Clinical Policy: Critical Issues in the Evaluation and Management of Emergency Department Patients With Suspected Appendicitis

From the American College of Emergency Physicians Clinical Policies Subcommittee (Writing Committee) on Critical Issues in the Evaluation and Management of Emergency Department Patients With Suspected Appendicitis:

John M. Howell, MD (Subcommittee Chair)
Orin L. Eddy, MD
Thomas W. Lukens, MD, PhD
Molly E. W. Thiessen, MD
Scott D. Weingart, MD
Wyatt W. Decker, MD (Committee Chair)

Members of the American College of Emergency Physicians Clinical Policies Committee (Oversight Committee):

Wyatt W. Decker, MD (Co-Chair 2006-2007, Chair 2007-2009)
Andy S. Jagoda, MD (Chair 2003-2006, Co-Chair 2006-2007)
Deborah B. Diercks, MD
Barry M. Diner, MD (Methodologist)
Jonathan A. Edlow, MD
Francis M. Fesmire, MD
John T. Finnell, II, MD, MSc (Liaison for Emergency Medical Informatics Section 2004-2006)
Steven A. Godwin, MD
Sigrid A. Hahn, MD
Benjamin W. Hatten, MD (EMRA Representative 2008-2009)
John M. Howell, MD
J. Stephen Huff, MD
Eric J. Lavonas, MD
Thomas W. Lukens, MD, PhD
Sharon E. Mace, MD
Donna L. Mason, RN, MS, CEN (ENA Representative 2004-2006)
Edward Melnick, MD (EMRA Representative 2007-2008)
Anthony M. Napoli, MD (EMRA Representative 2004-2006)
Devorah J. Nazarian, MD
AnnMarie Papa, RN, MSN, CEN, FAEN (ENA Representative 2007-2009)
Jim Richmann, RN, BS, MA(c), CEN (ENA Representative 2006-2007)
Scott M. Silvers, MD
Edward P. Sloan, MD, MPH
Molly E. W. Thiessen, MD (EMRA Representative 2006-2008)
Robert L. Wears, MD, MS (Methodologist)
Stephen J. Wolf, MD
Cherri D. Hobgood, MD (Board Liaison 2004-2006)
David C. Seaberg, MD, CPE (Board Liaison 2006-2009)
Rhonda R. Whitson, RHIA, Staff Liaison, Clinical Policies Committee and Subcommittees

Approved by the ACEP Board of Directors, October 2, 2009

Supported by the Emergency Nurses Association, November 3, 2009

0196-0644/$-see front matter

doi:10.1016/j.annemergmed.2009.10.004

[Ann Emerg Med. 2010;55:71-116.]

ABSTRACT

This clinical policy from the American College of Emergency Physicians is an update of a 2000 clinical policy on the evaluation and management of patients presenting with nontraumatic acute abdominal pain.[1] A writing subcommittee reviewed the literature to derive evidence-based recommendations to help clinicians answer the following critical questions: (1) Can clinical findings be used to guide decisionmaking in the risk stratification of patients with possible appendicitis? (2) In adult patients with suspected acute appendicitis who are undergoing a computed tomography scan, what is the role of contrast? (3) In children with suspected acute appendicitis who undergo diagnostic imaging, what are the roles of computed tomography and ultrasound in diagnosing acute appendicitis? Evidence was graded and recommendations were given based on the strength of the available data in the medical literature.

INTRODUCTION

Abdominal pain is a high-volume, high-risk chief complaint. In 2005, patients with abdominal pain composed 6.8% of 115 million annual emergency department (ED) visits.[2] Ten percent of closed malpractice claims for emergency physicians involve the missed diagnosis of abdominal pain.[3] Among children between 6 and 17 years of age, appendicitis is the second most common cause of malpractice litigation against emergency physicians.[4] The diagnosis of appendicitis can be challenging even in the most experienced of clinical hands.

Despite the increasing utilization of computed tomography (CT) in patients with possible appendicitis, such widespread use may be unnecessary. Clinical indicators (eg, signs, symptoms, laboratory tests) exist that might identify patients who require abdominal CT to diagnose acute appendicitis. Such indicators could facilitate the early identification of ED patients who do and do not require CT, but are such strategies effective?

Once the decision is made to image, performing a CT may or may not involve the use of contrast. If contrast is used, does it increase diagnostic performance in a clinically meaningful way? In children, some clinicians use ultrasound before or in lieu of CT to diagnose appendicitis. Although ultrasound does not involve ionizing radiation or the risks associated with contrast, the accuracy of either a positive or negative ultrasound result merits discussion.

Not every patient with possible appendicitis needs abdominal imaging. Although this clinical policy addresses diagnostic studies for appendicitis, not all patients with possible appendicitis require diagnostic tests. For example, patients with very low clinical suspicion for appendicitis may be discharged with minimal or no testing. Similarly, patients with high clinical suspicion for appendicitis may be referred to a surgeon, with minimal or no testing.[5] If the clinical presentation warrants, a surgical consultant should be notified as early as is clinically warranted.

This clinical policy addresses evidence-based questions framed around these issues. Rather than approach the topic of abdominal pain in its entirety, this policy's scope is limited to 3 questions:

1. Can clinical findings be used to guide decisionmaking in the risk stratification of patients with possible appendicitis?
2. In adult patients with suspected acute appendicitis who are undergoing a CT scan, what is the role of contrast?
3. In children with suspected acute appendicitis who undergo diagnostic imaging, what are the roles of CT and ultrasound in diagnosing acute appendicitis?

METHODOLOGY

This clinical policy was created after careful review and critical analysis of the medical literature. Multiple searches of MEDLINE and the Cochrane database were performed. Specific key words/phrases used in the searches are identified under each critical question. To update the 2000 American College of Emergency Physicians (ACEP) policy, all searches were limited to English-language sources, human studies, and to articles published from January 2000 to March 2007. Additional articles were reviewed from the bibliography of articles cited and from published textbooks and review articles. Subcommittee members supplied articles from their own files, and more recent articles identified during the process were also included.

The reasons for developing clinical policies in emergency medicine and the approaches used in their development have been enumerated.[6] This policy is a product of the ACEP clinical policy development process, including expert review, and is based on the existing literature; when literature was not available, consensus of emergency physicians was used. Expert review comments were received from individual emergency physicians and from individual members of the American Academy of Pediatrics, the American College of Radiology, the Society for Academic Emergency Medicine, the Society for Pediatric Radiology, ACEP's Pediatric Emergency Medicine Section, and ACEP's Emergency Ultrasound Section. Their responses were used to further refine and enhance this policy; however, their responses do not imply endorsement of this clinical policy. Clinical policies are scheduled for revision every 3 years; however, interim reviews are conducted when technology or the practice environment changes significantly.

All articles used in the formulation of this clinical policy were graded by at least 2 subcommittee members for strength of evidence and classified by the subcommittee members into 3 classes of evidence on the basis of the design of the study, with design 1 representing the strongest evidence and design 3 representing the weakest evidence for therapeutic, diagnostic, and prognostic clinical reports, respectively (Appendix A). Articles were then graded on 6 dimensions thought to be most relevant to the development of a clinical guideline: blinded versus nonblinded outcome assessment, blinded or randomized allocation, direct or indirect outcome measures (reliability and validity), biases (eg, selection, detection, transfer), external validity (ie, generalizability), and sufficient sample size. Articles received a final grade (Class I, II, III) on the basis of a predetermined formula, taking into account design and quality of study (Appendix B). Articles with fatal flaws were given an "X" grade and not used in formulating recommendations in this policy. Evidence grading was done with respect to the specific data being extracted and the specific critical question being reviewed. Thus, the level of evidence for any one study may vary according to the question, and it is possible for a single article to receive different levels of grading as different critical questions are answered. Question-specific level of evidence grading may be found in the Evidentiary Table included at the end of this policy.

Clinical findings and strength of recommendations regarding patient management were then made according to the following criteria:

Level A recommendations. Generally accepted principles for patient management that reflect a high degree of clinical certainty (ie, based on strength of evidence Class I or overwhelming evidence from strength of evidence Class II studies that directly address all of the issues).

Level B recommendations. Recommendations for patient management that may identify a particular strategy or range of management strategies that reflect moderate clinical certainty (ie, based on strength of evidence Class II studies that directly address the issue, decision analysis that directly addresses the issue, or strong consensus of strength of evidence Class III studies).

Level C recommendations. Other strategies for patient management that are based on preliminary, inconclusive, or conflicting evidence, or in the absence of any published literature, based on panel consensus.

There are certain circumstances in which the recommendations stemming from a body of evidence should not be rated as highly as the individual studies on which they are based. Factors such as heterogeneity of results, uncertainty about effect magnitude and consequences, strength of prior beliefs, and publication bias, among others, might lead to such a downgrading of recommendations.

When possible, clinically oriented statistics (ie, likelihood ratios, odds ratios, risk ratios, and number needed to treat) will be presented to help the reader better understand how the results can be used with the patient and will be given priority over simple descriptive statistics (eg, sensitivity, specificity, and predictive values). The former allow the reader to interpret study results taking into consideration probability of disease. For a more thorough explanation of these statistical methodologies, see Appendix C.

This policy is not intended to be a complete manual on the evaluation and management of patients with nontraumatic acute abdominal pain but rather a focused examination of critical issues that have particular relevance to the current practice of emergency medicine.

It is the goal of the Clinical Policies Committee to provide an evidence-based recommendation when the medical literature provides enough quality information to answer a critical question. When the medical literature does not contain enough quality information to answer a critical question, the members of the Clinical Policies Committee believe that it is equally important to alert emergency physicians to this fact.

Recommendations offered in this policy are not intended to represent the only diagnostic and management options that the emergency physician should consider. ACEP clearly recognizes the importance of the individual physician's judgment. Rather, this guideline defines for the physician those strategies for which medical literature exists to provide support for answers to the crucial questions addressed in this policy.

Scope of Application. This guideline is intended for physicians working in hospital-based EDs.

Inclusion Criteria. This guideline is intended for patients presenting to the ED with acute, nontraumatic abdominal pain and possible or suspected appendicitis.

Exclusion Criteria. This guideline is not intended to address the care of patients with trauma-related abdominal pain, or pregnant patients.

CRITICAL QUESTIONS

1. Can clinical findings be used to guide decisionmaking in the risk stratification of patients with possible appendicitis?

Patient Management Recommendations

Level A recommendations. None specified.

Level B recommendations. In patients with suspected acute appendicitis, use clinical findings (ie, signs and symptoms) to risk-stratify patients and guide decisions about further testing (eg, no further testing, laboratory tests, and/or imaging studies), and management (eg, discharge, observation, and/or surgical consultation).

Level C recommendations. None specified.

Key words/phrases for literature searches: appendicitis, abdominal pain, clinical indicators, clinical predictors, prediction rule, probability, sensitivity and specificity or predictive value of tests or ROC curve, diagnosis, differential, decisionmaking, decision support techniques, diagnostic errors, missed diagnoses, computed tomography, and variations and combinations of the key words/phrases.

Whereas the diagnosis of appendicitis is often straightforward, many patients present with early or atypical signs and symptoms. Further, laboratory test results may be normal in the setting of appendicitis. We reviewed the literature to determine which clinical findings, if any, risk-stratify patients with suspected appendicitis and suggest the need for either a radiologic procedure or surgery.

For the purposes of this publication, missed appendicitis is considered a false-negative clinical evaluation, and the removal of a normal appendix is considered a false-positive clinical evaluation.

History and Physical Examination

In a meta-analysis of approximately 4,000 patients (Class II), right lower quadrant abdominal pain was the most useful clinical finding in suspected appendicitis (positive likelihood ratio 95% confidence interval [CI] 7.31 to 8.46 and a negative likelihood ratio 95% CI 0 to 0.28).[7] The authors only reported 95% CI because the included studies were heterogeneous.[7] In a separate meta-analysis, Andersson[8] found that pain migration (positive likelihood ratio 2.06, 95% CI 1.63 to 2.60; and negative likelihood ratio 0.42, 95% CI 0.40 to 0.69) and pain progression (positive likelihood ratio 1.39, 95% CI 1.29 to 1.50; and negative likelihood ratio 0.46, 95% CI 0.27 to 0.77) were less helpful. Two Class III studies found that right lower quadrant tenderness had positive likelihood ratios of 2.3 and 1.1 and negative likelihood ratios of 0 and 0.1.[9,10] Rigidity on abdominal examination carried a positive likelihood ratio of 3.8. Anorexia, tenderness on rectal examination, guarding, fever, and percussion tenderness in the right lower quadrant all had positive likelihood ratios below 2.9.[7,8]

Laboratory Tests

Although the total WBC count is frequently used in the diagnostic evaluation of acute appendicitis, when used alone it is not a consistent predictor. Cardall et al[11] demonstrated a positive likelihood ratio for an elevated WBC count (>10,000/mm^3) of 1.59 and a negative likelihood ratio of 0.46. In the meta-analysis by Andersson,[8] the positive likelihood ratio of an elevated WBC count (>10,000/mm^3) for appendicitis was 2.47 (95% CI 2.06 to 2.95) and the negative likelihood ratio was 0.25 (95% CI 0.18 to 0.36). The positive likelihood ratio was 3.47 (95% CI 1.6 to 7.8) in those patients with a WBC count greater than 15,000/mm^3.[8]

In a Class III study, Kessler et al[12] found that an elevated WBC count (>10,000/mm^3) carried a positive likelihood ratio of 2.7 and a negative likelihood ratio of 0.5. Birchley[13] found similar results when evaluating the WBC count in a small single-surgeon series.

