

**American College of Radiology
ACR Appropriateness Criteria®
Right Lower Quadrant Pain-Suspected Appendicitis**

Variant 1: 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	☼☼☼
CT abdomen and pelvis without IV contrast	May Be Appropriate	☼☼☼
US abdomen	May Be Appropriate	○
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
US pelvis	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☼☼☼☼
Radiography abdomen	Usually Not Appropriate	☼☼
Fluoroscopy contrast enema	Usually Not Appropriate	☼☼☼
WBC scan abdomen and pelvis	Usually Not Appropriate	☼☼☼☼

Variant 2: Right lower quadrant pain, fever, leukocytosis. Possible appendicitis. Atypical presentation. Initial imaging.

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

RIGHT LOWER QUADRANT PAIN-SUSPECTED APPENDICITIS

Expert Panel on Gastrointestinal Imaging: Evelyn M. Garcia, MD^a; Marc A. Camacho, MD, MS^b; Daniel R. Karolyi, MD, PhD^c; David H. Kim, MD^d; Brooks D. Cash, MD^e; Kevin J. Chang, MD^f; Barry W. Feig, MD^g; Kathryn J. Fowler, MD^h; Avinash R. Kambadakone, MDⁱ; Drew L. Lambert, MD^j; Angela D. Levy, MD^k; Daniele Marin, MD^l; Courtney Moreno, MD^m; Christine M. Peterson, MDⁿ; Christopher D. Scheirey, MD^o; Alan Siegel, MD, MS^p; Martin P. Smith, MD^q; Stefanie Weinstein, MD^r; Laura R. Carucci, MD.^s

Summary of Literature Review

Introduction/Background

Appendicitis is the most common surgical pathology responsible for right lower quadrant (RLQ) abdominal pain presenting to emergency departments in the United States, where the incidence continues to increase despite reports of decreases in Europe and Canada [1]. 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 is unacceptably high, as high as 25% [2]. Clinical decision tools, such as the Alvarado score (AS), have not improved the outright diagnostic accuracy of the clinical examination [3], and demonstrate mixed results as an adjunct to help guide CT use [4,5].

Imaging remains the diagnostic mainstay in the workup of suspected appendicitis and RLQ abdominal pain. Modalities 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. The decrease in NAR is not accompanied by an increase in perforations from any introduced delays [6,7].

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 will be covered in the upcoming ACR Appropriateness Criteria[®] topic on “Suspected Appendicitis-Child” and will be made available on the [ACR website](#) when completed.

Special Imaging Considerations

Traditional graded compression grayscale ultrasound (US) has moderate performance characteristics for diagnosing appendicitis, exacerbated in North America by the decreased visualization rate of the appendix [8-12] in comparison to Europe and Asia. This modification to abdominal US takes advantage of patient respiratory motion, deepening abdominal compression using the transducer and both of the operator’s hands upon exhalation, in order to displace intervening organs and simulate clinical deep abdominal palpation [13].

In order to increase the sensitivity or specificity of imaging modalities in diagnosing appendicitis, 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. In appendicitis, investigators are using sonographic elastography, diffusion-weighted imaging (DWI) via MRI to increase diagnostic performance and decrease the dependence on CT, and modified CT protocols. All of these procedures are currently being investigated.

DWI sequences are well established in stroke and tumor imaging but are finding ever-increasing applications in abdominal conditions, in part due to echo planar imaging, which increases the speed of acquisition and reduces

