical diagnostic consideration is appendicitis. Alternative etiologies such as nonappendiceal gastrointestinal, genitourinary, hepato-pancreatic, and gynecologic conditions remain less likely diagnostic possibilities.

The "classic" clinical presentation of patients with appendicitis consisted of periumbilical abdominal pain migrating to the RLQ, loss of appetite, nausea, or vomiting, with fever, and leukocytosis is present in approximately 50% of patients. This explains the historical NAR of 14.7% and incidental appendectomy rate of 47%, in which incidental appendectomy refers to the practice of removing a normal appendix in the course of a nonrelated surgical procedure to prevent future development of appendicitis [31]. These statistics and growing recognition of the long-term morbidity associated with negative laparotomy have led to the incorporation of preoperative imaging of patients with suspected appendicitis into clinical management algorithms. The diagnostic performance of imaging modalities varies from each other and in different patient populations.

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
A. CT Abdomen and Pelvis

CT has become the most useful diagnostic imaging modality for the evaluation of patients with suspected appendicitis because of its high diagnostic yield. The use of CT for adult emergency department visits for diagnosis of appendicitis increased from 7.2% (95% CI: 2.7%-17.6%) to 83.3% (95% CI: 64.1%-93.3%) between 1997 to 2016 [30]. In the current literature, the NAR range with preoperative CT is 1.7% to 7.7% [8,53]. In a meta-analysis, Krajewski et al [10] reported that using

preoperative CT resulted in a NAR of 8.7% versus a rate of 16.7% with clinical evaluation alone. The sensitivities range from 85.7% to 100%, and the specificities range from 94.8% to 100% [54,55]. Sensitivity was lowest in nonenhanced CT without enteral contrast [55]. However, a meta-analysis of 7 prospective studies of nonenhanced CT that included patient populations of 49 to 296 resulted in a sensitivity of 0.90 (95% CI: 0.86-0.92) and a specificity of 0.94 (95% CI: 0.92-0.97) [56]. Concerns raised regarding delay in diagnosis and treatment that are due to oral contrast regimens with potential impact on patients of increased risk of perforation and associated morbidity have fueled evaluation of contrast-enhanced CT with versus without enteral contrast. Contrast-enhanced CT without enteral contrast sensitivities range from 90% to 100%, and specificities range from 94.8% to 100% [54,57], compared with contrast-enhanced CT with enteral contrast (oral or rectal), for which sensitivities range from 90.4% to 100% and specificities range from 97.67% to 100% [55,57]. In addition, a single-institution retrospective study of contrast-enhanced CT without enteral contrast in 1,922 patients (16-99 years of age) with a body mass index >25 and nontraumatic abdominal pain yielded 799 (40.1%) positive CT scans for acute abdominal pathology, explaining the patient's symptomatology. Subgroup analysis of 113 patients with appendicitis yielded a sensitivity of 100% and a specificity of 99.5% with only 4 patients (0.2%), none of whom were in the appendicitis subgroup, returning for repeat CT because of a lack of oral contrast [58].

In a recent meta-analysis of 71 study populations, Rud et al [28] reported a summary sensitivity of 0.95 (95% CI: 0.93-0.96) and a summary specificity of 0.94 (95% CI 0.92-0.95) for CT in the diagnosis of appendicitis. For standard dose unenhanced CT, the summary sensitivity and specificity from 19 studies were 0.91 (95% CI: 0.87-0.93) and 0.94 (95% CI: 0.90-0.96), respectively [28]. The summary sensitivity for contrast-enhanced CT (18 study populations in 17 studies) was higher (0.96, 95% CI: 0.92-0.98) compared with unenhanced CT (0.90, 95% CI: 0.87-0.93), whereas the summary specificity was comparable (0.93, 95% CI: 0.90-0.95 versus 0.94, 95% CI: 0.90-0.96) [28]. In 9 studies reporting CT with rectal contrast enhancement, the summary sensitivity was 0.97 (95% CI: 0.93-0.99), and the summary specificity was 0.95 (95% CI: 0.90-0.98), higher than unenhanced CT [28]. There was no significant difference between CT with oral contrast enhancement versus unenhanced CT [28]. The summary sensitivity for CT with IV and oral contrast enhancement (15 studies) was higher than unenhanced CT (0.96, 95% C:I 0.93-0.98) [28]. Low-dose CT regardless of contrast enhancement had similar summary sensitivity (0.94, 95% CI: 0.90-0.97) and specificity (0.94, 95% CI: 0.91-0.96) [28]. There are no studies comparing the utility of CT without and with IV contrast in the diagnosis of patients with suspected appendicitis.

CT signs of appendicitis have variable accuracy. In 1 retrospective study [59] of CT signs of appendicitis in 224 patients with negative or equivocal contrast-enhanced CT without enteral contrast, maximal outer diameter >6 mm, fat stranding, and absence of intraluminal gas were present in patients with appendicitis versus without: 66.3% versus 37.0% (P < .001), 34.1% versus 8.9% (P = .001), and 67.6% versus 48.9% (P = .024), respectively. With 2 or more signs present, the OR of appendicitis being present was 6.8 (95% CI: 3.013-15.454; P < .001). In a second retrospective study of 100 patients with inconclusive nonenhanced CT followed by contrast-enhanced CT, signs of appendicitis with statistical significance and cutoff values with best sensitivity and specificity were calculated. These were maximal cross-sectional diameter of 8.5 mm, 90.2% and 91.5%; presence of periappendiceal infiltrates 1.5, 53.7% and 94.9%; and periappendiceal fluid (graded 0-3 for absent to severe) 2.5, 22% and 100% [60]. An additional retrospective study reviewed contrast-enhanced CT without enteral contrast scans of 216 patients,

80 with pathologically proven appendicitis and 136 clinically negative for appendicitis, to evaluate the diagnostic performance and identify optimal cutoff of CT signs [61]. The maximum outer diameter (MOD) had an area under the curve (AUC) of 0.967 with an optimal cutoff of 8.2 mm yielding a sensitivity, specificity, and accuracy of 88.8%, 93.4%, and 91.7%, respectively. Diameter with compression (MOD minus compressible contents) had an AUC of 0.973 with an optimal cutoff value of 6.6 mm and a sensitivity, specificity, and accuracy of 93.8%, 94.9%, and 94.4%, respectively. Frequently referenced cutoff value of 6 mm for MOD yielded a sensitivity of 97.5%, a specificity of 59.6%, and an accuracy of 73.6%.

