Date of origin: 1996
Last review date: 2013

American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Right Lower Quadrant Pain—Suspected Appendicitis**

Variant 1: **Fever, leukocytosis, and classic clinical presentation for appendicitis in adults.**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis with IV contrast	8	Oral or rectal contrast may not be needed depending on institutional preference.	☢☢☢☢
CT abdomen and pelvis without IV contrast	7	Use of oral or rectal contrast depends on institutional preference.	☢☢☢☢
US abdomen	6	Perform this procedure with graded compression.	O
US pelvis	5	This procedure is appropriate in women with pelvic pain.	O
MRI abdomen and pelvis without and with IV contrast	5		O
X-ray abdomen	4	This procedure may be useful when there is concern for perforation and free air.	☢☢
CT abdomen and pelvis without and with IV contrast	4	Oral or rectal contrast may not be needed in this procedure depending on institutional preference.	☢☢☢☢
MRI abdomen and pelvis without IV contrast	4		O
X-ray contrast enema	2		☢☢☢
Tc-99m WBC scan abdomen and pelvis	2		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Variant 2: **Fever, leukocytosis; possible appendicitis, atypical presentation, adults and adolescents.**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis with IV contrast	8	Oral or rectal contrast may not be needed depending on institutional preference.	☢☢☢☢
X-ray abdomen	6	This procedure may be useful in excluding free air or obstruction.	☢☢
US abdomen	6	Perform this procedure with graded compression.	O
US pelvis	6	This procedure is appropriate for women with pelvic pain.	O
CT abdomen and pelvis without IV contrast	6	Use of oral or rectal contrast depends on institutional preference.	☢☢☢☢
MRI abdomen and pelvis without and with IV contrast	5		O
CT abdomen and pelvis without and with IV contrast	4	Oral or rectal contrast may not be needed depending on institutional preference.	☢☢☢☢
MRI abdomen and pelvis without IV contrast	4		O
X-ray contrast enema	2	The RRL for the adult procedure is ☢☢☢ .	☢☢☢☢
Tc-99m WBC scan abdomen and pelvis	2		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Right Lower Quadrant Pain—Suspected Appendicitis**

Variant 3: **Fever, leukocytosis, pregnant woman.**

Radiologic Procedure	Rating	Comments	RRL*
US abdomen	8	Perform this procedure with graded compression. This procedure is better in the first and early second trimester.	O
MRI abdomen and pelvis without IV contrast	7	This procedure may be useful following negative or equivocal US.	O
US pelvis	6		O
CT abdomen and pelvis with IV contrast	5	This procedure may be useful following negative or equivocal US and MRI. Oral or rectal contrast may not be needed depending on institutional preference.	☢☢☢☢
CT abdomen and pelvis without IV contrast	4	This procedure may be useful following negative or equivocal US and MRI. Use of oral contrast depends on institutional preference.	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	3		☢☢☢☢
MRI abdomen and pelvis without and with IV contrast	2		O
X-ray abdomen	2		☢☢
X-ray contrast enema	2		☢☢☢
Tc-99m WBC scan abdomen and pelvis	2		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Variant 4: **Fever, leukocytosis, possible appendicitis, atypical presentation in children (younger than age 14).**

Radiologic Procedure	Rating	Comments	RRL*
US abdomen	8	Perform this procedure with graded compression.	O
CT abdomen and pelvis with IV contrast	7	This procedure may be useful following negative or equivocal US. Oral or rectal contrast may not be needed depending on institutional preference.	☢☢☢☢
X-ray abdomen	6	This procedure may be useful in excluding free air or obstruction.	☢☢
US pelvis	5	This procedure is appropriate in women with pelvic pain.	O
CT abdomen and pelvis without IV contrast	5	Use of oral contrast depends on institutional preference.	☢☢☢☢
MRI abdomen and pelvis without and with IV contrast	5		O
MRI abdomen and pelvis without IV contrast	4		O
CT abdomen and pelvis without and with IV contrast	3		☢☢☢☢☢
X-ray contrast enema	2		☢☢☢☢
Tc-99m WBC scan abdomen and pelvis	2		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