^aVirginia Tech Carilion School of Medicine, Roanoke, Virginia. ^bThe University of South Florida Morsani College of Medicine, Tampa, Florida. ^cResearch Author, Carilion Clinic, Roanoke, Virginia. ^dPanel Chair, University of Wisconsin Hospital & Clinics, Madison, Wisconsin. ^eUniversity of Texas Health Science Center at Houston, McGovern Medical School, Houston, Texas; American Gastroenterological Association. ^fNewton-Wellesley Hospital, Newton, Massachusetts. ^gThe University of Texas MD Anderson Cancer Center, Houston, Texas; American College of Surgeons. ^hMallinckrodt Institute of Radiology, Saint Louis, Missouri. ⁱMassachusetts General Hospital, Boston, Massachusetts. ^jUniversity of Virginia Health System, Charlottesville, Virginia. ^kMedstar Georgetown University Hospital, Washington, District of Columbia. ^lDuke University Medical Center, Durham, North Carolina. ^mEmory University, Atlanta, Georgia. ⁿPenn State Health, Hershey, Pennsylvania. ^oLahey Hospital and Medical Center, Burlington, Massachusetts. ^pDartmouth-Hitchcock Medical Center, Lebanon, New Hampshire. ^qBeth Israel Deaconess Medical Center, Boston, Massachusetts. ^rUniversity of California San Francisco, San Francisco, California. ^sSpecialty Chair, Virginia Commonwealth University Medical Center, Richmond, Virginia.

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motion artifacts [14,15]. Adding DWI sequences when performing MRI to diagnose appendicitis in adults has been shown to have specificities and positive predictive values (PPV) of 100% each, and sensitivities and negative predictive values (NPV) between 97% to 99% for qualitative findings made by two experienced observers in high agreement [16]. Avcu et al [14] found similar results for DWI, with specificity and PPV of 100%, sensitivity of 98%, and NPV of 94%. In addition, they found a cut-off apparent diffusion coefficient 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 [15,16].

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 low-dose CT and limited coverage CT alternatives.

In an initial noninferiority study of low-dose CT randomly assigning 891 patients (15-44 years of age) to low-dose contrast-enhanced CT (CECT) (2 mSv) (444 patients) or standard-dose (447 patients) CECT of the abdomen and pelvis, low-dose CECT achieved noninferiority [17]. A subsequent study of low-dose CT that evaluated performance and learning curve of community radiologists and residents [18], in addition to performance of low-dose nonenhanced CT (270 patients) with coronal reconstructions compared to standard-dose nonenhanced CT and standard-dose CECT [19], demonstrated that radiologist performance was related to years of experience.

An additional imaging strategy is short z-axis CT for diagnosis of appendicitis. In retrospective single-institution studies [20-22], reconstructed standard abdominopelvic CT image data of patients with clinical suspicion of appendicitis were sorted into short z-axis image sets. Ranges of coverage varied from the inferior endplate of T10 [21], superior endplate of L2 [22], or top of the iliac crests [20] through the top of the pubic bones. Abbreviated abdominal data sets resulted in incomplete visualization of the appendix, range 80% to 94%. Accuracy of appendicitis diagnosis ranged from 95% in pelvic image sets to 100% in abdomen image sets. Estimated dose reduction ranged from 23% to 61%. The probability of correct diagnosis in limited pelvic sets was 68% as compared with 78% for limited abdomen sets [20].

Discussion of Procedures by Variant

Variant 1: Right lower quadrant pain, fever, leukocytosis. Suspected appendicitis. Initial imaging.

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 about 50% of patients. This explains the historical NAR of 14.7% and incidental appendectomy rate of 47%, where 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 [23]. 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.

CT Abdomen and Pelvis

CT has become the primary diagnostic imaging modality for the evaluation of patients with suspected appendicitis because of its high diagnostic yield. In the current literature, the NAR range with preoperative CT is 1.7% to 7.7% [5,24]. Sensitivities range from 85.7% to 100%, and specificities range from 94.8% to 100% [25,26]. Sensitivity was lowest in nonenhanced CT without enteral contrast [26]. However, a meta-analysis of prospective studies of nonenhanced CT, 7 studies included patient populations of 49 to 296, resulted in sensitivity of 0.90 (95% confidence interval [CI]: 0.86-0.92) and specificity of 0.94 (95% CI: 0.92-0.97) [27]. 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 CECT with versus without enteral contrast. CECT without enteral contrast sensitivities range from 90% to 100%, and specificities range from 94.8% to 100% [25,28] compared to CECT with enteral contrast (oral or rectal) for which sensitivities range from 90.4% to 100% and specificities that range from 97.67% to 100% [26,28]. In addition, a single-institution retrospective study of CECT without enteral contrast in 1,922 patients (16-99 years of age) with 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 sensitivity of 100% and specificity of 99.5% with only 4 patients (0.2%), none of which were in the appendicitis subgroup, returning for repeat CT because of a lack of oral contrast [29].