Historical perforation rates for men and women are 19.2% and 17.8%, respectively [31]. An association with increased morbidity, mortality, and length of stay drives the desire to identify early signs of appendiceal necrosis and occult perforation, before the development of phlegmon, abscess, or gross free peritoneal gas. A retrospective study of 102 patients, 49 with perforation, demonstrated that only 19 (37%) were diagnosed prospectively, yielding CT sensitivity, specificity, and PPV of 38%, 96%, and 90%, respectively [62]. Statistically, significantly associated findings were extraluminal gas (OR, 28.9; P = .02); intraluminal fecalith (OR, 5.7; P = .03); and wall thickness >3 mm (OR, 3.2; P = .02). Two retrospective studies [63,64] identified patients with pathologically proven appendicitis and excluded those with gross CT evidence of perforation resulting in patient cohorts of 374 and 339, respectively. Occult appendiceal perforation/necrosis rates were 65/374 (17.4%) and 75/339 (22.1%), respectively. Intraluminal gas and appendicoliths were predictive of the presence of perforation with an OR of 2.64 (95% CI: 1.48-4.73) and 2.67 (95% CI: 1.55-4.61), respectively [63]. Sensitivity and specificity for these 2 signs were 36.9% and 81.9% (intraluminal air) and 55.4% and 68.3% (intraluminal appendicolith), respectively. Kim et al [64] also found appendicoliths predictive (OR 2.47; P = .015) and the additional signs of focal wall defect (OR 23.40; P < .001), circumferential periappendiceal inflammatory changes (OR, 5.63; P < .001), and transverse diameter of the appendix (OR, 1.22; P = .003). Transverse diameter of ≥11 mm had the greatest sensitivity, 62.7% (range 29.3%-62.7%), and focal wall defect had the greatest specificity, 98.8% (range 66.3%-98.8%).

CT as Second-Line Imaging Test after Initial US: In a recent meta-analysis of second-line imaging modalities in the diagnosis of acute appendicitis after initial US, the pooled sensitivities and specificities for second-line CT in 11 studies that included 1,027 patients were 89.9% (95% CI: 85.4%-93.2%) and 93.6% (95% CI: 91.2%-95.3%), respectively [65]. Two single-institution studies reviewed the performance of CT following nondiagnostic US. One was a retrospective review of 119 patients [66] with suspected appendicitis and nonvisualized appendix on otherwise normally graded compression US, pelvic US in women with transvaginal US of childbearing age, if not declined, and body mass index <30. Contrast-enhanced CT was performed within 48 hours in all patients. Patients were additionally divided into groups based on an AS of 3 or less (49 patients) and of 4 or more (70 patients). Diagnostic rate for appendicitis in the low AS group was 0 of 49 patients; the high AS group was 12 of 70 patients, with 11 true positive, 1 false-negative, and 2 false-positives (17.1%). Alternate diagnoses were absent in 42 of 49 patients (85.7%) of the low AS group and 41 of 70 patients (58.6%) of the high AS group with 2 of 70 patients (2.9%) requiring surgery [66]. The second retrospective review evaluated 318 (150 adult and 168 pediatric) patients with suspected appendicitis, graded compression US as initial imaging study, nonvisualization of the appendix, and absence of other pathology on US who underwent contrast-enhanced CT without enteral contrast within 48 hours of US examination. Alternate diagnoses on CT included appendicitis in 52 (16.4%; 95% CI: 12.5%-20.9%), 7 perforated (13.5%; 95% CI: 5.6%-25.8%); other

diagnoses in 16 (5.0%; 95% CI: 2.9%-8.0%) with 2 of these requiring surgical intervention (0.6%); and 250 patients without identifiable etiology for their clinical presentation (78.6%; 95% CI: 73.7%-83.0%) [67].

Alternate Diagnoses: Several studies included information on the performance of CT for the detection of alternative diagnoses in this patient population presenting with classic symptomatology. Proportions of patients with identification of alternate etiologies for their clinical presentation ranged from a low of 23.2% [18] to a high of 45.3% [29]. The 2 studies with the highest performance at 42.5% [54] and 45.3% [29] were both conducted at tertiary care centers suggesting impact based on differences in patient population compared with rural or nontertiary centers. There is a wide range of etiologies, with the most common involving the gastrointestinal system, gynecologic, genitourinary, and hepatopancreaticobiliary systems. A single-institution retrospective study [27] demonstrated rates of 46.0%, 21.6%, 16.9%, and 7.7% for these systems, respectively.

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
B. Fluoroscopy Contrast Enema

There is no relevant literature supporting the use of contrast enema in the evaluation of RLQ pain, fever, leukocytosis, or suspected appendicitis.

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
C. MRI Abdomen and Pelvis

Studies reporting utility of MRI with IV contrast should be interpreted as MRI performed without and with IV contrast because noncontrast MRI sequences such as T2-weighted images, DWIs, and precontrast T1-weighted images are integral to all contrast-enhanced MRI examinations.

There is variability in the techniques employed and evaluated by the research groups with regards to MRI. Technical quality may also suffer in the acute setting because of patient discomfort with attendant motion artifacts. A single-institution retrospective study of 403 patients 3 to 49 years of age using 1.5T and 3.0T systems calculated the sensitivity and specificity for MRI detection of appendicitis to be 97.0% (95% CI: 89.6%-99.6%) and 99.4% (95% CI: 97.9%-99.9%), respectively. Imaging was performed without IV contrast. The average scan time for this study was 14 minutes. No significant difference was detected on subgroup analysis of pediatric and pregnant patients [36]. A prospective diagnostic study of 468 patients, 7 to 59 years of age, assessed the performance of T2 HASTE imaging on a 1.5T system for diagnosing appendicitis. The sensitivity and specificity were reported as 98% (CI 95%) and 92% (CI 95%), respectively, when compared with direct visualization (n = 90). Axial and coronal T2 HASTE images were acquired with a reported table time of <2 minutes [37]. In a single-institution retrospective study of 51 patients undergoing noncontrast MRI on a 1.5T system for acute appendicitis compared T2-weighted images alone with T2-weighted images and DWI. The accuracy for diagnosing acute appendicitis improved from 78.4% to 82.4% to 86.3% using combined T2-weighted images and DWI [23]. Two studies evaluated the diagnostic capability of MRI and reader experience on performance. A single-institution prospective study of 52 patients, aged 18 to 88 years, calculated the sensitivity and specificity for detecting appendicitis. For experienced readers, these were 85% and 97%, respectively. The sensitivity and specificity for less-experienced MRI readers were 77% and 79%, respectively. MRI was performed on a 1.5T system, without and with IV contrast with

administration of Buscopan to diminish peristalsis [3]. The second study, a prospective multicenter diagnostic accuracy study, was performed to determine the accuracy and interobserver agreement between MR-expert and MR-nonexpert radiologists. The study included 223 patients who were ≥18 years of age. Imaging was performed on a 1.5T system without IV contrast. The sensitivity for detecting appendicitis for nonexpert radiologists was 89% (95% CI: 84%-93%), compared with expert radiologists at 97% (95% CI: 0.91%-0.99%). The specificity for nonexpert radiologists was 83% (95% CI: 77%-88%), compared with expert radiologists at 93% (95% CI: 87%-97%). The PPV for nonexpert radiologists was 86% (95% CI: 81%-90%), compared with expert radiologists at 94% (95% CI: 88%-97%). The NPV for nonexpert radiologists was 88% (95% CI: 82%-91%), compared with that for expert radiologists at 96% (95% CI: 90%-98%). Interobserver agreement expressed as Cohen's κ was 0.71 (95% CI: 0.73-0.84), consistent with good (but not excellent) agreement [39]. For this document, it is assumed that the procedure is performed and interpreted by an expert.