Whereas neither the WBC count nor the C-reactive protein level consistently diagnoses or excludes appendicitis when used alone, the combination of C-reactive protein and WBC count is more helpful.[8] For a C-reactive protein level of 10 mg/L, Andersson[8] identified a positive likelihood ratio of 4.24 (95% CI 1.16 to 15.53) and a negative likelihood ratio of 0.11 (95% CI 0.05 to 0.25) for acute appendicitis. However, in this same meta-analysis, the negative likelihood ratio for the combination of a WBC count of 10,000/mm^3 and a C-reactive protein of 8 mg/L was 0.03 (95% CI 0.0 to 0.14). The positive likelihood ratio for the combination of both of these laboratory results was 23.32 (95% CI 6.87 to 84.79).

The Alvarado Score

Combining various signs and symptoms into a scoring system may be more useful in predicting the presence or absence of appendicitis. The Alvarado score, originally described in 1986, is the most widely reported scoring system for acute appendicitis[14] (Table 1). The score was developed retrospectively from patients hospitalized with suspected appendicitis. The Alvarado score combines patient symptoms, physical examination results, and laboratory values to assign a score from 0 to 10.

Table 1. Alvarado score in acute appendicitis.

		Value
Symptoms	Migration	1
	Anorexia-acetone (in the urine)	1
	Nausea-vomiting	1
Signs	Tenderness in right lower quadrant	2
	Rebound pain	1
	Elevation of temperature (>37.3°C measured orally)	1
Laboratory	Leukocytosis (>10,000/mm^3)	2
	Shift to the left (>75% neutrophils)	1
Total score		10
Score		
1-4	Appendicitis unlikely	
5-6	Appendicitis possible	
7-8	Appendicitis probable	
9-10	Appendicitis very probable	

Adapted from Alvarado A. A practical score for the early diagnosis of acute appendicitis. *Ann Emerg Med*. 1986;15:557-564 with permission from Elsevier.

Theoretically, higher Alvarado scores are associated with a higher likelihood of appendicitis and lower scores with a lower likelihood of appendicitis. Whether the Alvarado score can reliably predict the need for CT is debatable. In a Class III study, McKay and Shepherd[15] reviewed 150 charts to develop guidelines for CT scanning based on Alvarado scoring. Five percent of patients with scores of 3 or less had appendicitis, 36% of patients with scores between 4 and 6 had appendicitis, and 78% of patients with scores of 7 or higher had appendicitis. The authors concluded that patients with scores of 3 or less should not have CT (2 patients with appendicitis would have been missed in their series), those with scores between 4 and 6 should have CT, and those with scores 7 or higher would benefit from surgical consultation before CT. Chan et al,[16] in a Class III study, found that no patients with Alvarado scores below 5 had appendicitis.

In 2 other studies, a low Alvarado score did not reliably exclude appendicitis or the need for CT. In a Class III study, Gwynn[9] found that 12 (8.4%) of 143 subjects with appendicitis had Alvarado scores below 5. Patients in extremes of age (60 to 80 and 0 to 10 years of age) were misdiagnosed more frequently. In a small Class III study, Yildirim et al[17] found that 72% of patients with Alvarado scores between 1 and 4 ultimately had appendicitis, according to CT results and subsequent surgery. The authors recommended imaging even patients with low Alvarado scores.

Pediatric Considerations

In a Class II prospective cohort study, Kharbanda et al[18] identified 5 historical, physical examination, and laboratory findings that are significantly associated with pediatric appendicitis. The authors used logistic regression to identify nausea, a history of focal right lower quadrant pain, difficulty walking, rebound tenderness, and an absolute neutrophil count of greater than 6,750/mm^3 as significantly associated with acute appendicitis.[18] When these variables were combined into a scoring system and applied to a validation cohort, the scoring system resulted in a negative likelihood ratio of 0.058 (95% CI 0.008 to 0.41).

In a Class III study, Wang et al[19] evaluated the diagnostic performance of selected blood tests in children presenting to the ED with possible appendicitis. The authors defined an elevated WBC count and a left shift based on age-defined normal values. For both an elevated WBC count and a left shift, the positive likelihood ratio was 9.8. For either an elevated WBC count or a left shift, the negative likelihood ratio was 0.26. In contrast, the diagnostic performances of an elevated WBC count (positive likelihood ratio 3.4; negative likelihood ratio 0.41) and a left shift (positive likelihood ratio 5.9; negative likelihood ratio 0.45) individually were not as strong. The authors of this study did not disclose a criterion standard for the diagnosis or exclusion of acute appendicitis.

In a Class III prospective study, van den Broek et al[20] found that temperature greater than 38°C, a WBC count of 10,100/mm^3 or greater, and rebound tenderness were significantly associated with pediatric appendicitis. Using these factors in a scoring system, they created a prediction rule that resulted in a 1% missed appendicitis rate and a 9% negative appendectomy rate.

In a retrospective study, Klein et al[21] identified guarding and temperature greater than 38.4°C as predictive of appendicitis in girls 5 to 12 years of age, and tenderness and vomiting as predictive in boys 5 to 12 years of age. In boys older than 12 years, guarding and anorexia were predictive of appendicitis. In contrast to the studies by Kharbanda et al[18] and van den Broek et al,[20] Klein et al[21] found that adding WBC count to other clinical factors decreased diagnostic performance.

2. In adult patients with suspected acute appendicitis who are undergoing a CT scan, what is the role of contrast?

Patient Management Recommendations

Level A recommendations. None specified.

Level B recommendations. In adult patients undergoing a CT scan for suspected appendicitis, perform abdominal and pelvic CT scan with or without contrast (intravenous [IV], oral, or rectal). The addition of IV and oral contrast may increase the sensitivity of the CT scan for the diagnosis of appendicitis.

Level C recommendations. None specified.

Key words/phrases for literature searches: appendicitis, computed tomography, contrast, diagnosis, sensitivity, specificity, and variations and combinations of the key words/phrases.

Performing abdominal and pelvic CT without enteric or IV contrast for the evaluation of patients with suspected acute appendicitis is appealing for its speed and simplicity. Whether contrast provides a diagnostic advantage has been debated. IV contrast highlights inflammation in the wall of the appendix and in the tissue around the appendix.[22,23] Enteric contrast helps differentiate the appendix from surrounding structures.[24,25] Enteric and IV contrast may be more helpful in thin patients with low body mass index who lack sufficient mesenteric fat to demonstrate periappendiceal fat stranding that is associated with appendicitis.[26-28] Enteric and IV contrast also help identify conditions other than acute appendicitis (eg, diverticulitis, inflammatory bowel disease, cancer).[22,29,30]

Contrast has disadvantages. Oral contrast requires time to administer, requires time to transit the bowel, and may be difficult to tolerate for patients with abdominal pain and vomiting. Rectal contrast requires less time to administer than oral contrast but may be uncomfortable and unpleasant. IV contrast may lead to serious allergic reactions and renal failure. Contrast also adds to cost.[31] Increased sensitivity of newer-generation multislice CT scanners may improve diagnostic accuracy, obviating the need for contrast.

Multiple investigators have studied CT of the abdomen and pelvis for the evaluation of acute appendicitis (Table 2). Most of these studies evaluate a single CT technique (eg, noncontrast CT, CT with oral contrast, CT with rectal contrast, CT with IV contrast, CT with some combination of contrast types). In the majority of these studies, CT performs reasonably well, regardless of whether or not contrast is used.[22,26,27,31-49] When these studies are compared, it appears that the improvement in diagnostic accuracy achieved by the addition of IV or enteric contrast is small.

To determine the utility of oral contrast, Anderson et al[50] performed a systematic review of 23 prospective and retrospective reports on CT for suspected appendicitis. They reported the following weighted sensitivities and specificities: noncontrast CT 93% and 98%, CT with oral and IV contrast 93% and 93%, and CT with rectal contrast 97% and 97%. The authors concluded that oral contrast does not improve the accuracy of CT for the diagnosis of acute appendicitis.

The majority of publications concerning CT for the evaluation of acute appendicitis report on a single CT technique. Comparing the available studies of individual CT techniques is problematic. Study design varies significantly among the articles: setting (university versus community), study population (radiology series versus surgical series versus ED population), level of radiologist training and experience, inclusion criteria (all patients with suspected appendicitis versus those with equivocal presentations), CT slice type (helical versus conventional) and slice thickness (range 2.5 mm to 10 mm), enteric contrast protocol (type of oral contrast: barium, meglumine diatrizoate, diatrizoate sodium, or meglumine ioxitalamate), and contrast transit time (oral contrast transit times ranged from 40 minutes to longer than 2 hours).

To determine which CT technique is superior, CT techniques should be compared in a prospective, randomized trial. Only 3 studies have compared CT techniques head to

Table 2. Diagnostic accuracy of CT for diagnosing acute appendicitis in adults.

CT Technique	Study	No. Pts.	Prevalence %	Positive LR	Negative LR	Sensitivity %	Specificity %	Class
No contrast	Lane et al[27]	109	38	30	0.10	90	97	I
	in't Hof et al[33]	103	85	Undefined	0.05	95	100	I
	Lane et al[34]	300	38	96	0.04	96	99	I
	Ege et al[26]	296	36	48	0.04	96	98	II
	Malone et al[31]	211	36	29	0.13	87	97	II
	Hershko et al[32]*	70	41	6.4	0.12	90	86	II
	Cakirer et al[35]	130	72	12	0.05	95	92	II
	Horton et al[36]	49	76	Undefined	0.03	97	100	II
	Tamburrini et al[23]†	404	20	22	0.10	90	96	III
	D'Ippolito et al[45]	52	85	Undefined	0.09	91	100	III
	Morris et al[46]	129	30	9.8	0.13	88	91	III
Oral and IV contrast	Jacobs et al[22]*	210	22	18	0.10	91	95	I
	Hershko et al[32]*	84	51	9	0	100	89	II
	Balthazar et al[37]	100	64	5.8	0.02	98	83	II
	Hershko et al[38]	198	38	11	0.10	91	92	II
	Kamel et al[39]	100	24	Undefined	0.40	96	100	II
	Schuler et al[40]	97	52	49	0.02	98	98	II
	Ujiki et al[30]†	110	25	8.2	0.11	90	89	III
Rectal contrast	Rao et al[41]	100	53	49	0.02	98	98	I
	Hershko et al[32]*	78	50	19	0.07	93	95	II
	Pickuth and Spielmann[42]	120	78	8.6	0.06	95	89	II
	Walker et al[43]†	65	54	Undefined	0.06	94	100	II
	Wong et al[44]	50	74	12	0.05	95	92	II
	Mittal et al[51]*	39	92	Undefined	0.12	88	100	III
Oral contrast	Jacobs et al[22]*	210	22	13	0.26	76	94	I
	Wijetunga et al[28]	100	30	31	0.07	93	97	I
Rectal, oral, and IV contrast	Mittal et al[51]*	52	85	6.9	0.04	97	86	III
Rectal and IV contrast	Naffaa et al[47]	75	47	.10	0	100	90	II
Rectal+/-oral contrast	Funaki et al[24]	100	30	16	0.03	97	94	II
Oral and rectal contrast	Rao et al[48]	100	56	20	0	100	95	I
IV contrast	Mun et al[49]	173	32	33	0	100	97	III

Pts, patients; *LR*, likelihood ratio.
*Article appears in chart more than once because 2 or more techniques were studied.
†Analysis does not include inconclusive results.

head.[22,32,51] Two of these 3 studies suggest that the addition of contrast does improve the diagnostic performance of CT.[22,32]

CT With Oral and IV Contrast Versus CT With Rectal Contrast Versus Noncontrast CT

Hershko et al[32] published the only prospective randomized study comparing 3 different contrast protocols. CT with oral and IV contrast, and CT with rectal contrast were each more accurate than CT without contrast; CT with oral and IV contrast was more sensitive than CT with rectal contrast; CT with oral and IV contrast showed a trend toward increased sensitivity over CT without contrast. In this Class II study, Hershko et al[32] randomized 232 consecutive patients with suspected appendicitis to one of 3 protocols: 70 patients had CT without contrast, 78 patients had CT with rectal contrast, and 84 patients had CT with oral and IV contrast. CT with rectal contrast and CT with oral and IV contrast were both more accurate than CT without contrast: 94%, 94%, and 70%, respectively ($P<0.05$). CT with oral and IV contrast was more sensitive

Table 3. Diagnostic accuracy of ultrasound in diagnosing acute appendicitis in children.