RIGHT LOWER QUADRANT PAIN — SUSPECTED APPENDICITIS

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Summary of Literature Review

Introduction/Background

Relatively few comparative imaging studies evaluating right lower quadrant (RLQ) pain are available; most of the literature centers on the diagnosis of acute appendicitis (AA), the most common cause of acute RLQ pain requiring surgery [1]. For this reason, the focus of this narrative is on appendicitis and the accuracy of imaging procedures in diagnosing appendicitis, although consideration of other diseases is included.

In a few patients with AA, such as young men, imaging may not be necessary because the clinical presentation is sufficiently diagnostic to allow surgery [2,3]. Clinical prediction scores, such as the Alvarado score, have been used as a prediction rule for identifying patients with appendicitis; however, their accuracy is inferior to imaging and insufficient as a sole method for appendicitis evaluation [4]. In many published studies for appendicitis imaging, subjects with definitive clinical examination findings of appendicitis undergo operation without imaging. In the reported imaging studies, approximately 40% of imaged subjects on average had appendicitis and, in approximately 30% of subjects, another cause for RLQ pain was identified by imaging. Data on the overall effect of imaging on surgical treatment of appendicitis and patient outcome remain somewhat controversial, but growing evidence supports imaging use to reduce the negative appendectomy rate (NAR) [5-14].

Computed Tomography and Ultrasound

Computed tomography (CT) is the most accurate examination for evaluating patients without a clear clinical diagnosis of AA [15,16]. In a meta-analysis of 6 prospective studies through February 2006 of the accuracy of CT and ultrasound (US) in adolescents and adults, CT demonstrated superior sensitivity (91%; 95% confidence interval [CI], 84%–95%) and specificity (90%; 95% CI, 85%–94%) versus US (sensitivity, 78%; 95% CI, 67%–86%; specificity 83%, 95% CI, 76%–88%) [17]. The results of CT investigations were consistent across all studies and institutions, whereas US investigations demonstrated heterogeneity, suggesting greater dependence on operator skill [18]. The routine use of CT to evaluate for appendicitis has been shown to decrease overall costs by $447 to $1,412 per patient [13,19]. CT has been shown to decrease NAR from 16.7% to 8.6% in a meta-analysis of 20 studies with a broad range of 5,616 patients [20] and from 42.9% to 7.1% among 399 women aged 18–45 years at a single institution [21]. Accuracy of clinical diagnosis of the etiology of RLQ pain in women of childbearing age tends to be less accurate compared with adult men, thereby suggesting a lower threshold for imaging in this population [22]. In elderly patients with RLQ pain, the accuracy of clinical diagnosis also tends to be less accurate, and the increased risk of complications with AA in this population suggests a lower threshold for imaging with CT, as it has been shown to be highly accurate in depicting AA and its complications [23].

With the increased use of CT to evaluate for AA, concern has also increased about the effects of radiation exposure from CT, particularly since the majority of the population undergoing imaging for suspected AA is young or relatively young. A few studies have used algorithms with US as a first test to decrease the use of CT or have studied the use of CT with techniques that reduce the radiation dose while maintaining diagnostic accuracy. In 2 recent studies from Europe, diagnostic pathways used US as the primary modality after clinical evaluation by a surgeon. CT was reserved for cases where US was inconclusive [24] or negative [25]. These studies showed pathway sensitivity and specificity of 95.0% and 86.7% [24] with CT used in only 17.9% of cases, and 100% and