Two prospective multicenter studies were identified. The first, a prospective diagnostic performance study of 230 patients, was conducted to compare the performance of MRI with an US with conditional CT imaging strategy. The sensitivity and specificity for MRI were 97% and 93%, respectively. These values were similar to the US with conditional CT strategy. There were no statistically significant changes in sensitivity and specificity on the subgroup analysis of male and female patients. The MRI protocol included DWI without postcontrast imaging performed on 1.5T systems [39]. The second, a prospective diagnostic accuracy trial of 130 patients who were ≥18 years of age, was performed to determine the accuracy of MRI (1.5T system) compared with US with conditional CT in the differentiation of simple versus perforated appendicitis. The sensitivity and specificity of MRI for perforated appendicitis were 57% (95% CI: 39%-73%) and 86% (95% CI: 77%-91%), respectively. The PPV and NPV were 57% (95% CI: 39%-73%) and 86% (95% CI: 77%-91%). These values were not significantly different compared with US with conditional CT technique [38].

A meta-analysis of 30 studies from 1997 through 2015 included 2,665 pediatric, adult, and pregnant patients. The sensitivity and specificity for MRI detection of appendicitis were 96% (95% CI: 95%-97%) and 96% (95% CI: 95%-97%), respectively. This study did not find a statistically significant difference for the diagnostic accuracy of appendicitis between studies performed without versus those performed with IV contrast [40].

A recent meta-analysis of second-line imaging modalities in the diagnosis of acute appendicitis after initial US included 6 MRI studies and 427 patients. The pooled sensitivities and specificities for second-line MRI were 89.9% (95% CI: 84.8%-93.5%) and 93.6% (95% CI: 90.9%-95.5%), respectively [65].

There is no relevant literature comparing MRI with 1.5T versus 3.0T systems for the detection of acute appendicitis. No randomized control studies comparing MRI with CT, US, or US with conditional CT were included in the literature search strategy.

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
D. Radiography Abdomen
With the shift to cross-sectional imaging modalities for evaluation of patients with suspected appendicitis, there is little current literature on radiographic signs. A prospective single-institution study [41] of the fecal loading sign, cecum distended with stool containing innumerable punctate

lucencies, evaluated 470 adult and pediatric patients with acute abdominal pain. Patients were divided into 4 groups, with the appendicitis group subdivided into patients with preoperative only and both preoperative and postoperative abdominal radiographs. Fecal loading sign had a sensitivity, specificity, PPV, and NPV of 97.05%, 85.33%, 78.94%, and 98%, respectively. Fecal loading in the cecum was associated with all stages of appendicitis and disappeared after appendectomy. This sign was uncommon in other acute inflammatory diseases of the right side of the abdomen evaluated, which includes right nephrolithiasis (19%), right pelvic inflammatory disease (12%), and acute cholecystitis (13%).

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
E. US Abdomen

US research articles did not consistently differentiate abdominal from pelvic US protocols. The methods sections were reviewed, and, where specified, articles were separated into abdomen or pelvis. Studies of the right iliac fossa were designated pelvis. Articles referring to graded compression US technique [42,68], those that specified abdomen, and unspecified studies are included in this section. Graded compression is a modification to abdominal US taking advantage of patient respiratory motion, deepening abdominal compression using the transducer and both of the operator's hands upon exhalation to displace intervening organs and simulate clinical deep abdominal palpation [42].

Diagnostic performance of US in preoperative evaluation of patients presenting with typical signs and symptoms of appendicitis vary widely. Ranges for measures are as follows: NAR of 4.4% to 28.2%; sensitivity of 21.0% to 95.7%; specificity of 71.4% to 97.9%; PPV of 41.2% to 94%; and NPV of 49% to 89.6% [68-73]. When reported, appendix visualization ranged from 35% [73] to 52.9%, with difference by sex of 65% in men and 51.1% in women [71]. One study defined an equivocal group that consisted of incomplete or nonvisualization of the appendix, which comprised 81.4% of the total study population [72].

Subgroup analyses were performed in several studies. Comparison of US positive versus equivocal for appendicitis sensitivity and PPV (95% CI) were 48.4% (35.8-61.3) and 83.8% (68.0-93.8) for the positive group and 21.0% (9.0-38.9) and 41.2% (18.5-67.0) for the equivocal group, respectively [72]. Analysis of male versus female patients [69] resulted in sensitivity, specificity, and false-positive rates of 95.7%, 88.2%, and 6.2% in men and 84.6%, 71.4%, and 35.5% in women, respectively. This study also demonstrated significant differences in nonobese versus obese men and women, with false diagnosis (false-positive + false-negative) of 6.2% versus 34.4% ($P < .001$) in men and 38.5% versus 46.2% ($P < .001$) in women, respectively. Evaluation of various patient characteristics resulted in 3 with statistical significance. Subgroup of body mass index <22, pain index of >6, and AS >6 yielded 2.3-, 2.9-, and 3.8-fold greater likelihood appendix visualization at US, respectively [71].

A recent meta-analysis assessed the clinical value and accuracy of bedside US for diagnosis of acute appendicitis in the emergency department [74]. Shen et al [74] included 27 studies and 7,403 patients published between 1996 and 2018, which included 8 from the United States (30%), 7 from Europe (26%), 11 from Asia (41%), and 1 from Africa (3%). The mean sensitivity and specificity of bedside US for diagnosing acute appendicitis was 90% (95% CI: 82%-95%) and 95% (95% CI: 89%-98%), respectively. The diagnostic performance for US as a second-line imaging modality in the diagnosis of acute appendicitis was explored in a recent meta-analysis. The meta-analysis included

3 US studies and 169 patients. The pooled sensitivities and specificities for second-line US were 83.1% (95% CI: 70.3%-91.1%) and 93.6% (95% CI: 59.3%-98.6%), respectively [65].

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
F. US Pelvis

US research articles did not consistently differentiate abdominal from pelvic US protocols. The methods sections were reviewed, and, where specified, articles were separated into abdomen or pelvis. Studies of the right iliac fossa were designated pelvis. Three retrospective studies of pelvic US were identified, with 1 single-institution study combining transabdominal and transvaginal imaging in 292 women [75] and 2 multi-institutional studies [50,51] evaluating 573 and 620 male and female patients with iliac fossa US, respectively. The greatest sensitivity of 97.3%, specificity of 91.0%, PPV of 91.7%, and NPV of 97% were achieved when combining transabdominal US and transvaginal US performed by a single experienced operator in adult women (95% CI). Nonvisualization of the appendix ranged from 20.3% [50] to 45% [51]. There is wide variability, with ranges of sensitivity of 31.8% to 83.9%, specificity of 56.7% to 96.7%, PPV of 25% to 95.8%, and NPV of 57.2% to 83.3% related to presence and combination of clinical and US signs of appendicitis that include pain, hypertrophic fat, and diminished peristalsis [50]. NARs ranged from 8.3% [75] to 38.4% [51].