Reference	No. Subjects	Disease Prevalence, %	Positive LR	Negative LR	Sensitivity, %	Specificity, %	Class
Baldisserotto and Marchiori[55]	425	47	49.5	0.01	99 (95% CI 97-100)	98 (95% CI 97-99)	II
Kaiser et al[56]	283	41	17.2	0.14	86	95	II
Chang et al[57]	40	75	8.7	0.14	87	90	III
Dilley et al[58]	587	86	17.8	0.12	89	95	III
Lowe et al[59]	76	33	8.3	0	100	88	III
Sivit et al[60]	315	26	11.1	0.2	78	93	III
Teo et al[61]	129	22	31	0.07	93	97	III
Ranges	**40-587 subjects**	**22-86**	**8.3-49.5**	**0-0.2**	**78-100**	**88-98**	**II-III**

than CT with rectal contrast, 100% (negative likelihood ratio 0) versus 93% (negative likelihood ratio 0.07) ($P<0.05$). CT with oral and IV contrast was observed to differ from CT without contrast with sensitivities of 100% (negative likelihood ratio 0) versus 90% (negative likelihood ratio 0.12), respectively; however, this difference did not achieve statistical significance.

CT With Oral Contrast Versus CT With Oral and IV Contrast

In a Class I study, Jacobs et al[22] prospectively compared 2 different contrast protocols and concluded that IV contrast improved the sensitivity of CT. In a case-crossover-design trial that included 210 subjects, each patient had focused appendiceal CT with only oral contrast, followed by nonfocused abdomen and pelvis CT with oral and IV contrast. The sensitivity of the nonfocused abdomen and pelvis CT with oral and IV contrast was 91% (negative likelihood ratio 0.1), whereas the sensitivity of the focused appendiceal CT with oral contrast was 76% (negative likelihood ratio 0.26). The authors attributed the higher sensitivity of the nonfocused abdomen and pelvis CT to the use of IV contrast; they believed that IV contrast improved the ability of the radiologist to identify an inflamed appendix.

CT With Oral, Rectal, and IV Contrast Versus CT With Rectal Contrast

In a Class III study, Mittal et al[51] compared the accuracy of 2 contrast protocols. The authors prospectively compared CT of the abdomen and pelvis with oral, rectal, and IV contrast to focused CT of the lower abdomen and pelvis with rectal contrast only. They found that CT with oral, rectal, and IV contrast had a sensitivity of 97% and specificity of 86% (negative likelihood ratio 0.04 and positive likelihood ratio 6.9), whereas CT with rectal contrast had a sensitivity of only 88% and a specificity of 100% (negative likelihood ratio 0.12 and an undefined positive likelihood ratio). The authors did not report whether these differences were statistically significant.

Inconclusive Results and Noncontrast CT

Noncontrast CT may produce inconclusive results. In the previously described study by Hershko et al,[32] 14 (20%) of 70 patients in the CT without contrast group had inconclusive CT results. Nine (13%) patients had repeat CTs with oral and IV contrast. In a Class III study, Tamburrini et al[23] reported a CT protocol with selective use of contrast. Patients with suspected appendicitis were first evaluated with noncontrast CT of the abdomen and pelvis. Patients with inconclusive results were rescanned with contrast, the type of contrast determined on a case-by-case basis by the interpreting radiologist. The authors performed a retrospective review of 536 patients undergoing this protocol. Noncontrast CT was conclusive in 404 (75%) patients and inconclusive in 132 (25%). Repeat CT was performed with some type of contrast in 126 (24%) patients.

3. In children with suspected acute appendicitis who undergo diagnostic imaging, what are the roles of CT and ultrasound in diagnosing acute appendicitis?

Patient Management Recommendations

Level A recommendations. None specified.

Level B recommendations.

1. In children, use ultrasound to confirm acute appendicitis but not to definitively exclude acute appendicitis.
2. In children, use an abdominal and pelvic CT to confirm or exclude acute appendicitis.

Level C recommendations. Given the concern over exposing children to ionizing radiation, consider using ultrasound as the initial imaging modality. In cases in which the diagnosis remains uncertain after ultrasound, CT may be performed.

Key words/phrases for literature searches: children, appendicitis, computed tomography, ultrasound, radiation, diagnosis, abdominal pain, sensitivity, specificity, and variations and combinations of the key words/phrases.

The diagnosis of acute appendicitis is challenging in the pediatric population, particularly among infants and toddlers. Missed or delayed diagnosis may result in perforation. Perforation rates for the pediatric population range from 17% to 57%,[52] which may cause longer hospital stays, bowel obstruction, and sepsis.[53,54]

CT has been advocated because it is an accurate diagnostic modality. However, CT is expensive and often requires contrast. CT also exposes the patient to ionizing radiation. Ultrasound has been advocated because it is fast, well tolerated, and safe.

Table 4. Diagnostic accuracy of CT in diagnosing acute appendicitis in children.

Reference	No. Subjects	Disease Prevalence, %	Contrast Type	Positive LR	Negative LR	Sensitivity, %	Specificity, %	Class
Lowe et al[59]	72	33	None	Undefined	0.03	97	100	II
Kaiser et al[62]	306	42	Either no contrast or just IV contrast	No contrast: 6.6; IV contrast: 16	No contrast: 0.38; IV contrast: 0.04	No contrast: 66; IV contrast: 96	No contrast: 90; IV contrast: 94	II
Sivit et al[60]	153	26	IV in 145/153 (95%), and oral or rectal in 151/153 (99%)	13.6	0.05	95	93	III
Acosta et al[63]	94	16	Rectal (alone)	50	0	100 (95% CI 66-100)	98 (95% CI 88-100)	III
Hoecker and Billman[64]	112	38	None	14.7	0.13	88 (95% CI 76-95)	94 (95% CI 95-98)	III
Mullins et al[65]	199	33	Rectal (alone)	97	0.03	97	99	III
Kharbanda et al[66]	416	40	Either IV alone or IV and rectal	IV alone: 11.6; IV and rectal: 7.1	IV alone: 0.08; IV and rectal: 0.09	IV alone: 93 (95% CI 84-97); IV and rectal: 92 (95% CI 85-97)	IV alone: 92 (95% CI 85-96); IV and rectal: 87 (95% CI 79-92)	III
Ranges	**72-416**	**16-42**		**No contrast: 6.6-undefined; rectal contrast: 50-97; IV contrast: 11.6-16; IV and rectal contrast: 7.1; all results: 6.6-undefined**	**No contrast: 0.03-0.38; rectal contrast: 0-0.03; IV contrast: 0.04-0.08; IV and rectal contrast: 0.09; all results: 0-0.38**	**No contrast: 66-97; rectal contrast: 97-100; IV contrast: 93-96; IV and rectal contrast: 92; all results: 66-100**	**No contrast: 90-100; rectal contrast: 98-99; IV contrast: 92-94; IV and rectal contrast: 87; all results: 87-100**	**II-III**

Diagnostic Accuracy of Ultrasound

Ultrasound may be used to evaluate children for appendicitis and does not involve ionizing radiation exposure. Diagnostic criteria for appendicitis are an appendix greater than 6 mm in diameter, a noncompressible appendix, and appendiceal tenderness. However, the appendix may be obscured (by bowel gas) or difficult to find (eg, retrocecal position). The 7 studies that evaluate the diagnostic accuracy of ultrasound in pediatric appendicitis (Table 3) support the idea that ultrasound is better at positively identifying appendicitis than excluding it with a negative or equivocal result.[55-61] For example, although 3 of the 7 studies listed in Table 3 report negative likelihood ratios for ultrasound less than 0.1,[55,59,61] 5 of these 7 studies report positive likelihood ratios greater than 10.[55,56,58,60,61]

There are no Class I studies evaluating ultrasound for acute appendicitis in children. There are 2 Class II studies evaluating ultrasound in pediatric appendicitis.[55,56] Both studies are prospective evaluations that report positive likelihood ratios from 17.2 to 49.5 and negative likelihood ratios from 0.01 to 0.14. Baldisserotto and Marchiori[55] was limited by lack of operator (ie, radiologist) blinding. Also, the ultrasound technique used by Baldisserotto and Marchiori[55] did not assess compressibility of the appendix (a diagnostic criterion in most studies). In the study by Kaiser et al,[56] ultrasound results were interpreted by pediatric surgeons and surgical residents, not radiologists. This limited the study's generalizability.

Of the 5 Class III ultrasound studies, 3 are prospective[57,60,61] and 2 are retrospective.[58,59] These Class III studies report positive likelihood ratios from 8.3 to 31 and negative likelihood ratios from 0 to 0.2. Of these prospective Class III studies, the study by Chang et al[57] had a small sample size (40 subjects). Two of the studies did not adequately identify or describe the outpatient follow-up of subjects with negative study results.[60,61] The ultrasound outcomes from the study by Lowe et al[59] were taken from the retrospective control arm of a prospective study. Lowe et al[59] also did not describe the duration of outpatient follow-up of subjects with negative study results, and their study had a relatively small sample size (76 subjects). Dilley et al[58] did not describe a criterion standard for outpatient follow-up of negative ultrasound results.

Diagnostic Accuracy of Abdominal and Pelvic CT

According to Class II and III evidence, CT is better than ultrasound at confirming and excluding appendicitis. Seven studies evaluated abdominal CT in diagnosing pediatric appendicitis[59,60,62-66] (Table 4). Of the 7 studies that evaluated CT for pediatric appendicitis, all study arms that involved the use of some type of contrast reported negative likelihood ratios less than 0.1, and all but one study[66] involving some type of contrast reported positive likelihood ratios greater than 10. All studies except one[66] reported specificities of 90% or greater. Specifically, 2 Class III studies of rectal contrast only reported positive likelihood ratios from 50 to 97 and negative likelihood ratios from 0 to 0.03 for acute appendicitis.[63,65]

Four of these studies were prospective[59,60,62,63] and 3 were retrospective.[64,65,66] Limitations of the articles by Lowe et al[59] and Sivit et al[60] are discussed under the ultrasound section. CT outcomes from the study by Lowe et al[59] were graded as Class II because the data were collected prospectively.

The Class II 2004 study by Kaiser et al[62] was based on CT scans from their 2002 study. These scans were reread by 3 radiologists who were blinded to patient outcomes and compared with outcomes from the 2002 study. The prospective study by Acosta et al[63] was limited by sample size (43 children included in outcomes calculations), generalizability (excluded children younger than 6 years), and potential bias (CT scans read by 1 radiologist). In 2007, Kharbanda et al[66] retrospectively studied 416 children who received a CT with either IV or IV and rectal contrast. Although Kharbanda et al[66] collected data retrospectively, the study was designed to occur throughout 2 consecutive study periods, during which children received one of the 2 CT techniques. In the study by Hoecker and Billman,[64] which was retrospective, 15 of 112 children were lost to follow-up. Mullins et al[65] conducted a retrospective study that had possible selection bias; children chosen for study may have been more clinically straightforward.

We found no prospective, randomized comparisons of ultrasound and CT for pediatric appendicitis. Three studies attempted to compare CT and ultrasound.[56,59,60] The Sivit et al[60] study was not randomized, Lowe et al[59] used a historical control group, and Kaiser et al[56] compared CT with ultrasound followed by CT.

The value of using CT with oral and IV contrast to diagnose appendicitis in children remains unclear. We found no direct evaluation of the diagnostic performance of oral and IV contrast alone for appendicitis in children. Nevertheless, some clinicians use oral and IV contrast to diagnose pediatric appendicitis according to the adult literature (discussed under critical question 2 about the role of contrast in CT for acute appendicitis in adults). Most children are smaller than adults and may have different peritoneal fat distributions. The question of whether or not adult outcomes (for CT in appendicitis) can be applied to children of all ages and sizes remains unanswered.