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86% [25] with CT used in 39.7% of cases; all diagnostic errors in both studies were made in patients who underwent US only. Another European study of 183 patients first used an algorithm of US followed by low-dose (LD) CT when US was inconclusive, and then standard-dose (SD) CT when LDCT was inconclusive; 98.8% sensitivity and 96.9% specificity for diagnosing appendicitis were obtained with a 64% reduction in estimated dose compared to performing SDCT in all imaged patients [26]. A recent study comparing NAR between a SDCT (447 patients) and a LDCT technique (444 patients) in a routine university hospital emergency department (ED) showed no significant difference in NAR with the LD protocol using less than 25% of the estimated dose of the SDCT protocol [27]. In both studies, thin slices and multiplanar reformats were used to aid in diagnosis, which have also been shown in small studies to increase confidence in identifying the appendix [28-30].

When using CT, questions remain whether to use intravenous (IV) contrast, enteric contrast, both, or neither in the evaluation for AA. High accuracy has been reported for techniques using IV contrast as well as for those not using IV contrast (with or without enteric contrast), but few direct comparisons suggest higher accuracy when IV contrast is used [31]. A prospective study with 232 patients showed that non–contrast-enhanced CT (sensitivity, 90%; specificity, 86%) was inferior to rectal-only contrast (sensitivity, 93%; specificity, 95%) and IV and oral contrast (sensitivity, 100%; specificity, 89%) [32]. In lieu of individual patient contraindications to IV contrast, its use is recommended in evaluation of RLQ pain. However, if IV contrast is contraindicated, non–contrast-enhanced CT has been shown in 1 study of 300 patients to have a sensitivity of 96%, specificity of 99%, and accuracy of 97% [33] and in a meta-analysis of 7 studies with 1,060 patients to have a summary sensitivity of 92.7% (95% CI, 89.5%–95.0%) and specificity of 96.1% (95% CI, 94.2%–97.5%) [34].

The need for oral contrast when imaging suspected AA with CT, and particularly the need for rectal contrast, is less clear. In 1 prospective study, the use of rectal contrast has been shown to decrease ED stay by greater than 1 hour compared to oral contrast, without a significant difference in patient satisfaction or discomfort [35]. There is concern, however, that rectal contrast can be complicated by bowel perforation, with a cited number similar to barium enema of 0.04% [31]. One recent study showed similar sensitivity and specificity for detection of AA on 64-row multidetector CT (MDCT) with or without oral contrast performed with IV contrast [36]. Another recent study on 16-row MDCT showed no statistical difference either in sensitivity or specificity for detection of AA with or without oral contrast performed with IV contrast, and ED disposition was faster in the IV contrast only group [37]. In both of these studies, for the diagnosis of AA, sensitivity was 100%, and specificity was greater than 97% in the IV contrast only groups [36,37]. Another recent prospective study randomized patients to ingest or not ingest oral contrast; both groups then underwent IV unenhanced and enhanced standard dose MDCT with each study also using a simulated LD technique. The study determined that diagnostic correctness was more influenced by the reader than by the use of contrast medium or the LD technique [38]. With data from these and other studies, and the increased examination time, problems with patient tolerance, and potential increased radiation exposure from CT in patients with high-density enteric contrast, evidence is trending against the routine use of oral contrast, and particularly against the routine use of rectal contrast, for CT when IV contrast is used.

CT appears superior to US in identifying complications and in evaluating patients with periappendiceal abscess, especially when the abscesses become large [39]. CT results can be used to select therapeutic options other than immediate surgery, including antibiotic treatment with small abscesses and percutaneous drainage with well-defined or small, poorly defined abscesses [40]. Imaging-guided percutaneous drainage combined with antibiotics has been shown to be an effective initial treatment for AA complicated by perforation and abscess, followed by subsequent elective appendectomy or, in selected cases, conservative management [41]. High technical and clinical success rates have been shown with extraluminal appendicolith and large, poorly defined abscesses associated with repeat drainage and clinical failure in a recent study [42].