Variant 2: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
G. WBC Scan Abdomen and Pelvis

There is no recent literature regarding the use of Tc-99m WBC scan abdomen and pelvis in the evaluation of RLQ pain, fever, leukocytosis, and suspected appendicitis. However, in a blinded prospective study of 30 patients with suspected appendicitis, Foley et al [52] showed that the Tc-99m WBC scan achieved a sensitivity of 81%, a specificity of 100%, and an accuracy of 89%. Because delayed imaging, up to 4 hours post injection, may be required for diagnosis with this procedure, utility may be in identification of alternate diagnoses of abdominal pain other than appendicitis, especially given the diagnostic performance and rapidity of CT.

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.

In this clinical scenario, the patient is pregnant and presents with RLQ pain in which the leading clinical diagnostic consideration is appendicitis. Issues related to the safety to the fetus during diagnostic workup is a major consideration. Alternative etiologies such as nonappendiceal gastrointestinal, genitourinary, hepato-pancreatic, and gynecologic conditions remain less likely diagnostic possibilities.

Appendicitis is among the most frequently encountered nonobstetric surgical condition in pregnant women [76,77]. The EAST multicenter study [77], a post hoc analysis of 3,597 subjects, showed that pregnant women accounted for 1 in 20 women of childbearing age presenting with appendicitis and it most commonly manifested in early to mid-pregnancy. Pregnant women with appendicitis had similar clinical outcomes compared with nonpregnant women, although they were more likely to undergo nonsurgical management [77]. Pregnant women are more likely to present with complicated (perforated or gangrenous) appendicitis, and in those with perforation, there is higher risk of fetal loss underlining the need for early diagnosis and treatment [76,77]. Imaging plays an important role in the diagnosis and management of pregnant patients with RLQ

and suspected appendicitis. Vasileiou et al [77], leading the EAST multicenter study, reported that a combination of US abdomen and MRI was the most commonly used imaging modality (41%) followed by MRI alone (29%), US alone (22%), CT (5%), and no imaging (2%).

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
A. CT Abdomen and Pelvis

The literature specific to the use of CT in the evaluation of RLQ pain, fever, and leukocytosis in pregnant patients is limited. Several studies have included pregnant patients in their study populations. The first is Kontopodis et al [33], with a study of patients with atypical presentation that included 10 pregnant patients. These patients were proportionally distributed in the 4 subgroups, low or high AS with or without imaging, and demonstrated no significant difference from the nonpregnant patients. The second is Ramalingam et al [78], who evaluated a multimodality diagnostic strategy for pregnant patients, 9 of whom had CT after US (1 patient) or MRI (8 patients). No additional cases of appendicitis were detected by CT following US alone, MRI alone, or MRI following inconclusive US.

In a recent study, Poletti et al [79] evaluated unenhanced LDCT scan with oral contrast in assessment of pregnant women presenting with RLQ pain when MRI was not immediately available. In this single-institution study 37 pregnant patients 20 to 44 years of age with clinical suspicion of appendicitis were included. Among the 37 patients, 30% (n = 11) were in the first trimester, 38% (n = 14) were in the second trimester, and 32% (n = 12) were in the last trimester. LDCT was performed in 78% (n = 28) of patients with indeterminate or negative US with high/moderate clinical suspicious of appendicitis. LDCT was conclusive for diagnosis of appendicitis in 83% (n = 24/29) of patients and indeterminate in 17% (n = 5/29). In all patients (n = 9) undergoing surgery for appendicitis, LDCT suggested the diagnosis. In 2 patients, LDCT showed an alternate diagnosis (ureteral stone and terminal ileitis). In patients with indeterminate CT results, MRI was obtained in 3 patients and standard dose CT in 2 patients. In 2 of these patients, appendicitis was reported on imaging (MRI; n = 1, CT; n = 1) and confirmed at surgery [79].

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
B. Fluoroscopy Contrast Enema

There is no relevant literature supporting the use of contrast enema in the evaluation of RLQ pain, fever, and leukocytosis in pregnant women.

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
C. MRI Abdomen and Pelvis

Six retrospective studies that are specific to MRI diagnostic performance for appendicitis in pregnant women were identified. One study was multi-institutional in nature, and the remaining 5 were single-institution series.

The multi-institution study [80] reviewed 709 pregnant women 16 to 49 years of age with proven appendicitis and preoperative MRI. Gestational age ranged from 1 to 39 weeks, with a mean of 17 ± 8.5 weeks: 49.5% second trimester, 34.9% first trimester, and 15.6% third trimester. Sixty-six of 709 (9.3%) patients were diagnosed with appendicitis on MRI, with 61 of 66 proven pathologically. The 5 patients with false-positive results had pathologic diagnoses of torsed right ovary (n = 1),

appendicolith with mild lymphoid hyperplasia (n = 1), fibrous obliteration of the appendiceal lumen without changes of appendicitis (n = 1), and normal appendices (n = 2). Pooled sensitivity, specificity, accuracy, PPV, and NPV were 96.8%, 99.2%, 99.0%, 92.4%, and 99.7%, respectively. The pooled AUC was 0.98 (95% CI: 0.96-1.0, range 0.83-1 [P = .12-.99]). Other diagnoses were identified in 72 of the remaining 643 patients (10.1%). The appendix was not visualized in 207 of 709 (29.2%) patients.

The single-institution studies demonstrated similar performance of MRI in pregnant patients. Theilen et al [81] evaluated 171 pregnant patients with suspected appendicitis who had MRI (1.5T), showing that 53 of 171 (30.9%) patients had nonvisualization of the appendix. Of the 118 remaining patients, 18 had MRI evidence of appendicitis and appendectomy. Of these 18 patients, 12 (66.7%) were confirmed, yielding MRI sensitivity of 91.7%, specificity of 95.3%, PPV of 68.8%, and NPV of 99.0%. Of the remaining 6 women who underwent appendectomy, 3 women had no histopathologic abnormality, 1 woman had subserosal histiocytes, 1 woman had fibrous obliteration of the appendiceal lumen, and 1 woman had epithelial hyperplasia and mucocele. An alternate diagnosis on MRI was identified in 74 of 171 (43%) women. Ramalingam et al [78] evaluated a multimodality imaging algorithm for the diagnosis of appendicitis in 127 pregnant women. All patients were evaluated with US. US demonstrated 2 patients (1.9%) with evidence of appendicitis. Additionally, 103 of the 125 patients with nondiagnostic US underwent MRI. CT was reserved for patients with equivocal US and MRI, 9 patients (8.7%). The sensitivity, specificity, PPV, and NPV for US were 12.5%, 99.2%, 50%, and 94.4%, respectively; for MRI they were 100%, 93.6%, 57.1%, and 100%, respectively. Diagnostic performance of the multimodality strategy yielded a sensitivity, specificity, PPV, and NPV of 100%, 98.3%, 80%, and 100%, respectively. MRI identified 10 additional diagnoses as likely causes of pain.