Ionizing Radiation and CT

There are no prospective studies that prove a link between CT and cancer in children. However, 2 Class III unstructured reviews argue that, because ionizing radiation at high doses (eg, atomic bomb) is associated with cancer, and this high-dose risk may proceed in a predictable fashion with dose, there may be a similar but small risk to children receiving diagnostic radiologic procedures (eg, CT).[67,68]

Another Class III article develops the argument supporting the risk of ionizing radiation from CT in a slightly different way.[69] Brenner and Hall[69] first present data that about 30% of patients who receive an abdominal and pelvic CT also receive at least 3 such CT scans in the course of their care. The authors then present data that atomic bomb survivors who received 50 to 150 mSv* of radiation had a small increase in cancer risk. Two to 3 abdominal/pelvic CT scans expose patients to a level of millisieverts similar to that of some atomic bomb survivors who developed cancer. Extrapolating backwards, the authors estimate the lifetime attributable risk of all cancers from 1 abdominal and pelvic CT to be 0.14% in neonates and approximately 0.06% in adults. Children have a higher risk of developing cancer after radiation exposure because they have more years to develop those cancers and are more radiosensitive (children have more actively dividing cells than adults).

In an effort to limit ionizing radiation exposure, some centers are using a staged approach by initially using ultrasound, and then using CT either to confirm or exclude the diagnosis in selected cases.[70,71] At this writing, this strategy has not been definitively validated in prospective studies.

Future Areas of Research

The following are suggestions for future research:

1. A prospective comparison of CT with no contrast, IV contrast alone, and oral and IV contrast (for appendicitis), using the newest CT technology. This study could be done in both adult and pediatric populations.
2. An analysis of a Bayesian approach using ultrasound to diagnose appendicitis in children. For example, in a child with low pretest clinical suspicion of appendicitis, does a negative or nondiagnostic ultrasound result suffice to exclude the diagnosis?
3. An analysis of clinical factors using recursive partitioning to determine whether combinations of history, physical examination, and laboratory results can help diagnose or exclude appendicitis. For example, does a negative WBC count and C-reactive protein result, combined with other clinical factors, exclude acute appendicitis?
4. Research protocols that focus on techniques for limiting ionizing radiation exposure from CT used to diagnose appendicitis.
5. A study of the role of MRI in diagnosing appendicitis.

*Millisieverts are the measure of radiation dose to organs, and this measurement is generally used in risk assessments of radiation.

Relevant industry relationships of subcommittee members: There were no relevant industry relationships disclosed by the subcommittee members.

Relevant industry relationships are those relationships with companies associated with products or services that significantly impact the specific aspect of disease addressed in the critical question.

REFERENCES

1. American College of Emergency Physicians. Clinical policy: critical issues for the initial evaluation and management of patients presenting with a chief complaint of nontraumatic acute abdominal pain. *Ann Emerg Med*. 2000;36:406-415.
2. Centers for Disease Control and Prevention. CDC releases latest data on emergency department visits. Advance Data number 340. 2004-1250. Accessed January 26, 2009. Available at: http://www.cdc.gov/nchs/pressroom/04facts/emergencydept.htm.
3. Kachalia A, Gandhi TK, Puopolo AL, et al. Missed and delayed diagnoses in the emergency department: a study of closed malpractice claims from 4 liability insurers. *Ann Emerg Med*. 2007;49:196-205.
4. Selbst SM, Friedman MJ, Singh SB: Epidemiology and etiology of malpractice lawsuits involving children in US emergency departments and urgent care centers. *Pediatr Emerg Care*. 2005;21:165-169.
5. Bundy DG, Byerley JS, Liles EA, et al. Does this child have appendicitis? *JAMA*. 2007;298:438-451.
6. Schriger DL, Cantrill SV, Greene CS. The origins, benefits, harms, and implications of emergency medicine clinical policies. *Ann Emerg Med*. 1993;22:597-602.
7. Wagner JM, McKinney WP, Carpenter JL. Does this patient have appendicitis? *JAMA*. 1996;276:1589-1594.
8. Andersson REB. Meta-analysis of the clinical and laboratory diagnosis of appendicitis. *Br J Surg*. 2004;91:28-37.
9. Gwynn LK. The diagnosis of acute appendicitis: clinical assessment versus computed tomography evaluation. *J Emerg Med*. 2001;21:119-123.
10. Tzanakis NE, Efstathiou SP, Danulidis K, et al. A new approach to accurate diagnosis of acute appendicitis. *World J Surg*. 2005;29:1151-1156.
11. Cardall T, Glasser J, Guss DA. Clinical value of the total white blood cell count and temperature in the evaluation of patients with suspected appendicitis. *Acad Emerg Med*. 2004;11:1021-1027.
12. Kessler N, Cyteval C, Gallix B, et al. Appendicitis: evaluation of sensitivity, specificity, and predictive values of US, Doppler US, and laboratory findings. *Radiology*. 2004;230:472-478.
13. Birchley D. Patients with clinical acute appendicitis should have pre-operative full blood count and C-reactive protein assays. *Ann R Coll Surg Engl*. 2006;88:27-32.
14. Alvarado A. A practical score for the early diagnosis of acute appendicitis. *Ann Emerg Med*. 1986;15:557-564.
15. McKay R, Shepherd J. The use of the clinical scoring system by Alvarado in the decision to perform computed tomography for acute appendicitis in the ED. *Am J Emerg Med*. 2007;25:489-493.
16. Chan MYP, Tan C, Chiu MT, et al. Alvarado score: an admission criterion in patients with right iliac fossa pain. *Surg J R Coll Surg Edinb Irel*. 2003;1:39-41.
17. Yildirim E, Karagulle E, Kirbas I, et al. Alvarado scores and pain onset in relation to multislice CT findings in acute appendicitis. *Diagn Interv Radiol*. 2008;14:14-18.
18. Kharbanda AB, Taylor GA, Fishman SJ, et al. A clinical decision rule to identify children at low risk for appendicitis. *Pediatrics*. 2005;116:709-716.
19. Wang LT, Prentiss KA, Simon JZ, et al. The use of white blood cell count and left shift in the diagnosis of appendicitis in children. *Pediatr Emerg Care*. 2007;23:69-76.
20. van den Broek WT, van der Ende ED, Bijnen AB, et al. Which children could benefit from additional diagnostic tools in case of suspected appendicitis? *J Pediatr Surg*. 2004;39:570-574.
21. Klein MD, Rabbani AB, Rood KD, et al. Three quantitative approaches to the diagnosis of abdominal pain in children: practical applications of decision theory. *J Pediatr Surg*. 2001;36:1375-1380.
22. Jacobs JE, Birnbaum BA, Macari M, et al. Acute appendicitis: comparisons of helical CT diagnosis—focused technique with oral contrast material versus nonfocused technique with oral and intravenous contrast material. *Radiology*. 2001;220:683-690.
23. Tamburrini S, Brunetti A, Brown M, et al. Acute appendicitis: diagnostic value of nonenhanced CT with selective use of contrast in routine clinical settings. *Eur Radiol*. 2007;17:2055-2061.
24. Funaki B, Grosskreutz SR, Funake CN. Using unenhanced helical CT with enteric contrast material for suspected appendicitis in patients treated at a community hospital. *AJR Am J Roentgenol*. 1998;171:997-1001.
25. Giuliano V, Giuliano C, Pinto F, et al. CT method for visualization of the appendix using a fixed oral dosage of diatrizoate—clinical experience in 525 cases. *Emerg Radiol*. 2005;11:281-285.
26. Ege G, Akman H, Sahin A, et al. Diagnostic value of unenhanced helical CT in adult patients with suspected acute appendicitis. *Br J Radiol*. 2002;75:721-725.
27. Lane MJ, Katz DS, Ross BA, et al. Unenhanced helical CT for suspected acute appendicitis. *AJR Am J Roentgenol*. 1997;168:405-409.
28. Wijetunga R, Tan BS, Rouse JC, et al. Diagnostic accuracy of focused appendiceal CT in clinically equivocal cases of acute appendicitis. *Radiology*. 2001;221:747-753.
29. Raman SS, Lu DSK, Kadell BM, et al. Accuracy of nonfocused helical CT for the diagnosis of acute appendicitis: a 5-year review. *AJR Am J Roentgenol*. 2002;178:1319-1325.
30. Ujiki MB, Murayama KM, Cribbins AJ, et al. CT scan in the management of acute appendicitis. *J Surg Res*. 2002;105:119-122.
31. Malone AJ Jr, Wolf CR, Malmed AS, et al. Diagnosis of acute appendicitis: value of unenhanced CT. *AJR Am J Roentgenol*. 1993;160:763-766.
32. Hershko DD, Awad N, Fischer D, et al. Focused helical CT using rectal contrast material only as the preferred technique for the diagnosis of suspected acute appendicitis: a prospective, randomized, controlled study comparing three different techniques. *Dis Colon Rectum*. 2007;50:1223-1229.
33. in't Hof KH, van Lankeren W, Krestin GP, et al. Surgical validation of unenhanced helical computed tomography in acute appendicitis. *Br J Surg*. 2004;91:1641-1645.
34. Lane MJ, Liu DM, Huynh MD, et al. Suspected acute appendicitis: nonenhanced helical CT in 300 consecutive patients. *Radiology*. 1999;213:341-346.
35. Cakirer S, Basak M, Colakoglu B, et al. Diagnosis of acute appendicitis with unenhanced helical CT: a study of 130 patients. *Emerg Radiol*. 2002;9:155-161.
36. Horton MD, Counter SF, Florence MG, et al. A prospective trial of computed tomography and ultrasonography for diagnosing appendicitis in the atypical patient. *Am J Surg*. 2000;179:379-381.

37. Balthazar EJ, Megibow AJ, Siegel SE, et al. Appendicitis: prospective evaluation with high-resolution CT. *Radiology*. 1991; 180:21-24.
38. Hershko DD, Sroka G, Bahouth H, et al. The role of selective computed tomography in the diagnosis and management of suspected acute appendicitis. *Am Surg*. 2002;68:1003-1007.
39. Kamel IR, Goldberg SN, Keogan MT, et al. Right lower quadrant pain and suspected appendicitis: nonfocused appendiceal CT—review of 100 cases. *Radiology*. 2000;217:159-163.
40. Schuler JG, Shortsleeve MJ, Goldenson RS, et al. Is there a role for abdominal computed tomographic scans in appendicitis? *Arch Surg*. 1998;133:373-377.
41. Rao PM, Rhea JT, Novelline RA, et al. Helical CT combined with contrast material administered only through the colon for imaging of suspected appendicitis. *AJR Am J Roentgenol*. 1997;169: 1275-1280.
42. Pickuth D, Spielmann RP. Unenhanced spiral CT for evaluating acute appendicitis in daily routine. A prospective study. *Hepatogastroenterology*. 2001;48:140-142.
43. Walker S, Haun W, Clark J, et al. The value of limited computed tomography with rectal contrast in the diagnosis of acute appendicitis. *Am J Surg*. 2000;180:450-455.
44. Wong SK, Chan LP, Yeo A. Helical CT imaging of clinically suspected appendicitis: correlation of CT and histological findings. *Clin Radiol*. 2002;57:741-745.
45. D'Ippolito G, Netto de Mello GG, Szejnfeld J. The value of unenhanced CT in the diagnosis of acute appendicitis. *Sao Paulo Med J*. 1998;116:1838-1845.
46. Morris KT, Kavanagh M, Hansen P, et al. The rational use of computed tomography scans in the diagnosis of appendicitis. *Am J Surg*. 2002;183:547-550.
47. Naffaa LN, Ishak GE, Haddad MC. The value of contrast-enhanced helical CT scan with rectal contrast enema in the diagnosis of acute appendicitis. *J Clin Imaging*. 2005;29:255-258.
48. Rao PM, Rhea JT, Novelline RA, et al. Helical CT technique for the diagnosis of appendicitis: prospective evaluation of a focused appendix CT examination. *Radiology*. 1997;202:139-144.
49. Mun S, Ernst RD, Chen K, et al. Rapid CT diagnosis of acute appendicitis with IV contrast material. *Emerg Radiol*. 2006;12:99-102.
50. Anderson BA, Salem L, Flum DR. A systematic review of whether oral contrast is necessary for the computed tomography diagnosis of appendicitis in adults. *Am J Surg*. 2005;190:474-478.
51. Mittal VK, Goliath J, Sabir M, et al. Advantages of focused helical computed tomographic scanning with rectal contrast only vs triple contrast in the diagnosis of clinically uncertain acute appendicitis. A prospective randomized study. *Arch Surg*. 2004; 139:495-500.
52. Bendeck SE, Nino-Murcia M, Berry GJ, et al. Imaging for suspected appendicitis: negative appendectomy and perforation rates. *Radiology*. 2002;225:131-136.
53. Yao CC, Lin CS, Yang CC. Laparoscopic appendectomy for ruptured appendicitis. *Surg Laparosc Endosc Percutan Tech*. 1999;9:271-273.
54. Klempa I. Current therapy of complicated appendicitis. *Chirurg*. 2002;73:799-804.
55. Baldisserotto M, Marchiori E. Accuracy of noncompressive sonography of children with appendicitis according to the potential positions of the appendix. *AJR Am J Roentgenol*. 2000; 175:1387-1392.
56. Kaiser S, Frenckner B, Jorulf HK. Suspected appendicitis in children: US and CT—a prospective randomized study. *Radiology*. 2002;223:633-638.
57. Chang CC, Tsai CY, Lin CC, et al. Comparison between technetium-99m hexamethylpropyleneamineoxide labeled white blood cell abdomen scan and abdominal sonography to detect appendicitis in children with an atypical clinical presentation. *Hepatogastroenterology*. 2003;50:426-429.
58. Dilley A, Wesson D, Munden M, et al. The impact of ultrasound examinations on the management of children with suspected appendicitis: a 3-year analysis. *J Pediatr Surg*. 2001;36:303-308.
59. Lowe LH, Penney MW, Stein SM, et al. Unenhanced limited CT of the abdomen in the diagnosis of appendicitis in children: comparison with sonography. *AJR Am J Roentgenol*. 2001;176: 31-35.
60. Sivit CJ, Applegate KE, Stallion A, et al. Imaging evaluation of suspected appendicitis in a pediatric population: effectiveness of sonography versus CT. *AJR Am J Roentgenol*. 2000;175:977-980.
61. Teo EL, Tan KP, Lam SL, et al. Ultrasonography and computed tomography in a clinical algorithm for the evaluation of suspected acute appendicitis in children. *Singapore Med J*. 2000;41:387-392.
62. Kaiser S, Finnbogason T, Jorulf HK, et al. Suspected appendicitis in children: diagnosis with contrast-enhanced versus nonenhanced helical CT. *Radiology*. 2004;231:427-433.
63. Acosta R, Crain EF, Goldman HS. CT can reduce hospitalization for observation in children with suspected appendicitis. *Pediatr Radiol*. 2005;35:495-500.
64. Hoecker CC, Billman GF. The utility of unenhanced computed tomography in appendicitis in children. *J Emerg Med*. 2005;28: 415-421.
65. Mullins ME, Kircher MF, Ryan DP, et al. Evaluation of suspected appendicitis in children using limited helical CT and colonic contrast material. *AJR Am J Roentgenol*. 2001;176:37-41.
66. Kharbanda AB, Taylor GA, Bachur RG. Suspected appendicitis in children: rectal and intravenous contrast-enhanced versus intravenous contrast-enhanced CT. *Radiology*. 2007;243:520-526.
67. Brody AS, Frush DP, Huda W, et al. Radiation risk to children from computed tomography. *Pediatrics*. 2007;120:677-682.
68. American Academy of Pediatrics. Committee on Environmental Health. Risk of ionizing radiation exposure to children: a subject review. *Pediatrics*. 1998;101:717-719.
69. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med*. 2007;357:2277-2284.
70. Garcia Pena BM, Taylor GA, Fishman SJ, et al. Effect of an imaging protocol on clinical outcomes among pediatric patients with appendicitis. *Pediatrics*. 2002;110:1088-1093.
71. Wan MJ, Krahn M, Ungar WJ, et al. Acute appendicitis in young children: cost-effectiveness of US versus CT in diagnosis—a Markov decision analytic model. *Radiology*. 2009;250:378-386.