CT and US are effective in depicting alternative diagnoses for RLQ pain. In a large single-center study evaluating the diagnostic performance of MDCT for suspected AA, a cause of pain other than AA was established or suggested in a larger number of cases than AA (896 versus 675 in 2,871 patients) [43]. The range of diseases studied includes inflammatory bowel disease, infectious bowel disease, small-bowel obstruction, gynecological conditions, genitourinary conditions, and epiploic appendage, omental, and mesenteric inflammation.

Magnetic Resonance Imaging

At this time, few studies evaluate the value of magnetic resonance imaging (MRI) in the general population for AA. MRI is desirable due to its lack of ionizing radiation; however, its relative limitations include greater cost, longer acquisition time, and lesser clinical availability. A meta-analysis of 8 studies (5 retrospective) evaluating

MRI for the diagnosis of AA in adults, mostly pregnant women, showed a summary sensitivity of 97% (95% CI, 92%–99%) and specificity of 95% (95% CI, 94%–99%) [44]. Since that meta-analysis a prospective study of 138 patients exhibited a sensitivity of 100% and specificity of 99% for MRI [45], but another prospective study with only 52 patients exhibited a sensitivity of 85% and specificity of 97% [46]. It is anticipated that as MRI becomes more clinically available in the ED setting, the value of MRI for RLQ pain will be further elucidated.

Pediatric Patients

As in adults, appendicitis scoring systems have been inadequate as a single method for appendicitis evaluation and have been inferior to imaging [47]. Relatively, CT and US have been less well evaluated in children than in adults, but there are increasing data on imaging use in the pediatric population. Several factors are unique in children, including increased radiosensitivity to ionizing radiation, smaller body size, and less body fat, which favors initial use of US. A systematic literature review in July 2004 revealed 8 prospective evaluations of US for appendicitis in children [48]. The pooled sensitivity of graded-compression US was 91% (95% CI, 89%–93%), and the specificity was 97% (95% CI, 95%–99%). A meta-analysis published in October 2006 included 26 studies (15 prospective) of US and CT in the pediatric population. The pooled sensitivity of US was 88% (95% CI, 86%–90%) and specificity of 94% (95% CI, 92%–95%) compared with CT, which exhibited a pooled sensitivity of 94% (95% CI, 92%–97%) and specificity of 95% (95% CI, 94%–97%) [49]. These results suggest that although CT is more accurate, US is nearly as good in experienced hands and, given the lack of ionizing radiation, is the preferred modality in children, particularly if equivocal results are followed up by CT [50-54]. Thus the approach of CT after US appears to have excellent accuracy, with reported sensitivity and specificity of 94% in a small study [55] and sensitivity of 98.6% and specificity of 90.6% in a larger study [56]. A single retrospective study showed that in intermediate-to-high pretest probability children, US followed by CT is most cost-effective, whereas in low pretest probability patients, US alone is the most effective and least costly strategy [57].

A recent retrospective study examining practices at 40 pediatric hospitals between 2005–2009 reported a trend toward increasing use of US and decreasing use of CT, though in 2009 CT was still used more commonly in the ED than US (29.2% versus 24.5%, respectively) [58]. Using these same data, it was also observed that imaging in boys older than age 5 did not lower the NAR significantly, and therefore imaging in this group may be reserved safely for those with concern for complications or changes in surgical management [3]. If CT is performed, IV contrast is recommended; however, enteric contrast (oral or rectal contrast) has not been shown to increase sensitivity significantly in children, and it has been suggested that routine enteric contrast use be phased out [59] though there have not been larger, multisite trials related to this suggestion. Addition of multiplanar reformats, particularly coronal images, has been shown in a small study to increase reader confidence in identifying the appendix in its entirety and other periappendiceal findings and should be included in the CT protocol [60]. Recently, nonvisualization of the appendix on a normal CT has been shown to have a high negative predictive value of 98.7% (95% CI, 95.5%–99.8%) [61].