CT signs of appendicitis have variable accuracy. One retrospective study [30] of CT signs of appendicitis in 224 patients with negative or equivocal CECT 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 two or more signs present, odds ratio (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 CECT, 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% [31]. An additional retrospective study reviewed CECT 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 [32]. Maximum outer diameter (MOD) had areas under the receiver operating characteristic curve (AUC) of 0.967 with an optimal cutoff of 8.2 mm yielding sensitivity, specificity, and accuracy of 88.8%, 93.4%, and 91.7%, respectively. Diameter with compression (MOD less compressible contents) had an AUC of 0.973 with an optimal cutoff value of 6.6 mm and sensitivity, specificity, and accuracy of 93.8%, 94.9%, and 94.4%, respectively. Frequently referenced cutoff value of 6 mm for MOD yielded sensitivity of 97.5%, specificity of 59.6%, and accuracy of 73.6%.

Historical perforation rates for males and females are 19.2% and 17.8%, respectively [23]. Association with increased morbidity, mortality, and length of stay drives desire to identify early signs of appendiceal necrosis and occult perforation, prior to 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 [33]. 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 [34,35] 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 OR of 2.64 (95% CI: 1.48-4.73) and 2.67 (95% CI: 1.55-4.61), respectively [34]. Sensitivity and specificity for these two signs were 36.9% and 81.9% (intraluminal air) and 55.4% and 68.3% (intraluminal appendicolith), respectively. Kim et al [35] 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 Following Nondiagnostic US

Two current studies reviewing performance of CT following nondiagnostic US were identified. A retrospective review of 119 patients with suspected appendicitis and nonvisualized appendix on otherwise normally graded compression US, pelvic US in women with transvaginal US of child-bearing age, if not declined, and body mass index <30. CECT was performed within 48 hours in all patients. Patients were additionally divided into groups based on 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-positive (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 [36]. 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 CECT 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%) [37].

Alternate Diagnoses

Several studies included information on performance of CT for 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% [22] to a high of 45.3% [38]. The two studies

with the highest performance at 42.5% [25] and 45.3% [38] were both conducted at tertiary care centers suggesting impact based on differences in patient population as 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 [39] demonstrated rates of 46.0%, 21.6%, 16.9%, and 7.7% for these systems, respectively.

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 [13,40], 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 in order to displace intervening organs and simulate clinical deep abdominal palpation [13].

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% [40-45]. When reported, appendix visualization ranged from 35% [45] to 52.9% with difference by sex of 65% in males and 51.1% in females [43]. One study defined an equivocal group that consisted of incomplete or nonvisualization of the appendix, which comprised 81.4% of the total study population [44].

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 [44]. Analysis of male versus female patients [41] resulted in sensitivity, specificity, and false-positive rates of 95.7%, 88.2%, and 6.2% in males, and 84.6%, 71.4%, and 35.5% in females. This study also demonstrated significant differences in nonobese versus obese males and females, with false diagnosis (false-positive + false-negative) of 6.2% versus 34.4% ($P < .001$) in males and 38.5% versus 46.2% ($P < .001$) in females, respectively. Evaluation of various patient characteristics resulted in three 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 [43].

US Pelvis

Three retrospective studies of pelvic US were identified with one single-institution study combining transabdominal and transvaginal imaging in 292 women [46] and two multi-institutional studies [47,48] evaluating 573 and 620 male and female patients with iliac fossa US, respectively. 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% [48] to 45% [47]. 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 [48]. NARs ranged from 8.3% [46] to 38.4% [47].