Evidentiary Table.

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Bundy et al[5]	2007	Rational clinical examination	Evidence-based approach to the question "Does this child have appendicitis?"	Appendicitis	A thorough listing of diagnostic performance outcomes (for appendicitis) for history, physical examination, and selected diagnostic studies	No major limitations	III
Wagner et al[7]	1996	Meta-analysis of 10 articles with enough information to calculate likelihood ratios	Various signs, symptoms, and utility of laboratory tests in the diagnosis of appendicitis	Appendicitis at surgery or follow-up	More than 4,000 patients in the analysis; right lower quadrant pain sensitivity 0.81 but specificity of 0.53; positive likelihood ratio: 7.3-8.5; negative likelihood ratio: 0-0.28; next most useful sign was rigidity (positive likelihood ratio 3.76) and migration of the pain (positive likelihood ratio 3.18); no finding, or lack of finding, on examination definitely rules in appendicitis	Not all of the studies that were reviewed looked at all of the signs and symptoms	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Andersson[8]	2004	Meta-analysis; mostly prospective studies	24 studies compared	Surgery or observation	Average prevalence of appendicitis in studies: 60%; negative appendectomy range 5.2% to 42.2% (median 20.1%); variables with highest predictive value: migration of pain, rebound/guarding, C-reactive protein with elevated temperature, increased WBC count, neutrophils; appendicitis unlikely when all inflammatory variables were negative	Admitted patients only; variable diagnostic criteria for appendicitis	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Gwynn[9]	2001	Retrospective review of patients presenting with abdominal pain who had abdominal CT completed	Evaluated the Alvarado score as a diagnostic test compared with the effectiveness of CT in evaluating appendicitis	Appendicitis at surgery	215 patients, 163 had appendectomy; 143 true positives (88%); CT yielded correct diagnosis in 201 patients (93.4%); Alvarado score of 5 or greater considered positive for appendicitis with sensitivity of 91.6, specificity of 84.7; increase in sensitivity to 98.3, specificity 95.5 using clinical assessment with CT; Alvarado score 10 had positive likelihood ratio 12; AUC for Alvarado score was 0.94; elderly and young patients most likely to be misdiagnosed	Retrospective review; exclusions not recorded; decision to obtain CT not clear	III
Tzanakis et a[10]	2005	Observational study; 1 internal study for development and 1 for validation	Score developed for predicting presence of appendicitis; tested in validation study	Surgery or follow-up if discharged	303 patients admitted; 4 independent predictors found and points given for positive predictor: US for appendicitis (6), right lower quadrant tenderness (4), rebound tenderness (3), elevated WBC count (2); in external study of 201 patients, a cutoff of >8 points predicted appendicitis better than existing scores; 96.8% with scores between 8 and 15 had appendicitis	Follow-up not specified; imaging modality included; unlike other scoring systems; high diagnostic accuracy of US (90%)—others reported do not usually match this	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Cardall et al[11]	2004	Consecutive patients prospectively enrolled with primary diagnosis consideration of appendicitis using management guideline with WBC count and CT	WBC count obtained in subset of 274 patients (90%) of total CT in 80.5%	Appendicitis at surgery or 2-wk telephone follow-up	Prevalence of appendicitis 31%; sensitivity of increased WBC count in patients with appendicitis was 76% (95% CI 65% to 84%) and specificity 52% (95% CI 45% to 60%), positive likelihood ratio 1.59, negative likelihood ratio 0.46; positive likelihood ratio for increased temperature 1.3, and negative likelihood ratio 0.82; neither test is particularly useful in indicating appendicitis in group of those with suspected appendicitis	Laboratory examination obtained at discretion of ED physician, missed 10%; possible bias, likelihood ratio calculated from a continuous variable; clinicians not blinded to results	II
Kessler et al[12]	2004	Prospective evaluation of consecutive patients suspected at clinical examination of having appendicitis	Patients received abdominal US and WBC count and C-reactive protein assay	Appendicitis at surgery, or 6 mo follow-up for patients without surgery; no patients lost to follow-up	125 patients with suspected appendicitis, 46% prevalence; WBC count positive sensitivity 77%, specificity 63%; C-reactive protein positive: sensitivity 60%, specificity 68%; both WBC count and C-reactive protein positive: sensitivity 47%, specificity 84%; authors do not recommend laboratory tests as part of algorithm to restrict imaging	US was imaging modality, not CT; not generalizable: only experienced radiologist in gastrointestinal radiology did the study	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Birchley[13]	2006	Single-surgeon retrospective review of the data of his patients that were operated on for suspected appendicitis	Surgery, laboratory examination pre-operative	Comparing total WBC count and C-reactive protein in patients with or without acute appendicitis at surgery	22% negative laparotomy rate; positive likelihood ratio for increased WBC count: 2.34, negative likelihood ratio: 0.33; C-reactive protein: positive likelihood ratio: 1.34, negative likelihood ratio: 0.55; probability of normal appendix, given normal test result (WBC) count is 48%; combining WBC count with C-reactive protein brings probability to 71% if normal, positive likelihood ratio 2.10, negative likelihood ratio 0.12	Many patients did not have blood for laboratory tests drawn (13%); small series	III
Alvarado[14]	1986	Retrospective review	Patients hospitalized for possible appendicitis, observation or surgery	Appendicitis at surgery or observation	305 patients, 28 excluded; prevalence of appendicitis in remaining patients 81%; 11% negative appendectomy rate; diagnostic indicators: right lower quadrant pain and leukocytosis most reliable signs; specificity relatively low on all signs	Retrospective; patients all admitted with suspected appendicitis; very high prevalence of the disease—any sign or symptom associated with positive disease; bias introduced; follow-up of nonsurgical patients not defined; not all patients had all tests	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
McKay and Shepherd[15]	2007	Retrospective review of patients receiving CT examinations	Patients received CT by ED physicians for suspected appendicitis, then Alvarado score calculated retrospectively	Pathology at surgery or clinical follow-up	150 charts reviewed; Alvarado score 3 or less sensitivity for not having appendicitis 96% (53/55); Alvarado score 7 or greater, sensitivity 77% (28/36), specificity 100% (8/8); equivocal score: 4-6 had sensitivity 35.6% (21/59), and specificity 94% for appendicitis; sensitivity of CT in those with equivocal scores was 90.4% and 95%, respectively	Retrospective review of the records; small sample size; not all received criterion standard	III
Chan et al[16]	2003	Prospective evaluation of patients with suspected appendicitis	Patients had Alvarado score calculated and compared to surgical results or clinical follow-up in clinic	Pathology at surgery or clinic follow-up	175 patients, 15.7% negative appendectomy rate; patients with Alvarado score of 4 or less: none with acute appendicitis; 10/14 patients with score 9 had appendicitis; 15/22 with score of 8 had appendicitis	Decision to admit independent of score, admission criteria not specified; small numbers at each of the Alvarado scores	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Yildirim et al[17]	2008	Retrospective review of consecutive patients with abdominal pain	CT and Alvarado score completed on each patient	Pathology at surgery	143 patients, 13 (9%) negative appendicitis at surgery; 3 groups by Alvarado score: group 1: score 1-4, group 2: score 5-7, and group 3: score 8-10; 72.2% of group 1 had appendicitis, group 2: 84% had appendicitis, group 3: 93% had appendicitis; sensitivity and specificity of CT was 96.1 and 66.6 respectively; results in patients presenting with less than 12 h of pain not different from those of others presenting later	Retrospective; small number of patients; very high incidence of appendicitis in group with low Alvarado score—unlike other studies; very high prevalence of appendicitis in the entire study (about 80%)	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Kharbanda et al[18]	2005	Prospective cohort study; included children aged 3-18 y and underwent surgical consultation for possible appendicitis (as per hospital guidelines, all patients suspected of having appendicitis must see a surgeon before imaging ordered); excluded: pregnancy, previous abdominal surgery, chronic medical conditions, radiologic studies in previous 2 wks; total: 601 patients	24 demographic, historical, physical examination variables; data collection instrument completed before imaging, independent of surgical evaluation; patient record abstracted for WBC count, percentage of neutrophils, absolute neutrophil count, radiology, and pathology reports	Presence of appendicitis (by pathology, written postoperative diagnosis for perforation, telephone follow-up in 2-4 wks if no surgery done); χ^2 testing to identify predictors for appendicitis, as well as univariate recursive partitioning for continuous variables; logistic regression and recursive portioning used to create clinical decision rule; validation of same with cohort just after initial enrollment, same hospital	Derivation, logistic regression identified: nausea, history of focal right lower quadrant pain, difficulty walking, rebound tenderness and absolute neutrophil count >6.75x103 µL; score of 5 or less identified 108 patients, 106 if these did not have appendicitis—sensitivity 98.7% (95% CI 95.5%-99%), NPV 98.1% (95% CI 93.5%-99.7%); validation: sensitivity 96.3% (95% CI 87.5%-99%); NPV 95.6% (95% CI 90.8%-99%); recursive partitioning, derivation: absolute neutrophil count >6.75, nausea/emesis/anorexia, maximal tenderness in right lower quadrant; sensitivity 100% (95% CI 97.7%-100%), NPV 100% (95% CI 96.0%-100%); validation: sensitivity 98.1% (95% CI 90.1%-99.9%), NPV 97.5% (95% CI 86.8%-99.9%)	Patients identified as low risk by either prediction model should be considered for observation instead of imaging; data collection instrument "inherently subjective"; did not calculate κ values; surgical consultation thresholds vary by institution; derivation and validation in single center	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Wang et al[19]	2007	Retrospective study (data collected prospectively and some data collected retrospectively)	Evaluated diagnostic performance of various blood tests (eg, WBC count, left shift)	Outcome: acute appendicitis; criterion standard: not stated under methods	104 children studied; disease prevalence: 10.2%; high WBC count and left shift: sensitivity 59% and specificity 94%; LR+ for high WBC count and left shift: 9.8, LR- 0.44; for either elevated WBC count or left shift, sensitivity 79%, specificity 0%, LR+ 3.9 and LR- 0.26	Criterion standard not stated; did not account for dropouts and crossovers; poor generalizability	III
van den Broek et al[20]	2004	Prospective data collection, retrospective validation of scoring tool; children referred to hospital by general practitioner for suspected appendicitis; 2 groups during 2 time periods	Demographics, history and physical findings, and laboratory findings recorded with goal of creating a scoring/prediction tool; patients classified as unlikely, doubtful, or highly suspected of having appendicitis based on above by physicians, and then got observation, laparoscopy, or open appendectomy, respectively	Appendicitis—based on observation, laparoscopy, or open appendectomy; CT and US imaging were not used; (externally validated with patients from another abdominal pain study who did have US)	Temperature 38°C or greater ($P<0.024$), WBC count 10,100/mm^3 or greater ($P<0.001$), and rebound tenderness ($P<0.001$) predictive of appendicitis; each of these given score by logistic regression, 1, 2, 2, respectively; OR of score in groups: 1 (2.4); 2 (3.2); in validation gives missed appendectomy rate 1%, negative appendectomy rate of 9%	Temperature, WBC count, and rebound tenderness raise clinical suspicion for appendicitis; difficult to generalize because patients referred for possible appendicitis by general practitioner impression likely already have high pretest probability; useful to rule in, not rule out, negative appendectomy rates not improved using the scoring system	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Klein et al[21]	2001	Retrospective review, all patients to pediatric hospital with abdominal pain over 3 mos; review done within 72 h, follow-up done at 2 wks	Charts reviewed for history, physical, laboratory, and radiologic findings	Presence of appendicitis; recursive partitioning and logistic regression models done to assess diagnostic probability	Recursive partitioning identified: girls 5-12 y, guarding and temperature above 38.4°C; boys 5-12 y, tenderness and vomiting; boys >12 y, guarding, anorexia; binary logistic regression: history and physical examination (only) had predictive accuracy 94.4%, PPV 19%, NPV 99.2% (important variables: guarding, tenderness, vomiting, anorexia, temperature); history and physical examination with WBC count had predictive accuracy 89.1%, PPV 18%, NPV 98.8% (important variables: guarding, WBC count, tenderness, anorexia)	History and physical examination alone have high predictive accuracy and NPV, these were less when WBC count included; pediatrics only, retrospective, telephone follow-up; could test decision analysis on a different population	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Jacobs et al[22]	2001	Prospective	Comparison between focused appendix CT with oral contrast, without IV contrast, and nonfocused abdomen/pelvis CT with oral and IV contrast for the diagnosis of acute appendicitis; all patients enrolled had both types of CT scan; population: ED patients; aged 13-87 y	Detection of acute appendicitis on CT criterion standard: pathologic findings at surgery or clinical follow-up (reported but details not specified)	228 patients enrolled, 18 lost to follow-up; 51 (22%) confirmed appendicitis; focused CT without IV contrast results: sensitivity: 76%, specificity: 94%; nonfocused CT with IV contrast results: sensitivity: 91%, specificity: 95%; nonfocused CT with IV contrast more accurate than focused CT without IV contrast	3 radiologists with 20 y, 3 y, and 1 mo of experience as attending participated in the study	I
Tamburrini et al[23]	2007	Retrospective	Protocol used at 1 Italian institution reviewed; patients with suspected appendicitis first evaluated with noncontrast CT; patients with inconclusive results had CT with contrast (oral, rectal and/or IV); population: patients with uncertainty for appendicitis; aged 18-86 y; 316 female; 220 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 4 wks	536 consecutive patients; noncontrast CT conclusive in 404, inconclusive in 132 (25%); 126 (24%) patients had repeat CT with some type of contrast; CT results: sensitivity: noncontrast CT 90%, CT with contrast 96%, all CT 91%; specificity: noncontrast CT 96%, CT with contrast 92%, all CT 95%	Referral population not specified (ED, surgery service, outpatient); contrast protocol not standardized; contrast type at the discretion of the radiologist; patients therefore received a heterogeneous assortment of contrast cocktails; inconclusive CTs reviewed by abdominal radiologist who found 85 (16%) truly nondiagnostic; it is concerning that 24% of patients received 2 CT scans	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Funaki et al[24]	1998	Prospective	Helical CT, focused appendiceal, rectal or rectal+oral contrast; population: ED patients with uncertainty for appendicitis referred for CT; aged 6-71 y; 63 females; 37 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up for 2 mo	100 consecutive patients included; 30 (30%) patients had confirmed appendicitis; CT results: 29 true-positive, 4 false-positive, 66 true-negative, 1 false-negative; sensitivity: 97%; specificity: 94%; alternate diagnosis provided in 36 (54%)	Community hospital setting; no inclusion/exclusion criteria reported; included children; many more females than males enrolled; patients did not all receive the same type of contrast (some received rectal only, others oral and rectal)	II
Giuliano et al[25]	2005	Prospective	Helical CT, pelvis, oral and IV contrast; study to evaluate the efficacy of a new oral contrast agent in focused helical CT of the pelvis for identification of the appendix; population: outpatients; aged 8-68 y; 367 females; 158 males	Identification of appendix on CT; criterion standard: surgery or clinical follow-up	525 patients studied; 79 patients did not have a normal appendix identified on CT; 21 (4%) had findings consistent with appendicitis; all 21 confirmed appendicitis at surgery; CT for detection of appendicitis: sensitivity: 100%; specificity: 99%	Study done to evaluate effectiveness of new oral contrast agent in identifying the appendix; however, not compared with control or standard oral agent; not as useful for appendicitis question because of low rate of acute appendicitis and outpatient setting	I
Ege et al[26]	2002	Retrospective case series	Helical CT, pelvis, no contrast; population: surgical service patients with uncertainty for appendicitis; aged 16-69 y; 109 females; 187 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up for up to 3 mos	296 patients had CT; 123 patients had surgery; 108 (36%) confirmed appendicitis; CT results: 104 true-positive, 3 false-positive, 185 true-negative, 4 false-negative; sensitivity: 96%; specificity: 98%	No comment if patients were consecutive; authors comment that of the 4 patients with false-negative CT scans, all were slender with very little periappendiceal or pericecal fat	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Lane et al[27]	1997	Prospective	Helical CT, T12-pubic symphysis, no contrast; population: ED patients; age range not reported; 51 females; 58 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (reported but details not specified)	109 patients; 41(38%) confirmed appendicitis; CT results: 37 true-positive, 2 false-positive, 66 true-negative, 4 false-negative; sensitivity: 90%; specificity: 97%; alternative diagnosis identified by CT in 24 patients (22%)	Not reported to be a consecutive series of patients; number of patients eligible for enrollment, number of patients not enrolled, not reported; authors report they studied 109 ED patients referred for noncontrast CT to evaluate for appendicitis; were there patients who had contrast CT during the same period?; no inclusion criteria beyond referral from ED	I
Wijetunga et al[28]	2001	Prospective	Helical CT, appendiceal scan, oral contrast; ED population; patients with uncertainty for appendicitis included; patients were referred for CT by the general surgeon on call; aged 14-81 y; 59 female; 46 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up in the next 1-8 mo	105 consecutive patients, 5 lost to follow-up, 100 patients included; 30 (30%) confirmed appendicitis; CT results: 28 true-positive, 2 false-positive, 68 true-negative, 2 false-negative; sensitivity: 93%; specificity: 97%; alternative diagnosis identified by CT in 23 (33%) patients	Patients presenting between midnight and 8 AM were observed until morning, had CT after that	I