A comparison study was performed of US in 117 and MRI in 114 of 140 pregnant patients with suspected appendicitis [82]. Appendix visualization rates were 7% (8 of 117) for US and 80% (91 of 114) for MRI. Identification of alternate pathology was 2.6% (3 of 117) for US and 12% (14 of 114) for MRI. Diagnostic performance of US yielded a sensitivity of 18%, a specificity of 99%, a PPV of 66%, and an NPV of 92%. Diagnostic performance of MRI yielded a sensitivity of 100%, a specificity of 98%, a PPV of 89%, and an NPV of 100%. Diagnosis of appendicitis (16 of 18 patients) by MRI was proven by pathology. The 2 false-positive cases were found to be a neuroendocrine tumor and fibrous obliteration of the appendix by endometriosis. A single-institution retrospective review of 267 pregnant patients compared NAR before and after introduction of MRI for preoperative evaluation [83]. MRI was performed on 217 patients, 185 following nondiagnostic US. Surgery was performed on 31 patients in the pre-MRI era. The appendix was visualized on MRI in 70 of 217 (32%) cases. NAR before MRI was 55% (17 of 31). Following introduction of MRI, it was 29% (15 of 51), a 47% decrease. MRI yielded a sensitivity of 89% (17 of 19), a specificity of 97% (187 of 193), a PPV of 74% (17 of 23), and an NPV of 99% (187 of 189).

A single-institution retrospective study of MRI on a 1.5T system in 125 pregnant patients with suspected appendicitis investigated the value of additional DWI [76]. The sensitivity, specificity, and accuracy of MRI with DWI (n = 53, 100%, 95%, and 96%) were similar to MRI without DWI (n = 72, 100%, 94.7%, and 95.8%, P = .146).

The ACR Committee on Drugs and Contrast Media recommends the following concerning the performance of contrast-enhanced MRI examinations in pregnant patients: each case should be

reviewed carefully by members of the clinical and radiology service groups, and a gadolinium-based contrast agent should be administered only when there is a potential significant benefit to the patient or fetus that outweighs the possible but unknown risk of fetal exposure to free gadolinium ions [84].

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
D. Radiography Abdomen

There is no relevant literature supporting the use of radiographs in the evaluation of RLQ pain, fever, and leukocytosis in pregnant women.

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
E. US Abdomen

Research articles investigating role of US in pregnant patients with appendicitis did not consistently differentiate abdominal from pelvic US protocols. The methods sections were reviewed, and, where specified, articles were separated into abdomen or pelvis. Studies of the right iliac fossa were designated pelvis. Articles referring to graded compression US technique [42], those that specified abdomen, and unspecified studies are included in this section.

Three current studies evaluating US for the diagnosis of appendicitis in pregnant patients identified by the search methodology are included. Hiersch et al [85] compared diagnostic performance of US in pregnant (n = 81) and nonpregnant women (n = 243). There was no statistically significant difference in predictive performance of US between the 2 groups with a PPV and NPV of 88.2% and 100% (P = .011) and 92.9% and 57.1% (P < .001) [85]. In a similar study, Segev et a [86] found no statistically significant difference in predictive performance of US between the pregnant (n = 67) and nonpregnant women (n = 133) presenting with suspected appendicitis, with an AUC of 0.76 and 0.73, respectively (P = .78). Segev et al [86] also performed a subgroup analysis of each trimester and showed that there was no significant difference in the diagnostic performance of US by trimester. First trimester (n = 23): AUC 0.73, second trimester (n = 32): AUC 0.67, and third trimester (n = 12): AUC 0.86 (P = .4).

Lehnert et al [87] compared US performance in 99 pregnant women in their second or third trimester. The prevalence of appendicitis was 7.1% (7 of 99). US detected only 28.7% (2 of 7) of appendicitis cases and none of the remaining cases because of nonvisualization of the appendix, 71.3% (5 of 7).

As noted above, US performance is confounded by appendix visualization. Rates of nonvisualization in the 2 studies, where it is reported, were 34.1% of pregnant and 40.4% of nonpregnant patients [85] and 97% of all patients not stratified by trimester [87]. There is improved performance when stratified by trimester, 25% for first trimester versus 63% for third trimester [85], and in the presence of fever in pregnant patients, AUC 0.92 versus 0.72 (P = .07) [86].

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
F. US Pelvis

There is no recent literature supporting the use of pelvic US in the evaluation of RLQ pain, fever, or

leukocytosis in pregnant women.

Variant 3: Pregnant woman. Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.
G. WBC Scan Abdomen and Pelvis

There is no recent literature regarding the use of Tc-99m WBC scan abdomen and pelvis in the evaluation of RLQ pain, fever, and leukocytosis in pregnant women. A historical study retrospectively reviewed performance of Tc-99m WBC scans of 13 pregnant patients with suspected appendicitis. The WBC scan demonstrated a sensitivity, specificity, PPV, and NPV of 50%, 73%, 25%, and 89%, respectively [73]. The false-positive rate was 27% and the false-negative rate was 50%. The study is limited by the small sample size but nonetheless demonstrates that Tc-99m WBC scan is not reliable in the pregnant patient with suspected appendicitis.

Summary of Recommendations

- **Variant 1**: CT abdomen and pelvis with IV contrast is usually appropriate for the initial imaging of right lower quadrant pain.
- **Variant 2**: CT abdomen and pelvis with IV contrast is usually appropriate for the initial imaging of right lower quadrant pain with fever, leukocytosis, and suspected appendicitis.
- **Variant 3**: US abdomen or MRI abdomen and pelvis without IV contrast is usually appropriate for the initial imaging of a pregnant woman with right lower quadrant pain with fever, leukocytosis, and suspected appendicitis. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Safety Considerations in Pregnant Patients

Imaging of the pregnant patient can be challenging, particularly with respect to minimizing radiation exposure and risk. For further information and guidance, see the following ACR documents:

- ACR-SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI) [88]
- ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [89]
- ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound [90]
- ACR Manual on Contrast Media [84]

- [ACR Manual on MR Safety](#) [91]

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document [92].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv

☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. Morley EJ, Bracey A, Reiter M, Thode HC Jr, Singer AJ. Association of Pain Location With Computed Tomography Abnormalities in Emergeny Department Patients With Abdominal Pain. Journal of Emergency Medicine. 59(4):485-490, 2020 Oct.

2. Buckius MT, McGrath B, Monk J, Grim R, Bell T, Ahuja V. Changing epidemiology of acute appendicitis in the United States: study period 1993-2008. J Surg Res. 175(2):185-90, 2012 Jun 15.

3. Heverhagen JT, Pfestroff K, Heverhagen AE, Klose KJ, Kessler K, Sitter H. Diagnostic accuracy of magnetic resonance imaging: a prospective evaluation of patients with suspected appendicitis (diamond). J Magn Reson Imaging. 35(3):617-23, 2012 Mar.

4. Kim K, Kim YH, Kim SY, et al. Low-dose abdominal CT for evaluating suspected appendicitis. N Engl J Med. 366(17):1596-605, 2012 Apr 26.

5. Ferris M, Quan S, Kaplan BS, et al. The Global Incidence of Appendicitis: A Systematic Review of Population-based Studies. Annals of surgery 2017;266:237-41.

6. Raja AS, Wright C, Sodickson AD, et al. Negative appendectomy rate in the era of CT: an 18-year perspective. Radiology. 256(2):460-5, 2010 Aug.