MRI Abdomen and Pelvis

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 aged 3 to 49 years using 1.5 T and 3.0 T 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 intravenous (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 [49]. A prospective diagnostic study of 468 patients, age 7 to 59 years, assessed the performance of T2 half-Fourier acquisition single-shot turbo spin echo (HASTE) imaging on a 1.5 T system for diagnosing appendicitis. The sensitivity and specificity were reported as 98% (CI 95%) and 92% (CI 95%), respectively, when compared to direct visualization ($n = 90$). Axial and coronal T2 HASTE images were acquired with a reported table time of <2 minutes [50]. Two studies evaluated the diagnostic capability of MRI and reader experience on performance. A single-institution prospective study of 52 patients, age 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 1.5 T system, without and with IV contrast with administration of Buscopan to diminish peristalsis [51]. 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' that were ≥ 18 years. Imaging was performed on a 1.5 T system without IV contrast. The sensitivity for detecting appendicitis for nonexpert radiologists was 89%, (95% CI: 84%-93%) compared to expert radiologists at 97% (95% CI: 0.91%-0.99%). The specificity for nonexpert radiologists was 83%, (95% CI: 77%-88%) compared to expert radiologists at 93% (95% CI: 87%-97%). PPV for nonexpert radiologists was 86%, (95% CI: 81%-90%) compared to expert radiologists at 94% (95% CI: 88%-97%). NPV for nonexpert radiologists was 88%, (95% CI: 82%-91%) compared to that for expert radiologists at 96% (95% CI: 90%-98%). Interobserver agreement expressed as Cohen's kappa was 0.71 (95% CI: 0.73-0.84) consistent with good (but not excellent) agreement [52]. 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 1.5 T systems [53]. The second, a prospective diagnostic accuracy trial of 130 patients who were ≥ 18 years of age was performed to determine the accuracy of MRI (1.5 T system) compared to 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 to US with conditional CT technique [54].

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 [55].

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

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 [56] 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 four groups, with the appendicitis group subdivided into patients with preoperative only and both preoperative and postoperative abdominal radiographs. Fecal loading sign had 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%).

Fluoroscopy Contrast Enema

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

WBC Scan Abdomen and Pelvis

There is no recent literature regarding the use of technetium-99m (Tc-99m) white blood cell (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 [57], showed that the Tc-99m WBC scan achieved sensitivity of 81%, specificity of 100%, and accuracy of 89%. As delayed imaging, up to 4 hours postinjection, 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 2: Right lower quadrant pain, fever, leukocytosis. Possible appendicitis. Atypical presentation. Initial imaging.

CT Abdomen and Pelvis

Studies specific to atypical presentation of patients with suspected appendicitis are limited despite the fact that this represents approximately 50% of this patient population [23]. Two single-institution studies were identified [38,58], each evaluating patients presenting with nonspecific atraumatic abdominal pain. In these studies, 254 patients who underwent appendectomy, including 10 pregnant patients, were divided into four groups based on AS, with a dividing value of 5, and the presence or absence of preoperative CT. There was no significant difference in the distribution of pregnant patients between the groups, and no subgroup analysis for pregnancy was performed. NAR was determined for each group. The range was 2.6% to 18.7% with highest rate in the low probability (AS <5) non-CT group. The ORs of NAR for low and high probability were 5.6 (95% CI: 1.2-27.7) and 1.6 (95% CI: 0.2-14.2), respectively. Total NAR was 5.8%. Barksdale et al [38] 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. Two additional studies included atypical patients in their patient cohorts [29,31]. The first evaluated patients with body mass index >25 and demonstrated sensitivity, specificity, PPV, and NPV of 100%, 99.5%, 92%, and 100%, respectively, for the diagnosis of appendicitis. The second study evaluated the diagnostic power of CT signs for diagnosis of appendicitis in patients with nonenhanced plus CECT initially interpreted as inconclusive. This study found a transverse appendiceal diameter cutoff value of 8.5 mm to be most powerful with the greatest sensitivity and specificity at 90.2% and 91.5%, respectively. Maximal luminal diameter and maximal wall thickness of the appendix were also found to have good predictive value with good specificities at cut-off values of 4.5 mm (91.5%) and 3.5 mm (93.2%), respectively, but with much lower sensitivities at 63.4% and 48.8%, respectively.

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 [13,40], 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 by deepening abdominal compression using the transducer and both of the operator's hands upon exhalation in order to displace intervening organs and simulate clinical deep abdominal palpation [13].

Two studies, one retrospective and the second prospective, of US evaluation specifically of patients with atypical presentation of appendicitis, atypical lab results [59], or nonspecific abdominal pain [60] were identified in the current literature. The first 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 eFAST experience plus training, one day didactic and one 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) ($P = .000$). For this document, it is assumed that the procedure is performed and interpreted by an expert.