Investigation of MRI as a viable option to evaluate for AA has increased as MRI has been used more often in pediatric patients and has become more available in the ED setting of pediatric hospitals. One small prospective study of 42 patients receiving MRI without sedation or exogenous contrast administration, as an adjunct to CT or US, achieved 100% sensitivity in 12 cases of appendicitis [62]. In a larger prospective study of 208 pediatric patients suspected of having AA who underwent MRI without sedation or exogenous contrast administration a sensitivity of 97.6% (95% CI, 87.1%–99.9%) and specificity of 97% (95% CI, 93.2%–99%) was achieved with 40 cases of AA [63]. With lack of widespread experience and issues of cost, availability, and the potential need for sedation, the use of MRI for suspected AA in pediatric patients is currently limited to specialized pediatric hospitals.

Pregnant Patients

Evaluation of the accuracy of imaging in pregnant women has received more attention in the literature in recent years. In general, ionizing radiation from CT should be avoided during pregnancy. US is clearly a safer imaging option and is the first imaging test of choice [64], although CT after equivocal US has been validated for diagnosis [65]. A systematic literature review through August 2008 addressed 8 retrospective studies of CT and MRI after negative or inconclusive US in pregnant women [66]. The pooled sensitivity of CT after US was 86% (95% CI, 64%–97%), and the specificity was 97% (95% CI, 86%–100%). MRI is the preferred test after inconclusive US, as new studies have shown a comparable sensitivity and specificity with CT without exposing the fetus to ionizing radiation [67-69]. The pooled sensitivity of MRI after US was 80% (95% CI, 44%–98%), and the specificity was 99% (95% CI, 94%–100%) [66]. A more recent meta-analysis of 5 case series evaluating MRI for AA in pregnancy yielded a sensitivity of 90.5%, specificity of 98.6%, PPV of 90.4%, and NPV of 99.5%, with the appendix visualized in 92.1% of cases [70]. These data support an algorithm of US followed by MRI if the initial US is inconclusive, which is frequently the case as shown in the largest case series where the detection of a normal appendix in pregnant patients by US was 2%, but was 87% by MRI [71].

Abdominal and Pelvic Radiography

Radiography is of limited value for diagnosing AA except in occasional circumstances when an appendicolith or other ancillary findings are identified. Although barium enema has been used historically to diagnose appendicitis, its use depends on the negative finding of nonvisualization of the appendix and may be quite uncomfortable in patients with AA. Nonetheless, barium small-bowel follow-through or barium enema may be useful following cross-sectional imaging studies for other causes of RLQ pain, including suspected small-bowel obstruction, infectious ileitis, and inflammatory bowel disease. (See the ACR Appropriateness Criteria® topic on "Suspected Small Bowel Obstruction.")

Nuclear Medicine

Nuclear medicine imaging has also been reported for evaluating RLQ pain [72]. However, the sensitivity and specificity of nuclear scans for this indication have been shown to be significantly inferior to US, CT, and MRI [73].

Summary

- Appendicitis may be diagnosed clinically; however, imaging increases sensitivity and specificity for diagnosis.
- In general, CT is the most accurate imaging study for evaluating suspected appendicitis and alternative etiologies of RLQ abdominal pain. Data favor the use of IV contrast for CT, but the need for enteric contrast when IV contrast is used is not favored.
- Dose-reduction strategies in CT must be employed following the As Low As Reasonably Achievable principle. Minimizing radiation dose in CT while maintaining diagnostic accuracy is an area of active investigation.
- In children, US is the preferred initial examination as it is nearly as accurate as CT for diagnosis of appendicitis but is without ionizing radiation exposure.
- In pregnant women, data support the use of MRI after equivocal or inconclusive US.

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 Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation
- ACR-ACOG-AIUM Practice Guideline for the Performance of Obstetrical Ultrasound
- ACR Manual on Contrast Media
- ACR Guidance Document for Safe MR Practices

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, both because of 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 to 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.

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".		

Supporting Documents

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

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