7. Man E, Simonka Z, Varga A, Rarosi F, Lazar G. Impact of the Alvarado score on the diagnosis of acute appendicitis: comparing clinical judgment, Alvarado score, and a new modified score in suspected appendicitis: a prospective, randomized clinical trial. Surg Endosc. 28(8):2398-405, 2014 Aug.

8. Tan WJ, Acharyya S, Goh YC, et al. Prospective comparison of the Alvarado score and CT scan in the evaluation of suspected appendicitis: a proposed algorithm to guide CT use. J Am Coll Surg. 220(2):218-24, 2015 Feb.

9. Apisarnthanarak P, Suvannarerg V, Pattaranutaporn P, Charoensak A, Raman SS, Apisarnthanarak A. Alvarado score: can it reduce unnecessary CT scans for evaluation of acute appendicitis?. Am J Emerg Med. 33(2):266-70, 2015 Feb.

10. Krajewski S, Brown J, Phang PT, Raval M, Brown CJ. Impact of computed tomography of the abdomen on clinical outcomes in patients with acute right lower quadrant pain: a meta-analysis. Can J Surg. 2011;54(1):43-53.

11. Hendriks IG, Langen RM, Janssen L, Verrijth-Wilms IM, Wouda S, Janzing HM. Does the Use of Diagnostic Imaging Reduce the Rate of Negative Appendectomy?. Acta Chir Belg. 115(6):393-6, 2015 Nov-Dec.

12. Koberlein GC, Trout AT, Rigsby CK, et al. ACR Appropriateness Criteria® Suspected

Appendicitis-Child. J Am Coll Radiol 2019;16:S252-S63.

13. Mian M, Khosa F, Ali IT, et al. Faster magnetic resonance imaging in emergency room patients with right lower quadrant pain and suspected acute appendicitis. Pol J Radiol 2018;83:e340-e47.

14. Yun SJ, Kim HC, Yang DM, et al. Diagnostic Usefulness of Low-Dose Nonenhanced Computed Tomography With Coronal Reformations in Patients With Suspected Acute Appendicitis: A Comparison With Standard-Dose Computed Tomography. J Comput Assist Tomogr. 40(3):485-92, 2016 May-Jun.

15. Kolb M, Storz C, Kim JH, et al. Effect of a novel denoising technique on image quality and diagnostic accuracy in low-dose CT in patients with suspected appendicitis. Eur J Radiol. 116:198-204, 2019 Jul.

16. Brassart N, Winant C, Tack D, Gevenois PA, De Maertelaer V, Keyzer C. Optimised z-axis coverage at multidetector-row CT in adults suspected of acute appendicitis. Br J Radiol. 86(1028):20130115, 2013 Aug.

17. Corwin MT, Chang M, Fananapazir G, Seibert A, Lamba R. Accuracy and radiation dose reduction of a limited abdominopelvic CT in the diagnosis of acute appendicitis. Abdom Imaging. 40(5):1177-82, 2015 Jun.

18. O'Malley ME, Alharbi F, Chawla TP, Moshonov H. CT following US for possible appendicitis: anatomic coverage. Eur Radiol. 26(2):532-8, 2016 Feb.

19. Elbanna KY, Mohammed MF, Chahal T, et al. Dual-Energy CT in Differentiating Nonperforated Gangrenous Appendicitis From Uncomplicated Appendicitis. AJR Am J Roentgenol. 211(4):776-782, 2018 10.

20. Leeuwenburgh MM, Wiarda BM, Bipat S, et al. Acute appendicitis on abdominal MR images: training readers to improve diagnostic accuracy. Radiology. 264(2):455-63, 2012 Aug.

21. Avcu S, Cetin FA, Arslan H, Kemik O, Dulger AC. The value of diffusion-weighted imaging and apparent diffusion coefficient quantification in the diagnosis of perforated and nonperforated appendicitis. Diagn Interv Radiol. 19(2):106-10, 2013 Mar-Apr.

22. Inci E, Kilickesmez O, Hocaoglu E, Aydin S, Bayramoglu S, Cimilli T. Utility of diffusion-weighted imaging in the diagnosis of acute appendicitis. Eur Radiol. 21(4):768-75, 2011 Apr.

23. Inoue A, Furukawa A, Nitta N, et al. Accuracy, criteria, and clinical significance of visual assessment on diffusion-weighted imaging and apparent diffusion coefficient quantification for diagnosing acute appendicitis. Abdom Radiol. 44(10):3235-3245, 2019 10.

24. American College of Radiology. ACR Appropriateness Criteria®: Acute Pelvic Pain in the Reproductive Age Group. Available at: https://acsearch.acr.org/docs/69503/Narrative/.

25. American College of Radiology. ACR Appropriateness Criteria®: Acute Onset Flank Pain-Suspicion of Stone Disease (Urolithiasis). Available at: https://acsearch.acr.org/docs/69362/Narrative/.

26. Keyzer C, Cullus P, Tack D, De Maertelaer V, Bohy P, Gevenois PA. MDCT for suspected acute appendicitis in adults: impact of oral and IV contrast media at standard-dose and simulated low-dose techniques. AJR Am J Roentgenol. 193(5):1272-81, 2009 Nov.

27. Pooler BD, Lawrence EM, Pickhardt PJ. Alternative diagnoses to suspected appendicitis at CT. Radiology. 265(3):733-42, 2012 Dec.

28. Rud B, Vejborg TS, Rappeport ED, Reitsma JB, Wille-Jorgensen P. Computed tomography for diagnosis of acute appendicitis in adults. Cochrane Database Syst Rev. 2019(11), 2019 11 19.

29. Barksdale AN, Hackman JL, Gaddis M, Gratton MC. Diagnosis and disposition are changed when board-certified emergency physicians use CT for non-traumatic abdominal pain. Am J Emerg Med. 33(11):1646-50, 2015 Nov.

30. 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. American Journal of Roentgenology. 216(1):200-208, 2021 01.

31. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. Am J Epidemiol. 1990; 132(5):910-925.

32. Jones R, Olatunbode D, Dean J, et al. A feasibility randomised controlled trial to evaluate the role of computed tomography in adults with atypical right iliac fossa pain. Ann R Coll Surg Engl. 101(8):546-551, 2019 Nov.

33. Kontopodis N, Kouraki A, Panagiotakis G, Chatziioannou M, Spiridakis K. Efficacy of preoperative computed tomography imaging to reduce negative appendectomies in patients undergoing surgery for left lower quadrant abdominal pain. G Chir. 35(9-10):223-8, 2014 Sep-Oct.

34. Hlibczuk V, Dattaro JA, Jin Z, Falzon L, Brown MD. Diagnostic accuracy of noncontrast computed tomography for appendicitis in adults: a systematic review. Ann Emerg Med. 2010; 55(1):51-59 e51.

35. Leeuwenburgh MM, Wiarda BM, Jensch S, et al. Accuracy and interobserver agreement between MR-non-expert radiologists and MR-experts in reading MRI for suspected appendicitis. Eur J Radiol. 83(1):103-10, 2014 Jan.

36. Petkovska I, Martin DR, Covington MF, et al. Accuracy of Unenhanced MR Imaging in the Detection of Acute Appendicitis: Single-Institution Clinical Performance Review. Radiology. 279(2):451-60, 2016 May.