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Raman et al[29]	2002	Retrospective	Helical CT, abdomen/pelvis, variety of contrast; most (84%) had oral and IV, 1.5% had no contrast; population from radiology, surgery and pathology databases; aged 18-99 y; 424 female; 226 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (follow-up reported but details not specified)	650 consecutive patients; 98 did not have adequate follow-up and were excluded from analysis; 552 patients included; 142 (26%) confirmed appendicitis; CT results: 137 true-positive, 8 false-positive; 402 true-negative, 5 false-negative; sensitivity: 97%; specificity: 98%; during this period, 69% of patients with appendectomy for suspected appendicitis had surgery without preceding CT	Large number of patients lost to follow-up, not included in analysis; inconsistent use of contrast	III
Ujiki et al[30]	2002	Retrospective	Helical CT, abdomen and pelvis, oral and IV contrast; population: patients with uncertainty for appendicitis referred for CT; not clear where patients came from (ED, surgical service, primary care office?); aged 17-85 y; 69 female; 41 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up by telephone interview	110 patients; 1 patient scanned twice=111 CT scans; 28 (25%) confirmed appendicitis; CT results: 28 true-positive, 8 false-positive, 64 true-negative, 3 false-negative; 8 equivocal CTs; sensitivity: 90%; specificity: 89%; alternative diagnosis identified by CT in 31 (46%) patients	No comment on what happened to patients with equivocal CT scans; equivocal scans not included in statistical analysis	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Malone et al[31]	1993	Prospective	CT, lower abdomen, no contrast; population: patients referred for emergency barium study to rule out appendicitis first had noncontrast CT; aged 4-91 y; 130 females; 81 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up for 6 mo	211 patients; 94 patients had surgery; 75 (36%) confirmed appendicitis; CT results: 65 true-positive, 4 false-positive, 132 true-negative, 10 false-negative; sensitivity: 87%; specificity: 97%	Radiologists not reported to be blinded to barium study results; appears to be consecutive series; very specific population: patients referred for emergency barium study; there were patients who were referred for CT during the same period, not included in the study; barium study results not reported	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Hershko et al[32]	2007	Prospective randomized	CT without contrast (NCCT), CT with rectal contrast (RCCT), and CT with oral and IV contrast (DCCT) were compared; population unclear; aged 16-83 y	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up	232 consecutive patients with suspected appendicitis referred for CT randomly assigned to NCCT, RCCT or DCCT; 111 (48%) confirmed appendicitis; results: NCCT 70 patients, 29 (41%) confirmed appendicitis; RCCT 78 patients, 39 (50%) confirmed appendicitis; DCCT 84 patients, 43 (51%) confirmed appendicitis; sensitivity: NCCT 90%, RCCT 93%, DCCT 100%; specificity: NCCT 86%, RCCT 95%, DCCT 89%; significant differences with $P<0.05$ found: DCCT superior to RCCT for sensitivity; RCCT superior to DCCT for specificity; RCCT and DCCT were both more accurate than NCCT	Referral population not specified (ED, surgery service, outpatient); calculation of sensitivity/specificity for RCCT different than author: sensitivity=95%, specificity=92%; NCCT had 14 (20%) inconclusive results; 9 of these had additional CT with oral and IV contrast; these were not included in sensitivity/specificity analysis; CT initially interpreted by residents; attending radiologists overread films, were blinded to treatment plan, had good concordance with resident reading; follow-up reported but no specific details provided	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
in't Hof et al[33]	2004	Prospective	Helical CT, abdomen and pelvis, no contrast; patients with suspected appendicitis had CT followed by laparoscopy; population: ED patients; aged >16 y; 39 female; 64 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at laparoscopy; all patients had laparoscopy; follow-up at 1 wk and 6 wks as well	103 patients enrolled, 87 (84%) confirmed appendicitis; CT results: sensitivity: 95%; specificity: 100%	Higher rate of appendicitis than most series	I
Lane et al[34]	1999	Prospective	Helical CT, T12-pubic symphysis, no contrast; population: patients referred from ED or general surgery service; aged 8-86 y; 156 female; 144 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (follow-up reported but details not specified)	300 consecutive patients; 115 (38%) confirmed appendicitis; CT results: 110 true-positive, 4 false-positive, 181 true-negative, 5 false-negative; sensitivity: 96%; specificity: 99%; alternative diagnosis identified by CT in 63 (21%) of patients	No report about contrast CTs done during the same period; no inclusion criteria beyond referral from ED or general surgery service	I
Cakirer et al[35]	2002	Prospective	Helical CT, pelvis, no contrast; population: department of emergency surgery patients; aged 16-67 y; 63 female; 67 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (follow-up reported but details not specified)	141 consecutive patients; 11 excluded; 130 patients included; 94 (72%) confirmed appendicitis; CT results: 89 true-positive, 3 false-positive, 33 true-negative, 5 false-negative; sensitivity: 95%; specificity: 92%	Higher rate of appendicitis than most series; not reported if this was all patients with suspected appendicitis or only those with clinical uncertainty	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Horton et al[36]	2000	Prospective, randomized	Noncontrast pelvic CT and US were compared in patients with atypical presentations of appendicitis; populations: ED patients with uncertainty for appendicitis; age included but not reported, reported eligible aged 18-65 y; 48 females; 41 males	Detection of acute appendicitis on CT or US; criterion standard: pathologic findings at surgery or clinical follow-up (follow-up reported but details not specified)	89 patients enrolled, 49 had CT, 40 had US; CT results: sensitivity: 97%, specificity: 100%; US results: sensitivity: 76%, specificity: 90%; CT was more sensitive and specific for the diagnosis of acute appendicitis and more helpful in identifying other intra-abdominal pathology	Not reported to be a consecutive series of patients; number of patients eligible for enrollment, number not enrolled, not reported; characteristics of entire study group reported, however, characteristics of US and CT groups not reported and compared (ie, age, gender ratio, presenting signs and symptoms); this study is useful to show that CT is more sensitive, specific than US and also more helpful to identify other surgical pathology	II
Balthazar et al[37]	1991	Prospective	CT abdomen/pelvis, oral and IV contrast; population: patients on surgical service with uncertainty for appendicitis referred for CT; aged 9-87 y; 48 female; 52 male	Detection of appendicitis on CT; criterion standard: surgical findings, clinical follow-up, discharge diagnosis	100 consecutive patients, 64 (64%) confirmed appendicitis; CT results: 60 true-positive, 4 false-positive, 30 true-negative, 1 false-negative; 5 equivocal readings; sensitivity: 98%; specificity: 83%	Older study; higher prevalence of appendicitis than expected in typical ED population	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Hershko et al[38]	2002	Prospective evaluation of CT and retrospective case/control for evaluation of negative appendectomy rate	Helical CT, abdomen/pelvis, with oral and IV contrast; population: ED patients referred for surgical consultation; aged 15-83 y; 151 females;157 males; rate of negative appendectomy was compared for patients evaluated with CT vs patients evaluated on clinical presentation alone (without CT)	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (exact follow-up method not specified)	308 consecutive patients; 65 patients with "definite" appendicitis by clinical evaluation went straight to operating room; 57/65 (88%) confirmed appendicitis; 37 patients who were "unlikely" to have appendicitis did not have CT and were followed clinically; none had appendicitis; 198 patients with uncertainty for appendicitis had CT; 74 (37%) of these had confirmed appendicitis; CT results: 67 true-positive, 7 false-positive, 118 true-negative, 5 false-negative; 9 equivocal CTs; sensitivity: 91%; specificity: 92%; alternative diagnosis provided in 23 (19%); negative appendectomy rate for pre-CT era compared with study rate; pre-CT rate=24%; study rate=16%; difference P<0.05	Reported data confusing; numbers of patients do not add up; they report 198 patients had CT, 74 interpreted as positive, 123 negative, and 9 equivocal; 74+123+9=206; university setting, resident radiologists gave preliminary reading; attending radiologist reading correlated in all but 2 cases	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Kamel et al[39]	2000	Retrospective	Helical CT, abdomen/pelvis, oral and IV contrast; population: ED patients with uncertainty for appendicitis; aged 19-77 y; 63 female; 37 male	Detection of acute appendicitis or other surgical conditions on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 3 mo	100 consecutive patients; 34 patients had surgery; 24 (24%) confirmed appendicitis; none lost to follow-up; CT results: 23 true-positive, 0 false-positive,76 true-negative, 1 false-negative; sensitivity: 96%; specificity: 100%	Authors advocate CT of entire abdomen/pelvis rather than focused appendix; authors note that 4 patients with abnormalities requiring surgery had findings in the abdomen portion of the CT that would have been missed with a focused pelvic CT	II
Schuler et al[40]	1998	Retrospective	Helical CT, abdomen/pelvis, oral and IV contrast; population: unclear; appears to be surgical consultations and ED patients; 2 groups: (1) likely appendicitis, had surgery without second CT; (2) uncertain appendicitis, had CT; group 1: aged 17-68 y, 25 female, 27 male; group 2: aged 15-88 y, 59 female, 38 male; CT was evaluated for accuracy in diagnosis of appendicitis; negative appendectomy rates were compared for patients who went directly to surgery vs patients who had CT during the study period	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up by telephone call	149 patients; 52 patients judged to have appendicitis clinically and had surgery; negative appendectomy rate in this group=21%; 97 patients uncertain for appendicitis had CT, 50 confirmed appendix pathology (49 appendicitis, 1 endometriosis of the appendix); negative appendectomy rate in this group=5.8%; CT results: 49 true-positive, 1 false-positive, 43 true-negative, 1 false-negative; 3 equivocal; sensitivity: 98%; specificity: 98%; CT identified alternative diagnosis in 16 (34%) patients	Not reported to be consecutive; number of patients eligible for enrollment, number of patients not enrolled, not reported; negative appendectomy rate lower in group with CT than in group managed clinically; authors report overall negative appendectomy rate=13.5% for both groups; in the 3 y before use of CT, rate was 13.6%; perforation rates not reported	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Rao et al[41]	1997	Prospective	Helical CT, limited appendiceal scan, rectal contrast; population: patients admitted with suspected appendicitis; aged 6-75 y; 57 female; 43 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 1 wk and 2 mo	100 patients, appears consecutive; 53 (53%) confirmed appendicitis; CT results: 52 true-positive, 1 false-positive, 46 true-negative, 1 false-negative; sensitivity: 98%; specificity: 98%	Patients eligible only if admitted for evaluation	I
Pickuth and Spielmann[42]	2001	Prospective	Spiral CT, lower abdomen/upper pelvis, rectal contrast; population not specified; patients had uncertainty for appendicitis; aged 18-81 y; 63 female; 57 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (reported but details not specified)	120 consecutive patients referred for CT; 93 (78%) confirmed appendicitis; CT results: 88 true-positive, 3 false-positive, 24 true-negative, 5 false-negative; sensitivity: 95%; specificity: 89%; alternative diagnosis identified in 14 (52%) patients	CT repeated with patient in left lateral decubitus position if appendix not visualized on initial scan; higher prevalence of appendicitis than expected in typical ED population	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Walker et al[43]	2000	Prospective	Helical CT, appendiceal scan, rectal contrast; prospective randomized study comparing standard management with management with CT for patients with suspected appendicitis; ED population; patients included if they had a general surgery consultation for appendicitis; aged 18-80 y; 84 female; 44 male; no significant difference in age, gender ratio for CT group vs standard management group	Detection of acute appendicitis on CT vs clinical examination; criterion standard: pathologic findings at surgery or clinical follow-up by telephone call	128 patients, 65 randomized to CT group, 35 (54%) confirmed appendicitis; 63 randomized to standard management, 29 (46%) confirmed appendicitis; CT group: sensitivity: 94%, specificity: 100%; negative exploration rate: 5%; standard management group: sensitivity: 100%, specificity: 79%; negative exploration rate: 19%	Not reported to be consecutive; number of patients eligible for enrollment, number of patients not enrolled, not reported; patients in standard group were allowed to have CT if surgeon requested; however, authors did not report how many actually did; equivocal CT not included in statistical analysis; negative exploration rate lower in CT group than standard management group; perforation rates in 2 groups not reported	II
Wong et al[44]	2002	Prospective	Helical CT, appendiceal scan, rectal contrast; population: patients with suspected appendicitis who were scheduled for appendectomy, prospectively enrolled; aged 16-75 y; 21 female; 29 male	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery, all patients had surgery	50 patients with suspected appendicitis scheduled for surgery were included; 37 (74%) confirmed appendicitis; negative appendectomy rate=26%; CT results: 35 true-positive, 1 false-positive, 12 true-negative, 2 false-negative; sensitivity: 95%; specificity: 92%	Not reported to be consecutive; number of patients eligible for enrollment, number of patients not enrolled, not reported; surgeons blinded to CT results unless the results would alter surgical approach; higher prevalence of appendicitis than expected in typical ED population	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
D'Ippolito et al[45]	1998	Prospective case series	CT pelvis, no contrast; population: series of patients who had both surgery for suspected appendicitis and a preceding CT; aged 6-64 y; 27 females, 25 males	Detection of acute appendicitis on CT; criterion standard: surgery (all patients had surgery)	52 patients included; all had surgery within 5 days of CT; 44 (85%) confirmed appendicitis; CT results: 40 true-positive, 0 false-positive, 8 true-negative, 4 false-negative; sensitivity: 91% (95% CI 78%-98%); specificity: 100% (95% CI 63%-100%)	Appears to be a series of patients who had both unenhanced CT and an operation; higher prevalence of appendicitis than expected in typical ED population	III
Morris et al[46]	2002	Retrospective	CT "limited" scan, no contrast; ED CT accuracy was compared with surgeon opinion accuracy based on surgeon review of chart; population: ED patients; aged 16-95 y; 71 females, 58 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up (reported but details not specified)	129 patients; 39 (30%) had confirmed appendicitis; CT results: 38 true-positive, 8 false-positive; 82 true-negative, 1 false-negative; authors' calculations: sensitivity: 88%; specificity: 91%	CT ordered by the ED; sensitivity calculated by authors=88%; calculations differed: sensitivity=97% for detection of appendicitis; a panel of surgeons reviewed ED history and physical examination data, provided their evaluation: take to operating room for appendicitis, admit for observation, or discharge; sensitivity and specificity of surgeon evaluation was compared with CT, found to be similar	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Naffaa et al[47]	2005	Retrospective	Helical CT, abdomen/pelvis; rectal and IV contrast; population: ED patients with uncertainty for appendicitis; aged 7-87 y; 40 females, 35 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 6 mo	75 consecutive patients; 35 (47%) had confirmed appendicitis; CT results: 35 true-positive, 4 false-positive, 36 true-negative, 0 false-negative; sensitivity: 100%; specificity: 90%	Children and young women had US before CT; only those with inconclusive US had CT; no inclusion criteria beyond referral from ED	II
Rao et al[48]	1997	Prospective	Helical CT; limited appendiceal scan; oral and rectal contrast; population: patients from ED or private surgeon's office with uncertainty for appendicitis; aged 6-84 y; 54 females, 46 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 1 wk, 1 mo, and 3 mos	100 study patients 56 (56%) confirmed appendicitis; CT results: 56 true-positive, 2 false-positive, 41 true-negative, 0 false-negative; 1 indeterminate CT; sensitivity: 100%; specificity: 95%		I
Mun et al[49]	2006	Retrospective	Helical CT, abdomen/pelvis; IV contrast, no oral or rectal; population: ED patients; aged >17 y; 98 females, 75 males	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up at 1 wk	271 patients with CT, 98 excluded, including 35 lost to follow-up, 173 patients included, 56 (32%) confirmed appendicitis; CT results: 56 true-positive, 3 false-positive, 114 true-negative, 0 false-negative; sensitivity: 100%; specificity: 97%	Authors searched radiology database for eligible patients; search for eligible patients required the word "appendicitis" in the radiology report; large number of patients lost to follow-up, not included in analysis	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Anderson et al[50]	2005	Systematic review	Reviewed 23 studies investigating the accuracy of CT for diagnosis of acute appendicitis	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or clinical follow-up	23 studies, 19 prospective, 3,474 patients; CT with oral+IV contrast (N=914): sensitivity: range 90%-98%, weighted average 93%; specificity: range 85%-100%, weighted average 93%; CT no contrast (N=1,510): sensitivity: range 87%-97%, weighted average 93%; specificity: range 91%-100%, weighted average 98%	Authors conclude noncontrast CT technique is similar and may be superior to CT with oral contrast for the diagnosis of acute appendicitis; comparing studies is difficult because methods varied	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Mittal et al[51]	2004	Prospective	Prospective randomized study comparing accuracy of triple-contrast abdominal pelvic CT to focused pelvic CT with rectal contrast only; included patients uncertain for appendicitis	Detection of acute appendicitis on CT; criterion standard: pathologic findings at surgery or 23 h inpatient observation and clinical follow-up	91 patients randomized, 80 (88%) confirmed appendicitis; triple-contrast abdominal pelvic CT 52 patients, 44 (85%) confirmed appendicitis; focused pelvic CT with rectal contrast 39 patients, 36 (92%) confirmed appendicitis; sensitivity: triple-contrast abdominal pelvic CT 97%, focused pelvic CT with rectal contrast 88%; specificity: triple-contrast abdominal pelvic CT 86%, focused pelvic CT with rectal contrast 100%	Very high rate of appendicitis compared with other series; triple-contrast abdominal pelvic CT and focused pelvic CT with rectal contrast groups dissimilar in many ways; considerably larger number of patients in triple-contrast abdominal pelvic CT group, patients older, and patients had much longer time to presentation than focused pelvic CT with rectal contrast, 39 vs 30 h; focused pelvic CT with rectal contrast had more female patients; triple-contrast abdominal pelvic CT patients had much higher number of patients with perforation, 13 vs 1; authors attributed difference in perforation rate to significantly longer time to presentation rather than prolonged ED time because of need to ingest contrast or time to surgery; for triple-contrast abdominal pelvic CT, calculation of specificity=50%, for focused pelvic CT with rectal contrast, calculation of sensitivity=100%, different from authors	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Bendeck et al[52]	2002	Retrospective cohort	Either abdominal/pelvic CT or US; CT technique was not standardized; children received no enteral contrast, oral contrast, or rectal contrast	Negative appendectomy rate, perforation rate, and diagnostic performance; criterion standard: operative findings	Negative appendectomy rate: CT: 5/31 (16%), US: 5/51 (10%); perforation rate: CT: 11/32 (34%), US: 9/50 (18%); OR for CT vs US for negative appendectomy rate: 1.77 (95% CI 0.47-6.7); OR for CT vs US for perforation rate: 2.38 (95% CI 0.86-6.7); diagnostic performance not reported	Study type not standardized (CT vs US); enteral contrast use not standardized (oral vs rectal vs none); patients already selected for appendectomy based on diagnostic study (re: diagnostic performance); study groups not compared to exclude baseline clinical differences	III for negative appendectomy rate and perforation rate; X for diagnostic performance
Baldisserotto and Marchiori[55]	2000	Prospective cohort	Sonography using (first) noncompressive and then compressive technique if necessary	Sonographic evidence of acute appendicitis; criterion standard: either operative findings or telephone follow-up 1 wk later	Sensitivity: 98.5% (95% CI 96.8%-100%); specificity: 98.2% (95% CI 96.5%-99.9%); NPV: 98.7% (95% CI 97.2%-100%); PPV: 98% (99.9%); appendicitis rate: 199/425 (47%)	Possible selection bias: patients entered into study only during weekdays; generalizability: high appendicitis rate 199/425 (47%); blinding: not mentioned whether radiologists were blinded to clinical data	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Kaiser et al[56]	2002	Prospective, randomized, nonblinded comparison of 2 diagnostic approaches	Either US or US followed by CT in diagnosing acute appendicitis in 600 children; CT used IV contrast, not oral or enteral contrast; each abdomen that received a CT scan first received a limited, noncontrast scan of the lower abdomen, and then a CT of the entire abdomen with IV contrast only	Outcome: appendicitis; criterion standard: operative findings and written survey at 6 mo	US only (283 patients): sensitivity: 86%, specificity: 95%, PPV: 91%, NPV: 92%, diagnostic accuracy: 92%; US, then CT (317 patients): sensitivity: 99%, specificity: 89%, PPV: 87%, NPV: 99%, diagnostic accuracy: 93%; disease prevalence: 244/600 (40.7%)	US were interpreted by either a pediatric surgeon or a surgical resident	II
Chang et al[57]	2003	Prospective cohort	40 children received both radionuclear scan and abdominal US to diagnose acute appendicitis; US performed after radionuclide injection	Appendicitis; criterion standard: operative findings or telephone follow-up at 1 mo	For US: sensitivity: 86.6%, specificity: 90%; CI and disease prevalence not available; not reported by the authors	Generalizability: performed in Taiwan where patients referred directly to surgeon for evaluation; small sample size (40 children); blinding not stated	III
Dilley et al[58]	2001	Retrospective observational study (retrospective cross-referencing of surgical, pathologic, and radiologic databases)	US to diagnose acute appendicitis in 587 children	Appendicitis; criterion standard: retrospectively evaluated pathology reports; no follow-up of patients with negative US	Sensitivity: 89%; specificity: 95%; PPV: 86%; NPV: 96%; appendicitis rate: 86%; perforation rate: 26.1%	No criterion standard for patients with negative scan results	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Lowe et al[59]	2001	Prospective cohort of 72 children who received CT to diagnose appendicitis; this group was compared with a retrospective (historical) cohort of 76 children who received US	Either CT (no IV or enteral contrast) or US to diagnose appendicitis	Outcome: appendicitis; criterion standard: operative findings, chart review, and 6-mo telephone follow-up	CT: sensitivity 97% (95% CI 91%-100%), specificity 100%, accuracy 99% (95% CI 96%-100%); US: sensitivity 100% , specificity 88% (95% CI 80%-96%), accuracy 91% (95% CI 85%-97%); disease prevalence: 33%	Small sample size for each cohort; adequacy of outpatient follow-up unclear in retrospective (US) group	CT: II US: III
Sivit et al[60]	2000	Prospective cohort of 315 children receiving US and 153 receiving CT	CT, US, or US and CT to diagnose appendicitis	Outcome: appendicitis; criterion standard: operative findings and "clinical follow-up"	CT: sensitivity: 95%, specificity: 93%, accuracy: 94%; US: sensitivity: 78%, specificity: 93%, accuracy: 89%; disease prevalence: 26% (84/315)	Outpatient follow-up of negative clinical evaluations not defined; bias may have existed in how studies were chosen for each subject	III
Teo et al[61]	2000	Prospective cohort of 129 children with suspected appendicitis	US to diagnose appendicitis	Outcome: appendicitis; criterion standard: operative findings; no outpatient follow-up of negatives stated	Sensitivity: 92.9%; specificity: 96.9%; PPV: 89.7%; NPV: 97.9%; disease prevalence: 22%	No outpatient follow-up of negative studies; children put into 1 of 3 risk groups before US performed; not stated if radiologist blinded to these classifications	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Kaiser et al[62]	2004	CTs prospectively collected from a previous study (Kaiser 2002) were prospectively reviewed by 2 blinded radiologists; the subjects were 306 children suspected of having appendicitis; patients received both limited CT with no contrast and IV contrast CT of the entire abdomen; no patients received enteral contrast of any kind	Limited, nonenhanced CT of the lower abdomen or IV contrast (only) of the entire abdomen	Outcome: appendicitis; criterion standard: operative findings and written survey follow-up 6 mo later	Limited, unenhanced CT of lower abdomen: sensitivity: 66%, specificity: 96%; IV contrast (no oral or rectal contrast) CT of entire abdomen: sensitivity: 90%, specificity: 94%; disease prevalence: 129/306 (42%)	Re-evaluation of radiographs that were obtained prospectively from an earlier study	II