US Pelvis

Two multi-institution retrospective studies were identified, which included all patients who had undergone US prior to appendectomy [47,48]. D'Souza et al [47] 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 by expert physicians [48] yielded a nonvisualization rate of 27.7%. Evaluation of indirect signs of appendicitis in the nonvisualization subgroup yielded 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%, depending on presence and combination of the evaluated indirect signs, pain, hypertrophic periappendiceal fat, and diminished periappendiceal peristalsis.

MRI Abdomen and Pelvis

Relevant articles from the literature search included one retrospective study, five prospective studies, and one meta-analysis for the topic of MRI use for diagnosis of appendicitis in adult patients, not limited to pregnant patients.

Acute Appendicitis

MRI in the diagnosis of simple appendicitis for experienced readers had sensitivity of 85% to 98% [50,51], specificity of 93% to 99.4% (95% CI: 97.9%-99.9%) [49,53], PPV of 94% (95% CI: 88%-97%), NPV of 100% [14,52], and accuracy of 93.75% to 96% [14,52]. Values for less-experienced readers were sensitive of 77% to 89% (95% CI: 77%-88%) [51,52], specificity of 79% to 83% (95% CI: 77%-88%) [51,52], PPV of 86% (95% CI: 81%-90%), and NPV of 88% (95% CI: 82%-91%) [52]. 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 two studies [14,54] and 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 two studies without reaching statistical significance in either [49,53]. This finding was also not significantly different when compared with US with conditional CT diagnostic strategy [54].

Specific variations in technique were evaluated prospectively in two studies. Diagnostic performance to assess T2 HASTE imaging in 468 patients (age 7-59 years) yielded sensitivity and specificity of 98% (95% CI) and 92% (95% CI), respectively [50]. Evaluation of DWI and apparent diffusion coefficient demonstrated mean apparent diffusion coefficient value for patients with appendicitis were significantly lower compared with controls. Sensitivity, specificity, NPV, and PPV for detecting appendicitis were reported as 97.5%, 100%, 93.75%, and 100%, respectively [14]. The protocol [53] also included DWI with procedure sensitivity and specificity of 97% and 93%, respectively. Combined diagnostic performance of 1.5 T and 3.0 T systems demonstrated 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 two field strengths [49].

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 [55].

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 [54].

Alternate Diagnoses

Imaging methods that can detect alternative diseases are useful, particularly in patients with RLQ pain with presentations atypical for appendicitis. A detailed review of the accuracy of MRI to detect alternative disease processes is beyond the scope of this literature review; however, the rates and types of alternative diagnoses were included in a subset of the studies.

A prospective multicenter diagnostic accuracy study performed to determine the accuracy and interobserver agreement between MR-expert and MR-nonexpert radiologists also 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 to 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 to expert radiologists at 100% (95% CI: 76%-100%). Interobserver agreement expressed as Cohen's kappa was 0.63 (95% CI: 0.55-0.70) consistent with good (but not excellent) agreement [52]. For this document, it is assumed that the procedure is performed and interpreted by an expert.

A single-institution retrospective study of 403 patient's aged 3 to 49 years identified both urgent and nonurgent alternative diagnoses in 336 patients. These conditions included gastrointestinal, gynecologic, urinary tract, musculoskeletal, inflammatory, neoplastic, and congenital conditions [49]. A prospective study identified alternative diagnoses in 27 of 38 patients with true-negative results for appendicitis [51].

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 [56] of the fecal loading sign evaluated 470 adult and pediatric patients with acute abdominal pain. Patients were divided into four groups with the appendicitis group subdivided into patients with preoperative only and both preoperative and postoperative abdominal radiographs. Fecal loading sign had 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%).

Fluoroscopy Contrast Enema

There is no relevant literature regarding the use of contrast enema in the evaluation of RLQ pain, fever, leukocytosis, and possible appendicitis with atypical presentation.