37. Byott S, Harris I. Rapid acquisition axial and coronal T2 HASTE MR in the evaluation of acute abdominal pain. Eur J Radiol. 85(1):286-290, 2016 Jan.

38. Leeuwenburgh MM, Wiezer MJ, Wiarda BM, et al. Accuracy of MRI compared with ultrasound imaging and selective use of CT to discriminate simple from perforated appendicitis. Br J Surg. 101(1):e147-55, 2014 Jan.

39. Leeuwenburgh MM, Wiarda BM, Wiezer MJ, et al. Comparison of imaging strategies with conditional contrast-enhanced CT and unenhanced MR imaging in patients suspected of having appendicitis: a multicenter diagnostic performance study. Radiology. 268(1):135-43, 2013 Jul.

40. Duke E, Kalb B, Arif-Tiwari H, et al. A Systematic Review and Meta-Analysis of Diagnostic Performance of MRI for Evaluation of Acute Appendicitis. [Review]. AJR Am J Roentgenol. 206(3):508-17, 2016 Mar.

41. Petroianu A, Alberti LR. Accuracy of the new radiographic sign of fecal loading in the cecum for differential diagnosis of acute appendicitis in comparison with other inflammatory diseases of right abdomen: a prospective study. J. med. life. 5(1):85-91, 2012 Feb 22.

42. Puylaert JB.. Acute appendicitis: US evaluation using graded compression. Radiology.

158(2):355-60, 1986 Feb.

43. Rioux M.. Sonographic detection of the normal and abnormal appendix. AJR Am J Roentgenol. 158(4):773-8, 1992 Apr.

44. Jeffrey RB Jr, Laing FC, Townsend RR. Acute appendicitis: sonographic criteria based on 250 cases. Radiology. 167(2):327-9, 1988 May.

45. Jeffrey RB Jr, Laing FC, Lewis FR. Acute appendicitis: high-resolution real-time US findings. Radiology. 163(1):11-4, 1987 Apr.

46. Garcia Pena BM, Mandl KD, Kraus SJ, et al. Ultrasonography and limited computed tomography in the diagnosis and management of appendicitis in children. JAMA. 1999; 282(11):1041-1046.

47. Lee JH, Jeong YK, Park KB, Park JK, Jeong AK, Hwang JC. Operator-dependent techniques for graded compression sonography to detect the appendix and diagnose acute appendicitis. AJR Am J Roentgenol. 184(1):91-7, 2005 Jan.

48. Sezer TO, Gulece B, Zalluhoglu N, Gorgun M, Dogan S. Diagnostic value of ultrasonography in appendicitis. Adv. Clin. Exp. Med.. 21(5):633-6, 2012 Sep-Oct.

49. Hasani SA, Fathi M, Daadpey M, Zare MA, Tavakoli N, Abbasi S. Accuracy of bedside emergency physician performed ultrasound in diagnosing different causes of acute abdominal pain: a prospective study. Clinical Imaging. 39(3):476-9, 2015 May-Jun.

50. Kouame N, N'goan-Domoua AM, N'dri KJ, et al. The diagnostic value of indirect ultrasound signs during acute adult appendicitis. Diagn Interv Imaging. 93(3):e24-8, 2012 Mar.

51. D'Souza N, D'Souza C, Grant D, Royston E, Farouk M. The value of ultrasonography in the diagnosis of appendicitis. Int J Surg. 13:165-169, 2015 Jan.

52. Foley CR, Latimer RG, Rimkus DS. Detection of acute appendicitis by technetium 99 HMPAO scanning. Am Surg. 1992; 58(12):761-765.

53. Soyer P, Dohan A, Eveno C, et al. Pitfalls and mimickers at 64-section helical CT that cause negative appendectomy: an analysis from 1057 appendectomies. Clin Imaging. 37(5):895-901, 2013 Sep-Oct.

54. Chiu YH, Chen JD, Wang SH, et al. Whether intravenous contrast is necessary for CT diagnosis of acute appendicitis in adult ED patients?. Acad Radiol. 20(1):73-8, 2013 Jan.

55. Drake FT, Alfonso R, Bhargava P, et al. Enteral contrast in the computed tomography diagnosis of appendicitis: comparative effectiveness in a prospective surgical cohort. Ann Surg. 260(2):311-6, 2014 Aug.

56. Xiong B, Zhong B, Li Z, et al. Diagnostic Accuracy of Noncontrast CT in Detecting Acute Appendicitis: A Meta-analysis of Prospective Studies. [Review]. Am Surg. 81(6):626-9, 2015 Jun.

57. Wadhwani A, Guo L, Saude E, et al. Intravenous and Oral Contrast vs Intravenous Contrast Alone Computed Tomography for the Visualization of Appendix and Diagnosis of Appendicitis in Adult Emergency Department Patients. Can Assoc Radiol J. 67(3):234-41, 2016 Aug.

58. Uyeda JW, Yu H, Ramalingam V, Devalapalli AP, Soto JA, Anderson SW. Evaluation of Acute

Abdominal Pain in the Emergency Setting Using Computed Tomography Without Oral Contrast in Patients With Body Mass Index Greater Than 25. J Comput Assist Tomogr 2015;39:681-6.

59. Park G, Lee SC, Choi BJ, Kim SJ. Stratified computed tomography findings improve diagnostic accuracy for appendicitis. World J Gastroenterol. 20(38):13942-9, 2014 Oct 14.

60. Lai V, Chan WC, Lau HY, Yeung TW, Wong YC, Yuen MK. Diagnostic power of various computed tomography signs in diagnosing acute appendicitis. Clin Imaging. 36(1):29-34, 2012 Jan-Feb.

61. Kim MY, Kim Y, Ryu JA, Kim TY. How to evaluate appendices with borderline diameters on CT: proposal of a quick solution to overcome the limitations of the established CT criteria. Acad Radiol. 21(12):1573-8, 2014 Dec.

62. Verma R, Grechushkin V, Carter D, Barish M, Pryor A, Telem D. Use and accuracy of computed tomography scan in diagnosing perforated appendicitis. Am Surg. 81(4):404-7, 2015 Apr.

63. Azok JT, Kim DH, Munoz Del Rio A, et al. Intraluminal air within an obstructed appendix: a CT sign of perforated or necrotic appendicitis. Acad Radiol. 19(10):1175-80, 2012 Oct.

64. Kim MS, Park HW, Park JY, et al. Differentiation of early perforated from nonperforated appendicitis: MDCT findings, MDCT diagnostic performance, and clinical outcome. Abdom Imaging. 39(3):459-66, 2014 Jun.

65. Eng KA, Abadeh A, Ligocki C, et al. Acute Appendicitis: A Meta-Analysis of the Diagnostic Accuracy of US, CT, and MRI as Second-Line Imaging Tests after an Initial US. Radiology. 288(3):717-727, 2018 Sep.