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Acosta et al[63]	2005	Prospective cohort	Abdominal/pelvic CT with rectal contrast	Radiographic criteria for acute appendicitis; criterion standard: either operative findings or telephone follow-up 3 wks later	94 patients underwent CT; 53 had contrast reflux into the terminal ileum; of these, the appendix was visualized in 43 (43/94=46%); 10 had appendicitis; when the appendix was visualized, sensitivity was 100% (95% CI 66.4%-100%), specificity was 97.7% (95% CI 88%-99.9%), the NPV was 100% (95% CI 91.8%-100%), and the PPV was 90% (95% CI 55.5%-99.8%); overall appendicitis rate: 15/94 (16%)	Generalizability: only children 6-17 y of age included; only children identified for admission and observation were studied; 43 children had the appendix identified and were included in the evaluation of diagnostic performance; potential bias: only 1 radiologist read all CTs	III
Hoecker and Billman[64]	2005	Retrospective cohort	Unenhanced CT (ie, no oral, rectal, or IV contrast); all study subjects received CT	Outcome: appendicitis; criterion standard: operative findings only; outpatient follow-up was not done; instead, the authors reviewed the hospital records for 3 mos following the initial hospital visit to look for readmissions	Sensitivity: 87.5 % (95% CI 75.8%-94.8%); specificity: 93.7% (95% CI 95.4%-98%); NPV: 90.8% (95% CI 83.7%-97.8%); PPV: 91.3% (95% CI 83.2%-99.4%); positive likelihood ratio 13.8 (5.3-35.8); negative likelihood ratio 0.13 (0.06-0.28); 112 patients; disease prevalence: 38%	15 patients lost to follow-up after an initially negative CT; appendicitis among these 15 subjects would have further decreased the sensitivity of CT for appendicitis	III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Mullins et al[65]	2001	Retrospective cohort of 199 children who received limited CT with rectal contrast only (no IV or oral)	Limited CT with rectal contrast only (no IV or oral)	Outcome: appendicitis criterion standard: operative findings; adequacy of clinic follow-up unclear; no telephone follow-up	Sensitivity: 97%; specificity: 99%; PPV: 98%; NPV: 98%; disease prevalence: 33%	Adequacy of criterion standard unclear; possible selection bias; patients who were chosen for rectal contrast only may have been more straightforward clinically	III
Kharbanda, et al[66]	2007	Retrospective	Children broken down into 2 consecutive retrospective cohorts, one group evaluated with CT using only IV contrast and the other group evaluated with CT using IV and rectal contrast	Outcome: appendicitis; criterion standard: operative findings or telephone follow-up at 2-4 wks for negatives	416 children aged 5-21 y studied; IV and rectal: sensitivity 92% (95% CI 85%-97%) and specificity 87% (95% CI 79%-92%); IV alone: sensitivity 93% (95% CI 84%-97%) and specificity 92% (95% CI 85%-96%); disease prevalence: 40%	Generalizability; post hoc analysis; no information on excluded patients	III
Brody et al[67]	2007	Unstructured review			Discusses a logical argument that diagnostic radiologic procedures may carry a small cancer risk in children; states that the benefits of most CT scans outweigh the small, associated cancer risk; discusses strategies to approach the potential risk of ionizing radiation to children		III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
American Academy of Pediatrics Committee on Environmental Health[68]	1998	Unstructured review			Develops an argument that because larger doses of ionizing radiation (eg, atomic bomb) are associated with cancer risk, there may be an associated risk to diagnostic procedures; provides a list of diagnostic radiologic procedures and their respective radiation doses		III
Brenner and Hall[69]	2007	Review and concept piece			In part, the authors develop the argument that ionizing radiation in the range of 50-150 mSv was associated with a small cancer risk after atomic bomb exposures and is equivalent to the cumulative organ radiation dose from 2-3 abdominal/pelvic CT scans; further, about 30% of patients who receive 1 abdominal/pelvic CT also receive a total of 3 such CT scans during the course of their treatment; consequently, the authors surmise there may be a small cancer risk from these radiographs, especially in children, who have more dividing cells and a longer life span to develop cancer than adults		III