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 possible appendicitis with atypical presentation. However, in a blinded prospective study of 30 patients with suspected appendicitis, Foley et al [57] showed that the Tc-99m WBC scan achieved sensitivity of 81%, specificity of 100%, and accuracy of 89%. As delayed imaging, up to 4 hours postinjection, 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.

CT Abdomen and Pelvis

There is no current literature specific to the use of CT in the evaluation of RLQ pain, fever, and leukocytosis in pregnant patients. Several studies included pregnant patients in their study populations. The first is Kontopodis et al [58], 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 [61], 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.

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 [13,40], 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. Two [62,63] compared diagnostic performance of US in pregnant and nonpregnant women with cohorts of 67 and 133 for the first study and 81 and 243 for the second study, respectively. There was no statistically significant difference in predictive performance of US between the groups with AUC of 0.76 and 0.73, respectively ($P = .78$) [63], and PPV and NPV of 88.2% and 100%, ($P = .011$) and 92.9% and 57.1% ($P < .001$), respectively [62].

Segev et al [63] in a subgroup analysis of each trimester 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 [64] 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 [62] and 97% of all patients not stratified by trimester [64]. There is improved performance when stratified by trimester, 25% for first

trimester versus 63% for third trimester [62], and in the presence of fever in pregnant patients, AUC 0.92 versus 0.72 ($P = .07$) [63].

US Pelvis

There is no recent literature regarding the use of pelvic US in the evaluation of RLQ pain, fever, or leukocytosis in pregnant women.

MRI Abdomen and Pelvis

Five 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 4 were single-institution series.

The multi-institution study [65] reviewed 709 pregnant women aged 16 to 49 years 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 false-positive patients 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 [66] evaluated 171 pregnant patients with suspected appendicitis who had MRI (1.5 T) 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 [61] 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%). Sensitivity, specificity, PPV, and NPV for US were 12.5%, 99.2%, 50%, and 94.4%, respectively; and for MRI they were 100%, 93.6%, 57.1%, and 100%, respectively. Diagnostic performance of the multimodality strategy yielded 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 [67]. 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 sensitivity of 18%, specificity of 99%, PPV of 66%, and NPV of 92%. Diagnostic performance of MRI yielded sensitivity of 100%, specificity of 98%, PPV of 89%, and NPV of 100%. Diagnosis of appendicitis (16 of 18 patients) by MRI was proven by pathology. The two 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 [68]. 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 sensitivity of 89% (17 of 19), specificity of 97% (187 of 193), PPV of 74% (17 of 23), and NPV of 99% (187 of 189).

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 [69].

Radiography Abdomen

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

Fluoroscopy Contrast Enema

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

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 sensitivity, specificity, PPV, and NPV of 50%, 73%, 25%, and 89%, respectively [70]. False-positive rate was 27% and 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

- **Variante 1:** In patients with RLQ pain with fever and leukocytosis, CT abdomen and pelvis with IV contrast is usually appropriate to evaluate for suspected appendicitis.
- **Variante 2:** In patients with RLQ pain with fever and leukocytosis in an atypical presentation, CT abdomen and pelvis with IV contrast is usually appropriate to evaluate for possible appendicitis.
- **Variante 3:** MRI abdomen and pelvis without IV contrast or US abdomen is the primary modality for interrogation of the pregnant patient with suspected appendicitis.

Summary of Evidence

Of the 75 references cited in the *ACR Appropriateness Criteria® Right Lower Quadrant Pain-Suspected Appendicitis* document, 1 is categorized as a good-quality therapeutic reference. Additionally, 71 references are categorized as diagnostic references including 1 well-designed study, 24 good-quality studies, and 32 quality studies that may have design limitations. There are 14 references that may not be useful as primary evidence. There are 3 references that are good meta-analysis studies.

The 75 references cited in the *ACR Appropriateness Criteria® Right Lower Quadrant Pain-Suspected Appendicitis* document were published from 1986-2016.

Although there are references that report on studies with design limitations, 26 well-designed or good-quality studies provide good evidence.

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 \(MRI\)](#) [71]
- [ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#) [72]
- [ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound](#) [73]
- [ACR Manual on Contrast Media](#) [69]
- [ACR guidance document on MR safe practices: 2013](#) [74]

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 [75].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	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".

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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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.