66. Jones RP, Jeffrey RB, Shah BR, Desser TS, Rosenberg J, Olcott EW. Journal Club: the Alvarado score as a method for reducing the number of CT studies when appendiceal ultrasound fails to visualize the appendix in adults. AJR Am J Roentgenol. 204(3):519-26, 2015 Mar.

67. Shah BR, Stewart J, Jeffrey RB, Olcott EW. Value of short-interval computed tomography when sonography fails to visualize the appendix and shows otherwise normal findings.[Erratum appears in J Ultrasound Med. 2015 Jul;34(7):1300 Note: Jeffery, R Brooke [corrected to Jeffrey, R Brooke]; PMID: 26112634]. J Ultrasound Med. 33(9):1589-95, 2014 Sep.

68. Piyarom P, Kaewlai R. False-negative appendicitis at ultrasound: nature and association. Ultrasound Med Biol. 40(7):1483-9, 2014 Jul.

69. Al-Ajerami Y.. Sensitivity and specificity of ultrasound in the diagnosis of acute appendicitis. East Mediterr Health J. 18(1):66-9, 2012 Jan.

70. Boonstra PA, van Veen RN, Stockmann HB. Less negative appendectomies due to imaging in patients with suspected appendicitis. Surg Endosc. 29(8):2365-70, 2015 Aug.

71. Kaewlai R, Lertlumsakulsub W, Srichareon P. Body mass index, pain score and Alvarado score are useful predictors of appendix visualization at ultrasound in adults. Ultrasound Med Biol. 41(6):1605-11, 2015 Jun.

72. Lourenco P, Brown J, Leipsic J, Hague C. The current utility of ultrasound in the diagnosis of acute appendicitis. Clin Imaging. 40(5):944-8, 2016 Sep-Oct.

73. Stewart JK, Olcott EW, Jeffrey RB. Sonography for appendicitis: nonvisualization of the

appendix is an indication for active clinical observation rather than direct referral for computed tomography. J Clin Ultrasound. 40(8):455-61, 2012 Oct.

74. Shen G, Wang J, Fei F, Mao M, Mei Z. Bedside ultrasonography for acute appendicitis: An updated diagnostic meta-analysis. Int J Surg. 70:1-9, 2019 Oct.

75. Bondi M, Miller R, Zbar A, et al. Improving the diagnostic accuracy of ultrasonography in suspected acute appendicitis by the combined transabdominal and transvaginal approach. Am Surg. 78(1):98-103, 2012 Jan.

76. Wi SA, Kim DJ, Cho ES, Kim KA. Diagnostic performance of MRI for pregnant patients with clinically suspected appendicitis. Abdom Radiol. 43(12):3456-3461, 2018 12.

77. Vasileiou G, Eid AI, Qian S, et al. Appendicitis in Pregnancy: A Post-Hoc Analysis of an EAST Multicenter Study. Surg Infect (Larchmt). 21(3):205-211, 2020 Apr.

78. Ramalingam V, LeBedis C, Kelly JR, Uyeda J, Soto JA, Anderson SW. Evaluation of a sequential multi-modality imaging algorithm for the diagnosis of acute appendicitis in the pregnant female. EMERG. RADIOL.. 22(2):125-32, 2015 Apr.

79. Poletti PA, Botsikas D, Becker M, et al. Suspicion of appendicitis in pregnant women: emergency evaluation by sonography and low-dose CT with oral contrast. European Radiology. 29(1):345-352, 2019 Jan.

80. Burke LM, Bashir MR, Miller FH, et al. Magnetic resonance imaging of acute appendicitis in pregnancy: a 5-year multiinstitutional study. Am J Obstet Gynecol. 213(5):693.e1-6, 2015 Nov.

81. Theilen LH, Mellnick VM, Longman RE, et al. Utility of magnetic resonance imaging for suspected appendicitis in pregnant women. Am J Obstet Gynecol. 212(3):345.e1-6, 2015 Mar.

82. Konrad J, Grand D, Lourenco A. MRI: first-line imaging modality for pregnant patients with suspected appendicitis. Abdom Imaging. 40(8):3359-64, 2015 Oct.

83. Rapp EJ, Naim F, Kadivar K, Davarpanah A, Cornfeld D. Integrating MR imaging into the clinical workup of pregnant patients suspected of having appendicitis is associated with a lower negative laparotomy rate: single-institution study. Radiology. 267(1):137-44, 2013 Apr.

84. American College of Radiology. ACR Committee on Drugs and Contrast Media. Manual on Contrast Media. Available at: https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Contrast-Manual.

85. Hiersch L, Yogev Y, Ashwal E, From A, Ben-Haroush A, Peled Y. The impact of pregnancy on the accuracy and delay in diagnosis of acute appendicitis. J Matern Fetal Neonatal Med. 27(13):1357-60, 2014 Sep.

86. Segev L, Segev Y, Rayman S, Nissan A, Sadot E. The diagnostic performance of ultrasound for acute appendicitis in pregnant and young nonpregnant women: A case-control study. Int J Surg. 34:81-85, 2016 Oct.

87. Lehnert BE, Gross JA, Linnau KF, Moshiri M. Utility of ultrasound for evaluating the appendix during the second and third trimester of pregnancy. EMERG. RADIOL.. 19(4):293-9, 2012 Aug.

88. American College of Radiology. ACR–SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI). Available at:

https://gravitas.acr.org/PPTS/GetDocumentView?docId=89+&releaseId=2.

89. American College of Radiology. ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Patients with Ionizing Radiation. Available at: https://gravitas.acr.org/PPTS/GetDocumentView?docId=23+&releaseId=2.

90. American College of Radiology. ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound. Available at: https://gravitas.acr.org/PPTS/GetDocumentView?docId=28+&releaseId=2.

91. American College of Radiology. ACR Committee on MR Safety. 2024 ACR Manual on MR Safety. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Radiology-Safety/Manual-on-MR-Safety.pdf.

92. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

[a]Massachusetts General Hospital, Boston, Massachusetts. [b]University of California San Diego, San Diego, California. [c]Panel Chair, University of Wisconsin Hospital & Clinics, Madison, Wisconsin. [d]Panel Vice-Chair, University of California San Diego, San Diego, California. [e]Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania. [f]The University of South Florida Morsani College of Medicine, Tampa, Florida; Committee on Emergency Radiology-GSER. [g]University of Texas Health Science Center at Houston and McGovern Medical School, Houston, Texas; American Gastroenterological Association. [h]NYU Grossman School of Medicine, New York, New York. [i]Medstar Georgetown University Hospital, Washington, District of Columbia, Primary care physician. [j]Santa Barbara Cottage Hospital, Santa Barbara, California; American College of Surgeons. [k]Oregon Health and Science University, Portland, Oregon. [l]Cleveland Clinic, Cleveland, Ohio. [m]Duke University Medical Center, Durham, North Carolina. [n]Duke Signature Care, Durham, North Carolina; American College of Physicians. [o]University of Alabama at Birmingham, Birmingham, Alabama. [p]University of California San Francisco, San Francisco, California.

[q]McMaster University, Hamilton, Ontario, Canada; Commission on Nuclear Medicine and Molecular Imaging. [r]Specialty Chair, Virginia Commonwealth University Medical Center, Richmond, Virginia.