Evidentiary Table (continued).

Study	Year	Design	Intervention(s)/Test(s)/ Modality	Outcome Measure/Criterion Standard	Results	Limitations/Comments	Class
Garcia Pena et al[70]	2002	Retrospective; data collected retrospectively before and after the implementation of a diagnostic protocol	Diagnostic protocol: US followed by CT in selected children admitted with possible appendicitis	Appendicitis; diagnostic criterion: surgical outcome; no limited criterion standard for discharged patients in the preprotocol group; telephone follow-up of negatives in the postprotocol cohort	1,338 children studied; after implementation of the protocol, the perforation rate decreased from 35% to 15% and the missed appendicitis rate dropped from 14% to 4%	Unstated criterion standard for discharged patients in the preprotocol cohort	III
Wan et al [71]	2009	Retrospective (based on literature review)	The authors used a Markov decision analytic model based on a theoretical clinical case of a 5-y-old with possible appendicitis; 3 diagnostic methods evaluated: US alone, CT alone, and US followed by CT in selected cases	Outcome: cost and effectiveness in diagnosing acute appendicitis; criterion standard: based on supporting literature	US followed by CT was the most costly and most effective method; CT alone was the second most costly and second most effective; US alone was the least costly and least effective strategy	Retrospective study based on a theoretical case	III

AUC, area under the curve; *CI*, confidence interval; *CT*, computed tomography; *DCCT*, CT with oral and IV contrast; *ED*, emergency department; *h*, hour; *IV*, intravenous; *LR*, likelihood ratio; *mSv*, millisieverts; *mo*, month; *NCCT*, CT without contrast; *NPV*, negative predictive value; *OR*, odds ratio; *PPV*, positive predictive value; *RCCT*, CT with rectal contrast; *US*, ultrasound; *vs*, versus; *WBC*, white blood cell; *wk*, week; *y*, year.

Appendix A. Literature classification schema.*

Design/Class	Therapy[†]	Diagnosis[‡]	Prognosis[§]
1	Randomized, controlled trial or meta-analyses of randomized trials	Prospective cohort using a criterion standard	Population prospective cohort
2	Nonrandomized trial	Retrospective observational	Retrospective cohort Case control
3	Case series Case report Other (eg, consensus, review)	Case series Case report Other (eg, consensus, review)	Case series Case report Other (eg, consensus, review)

*Some designs (eg, surveys) will not fit this schema and should be assessed individually.
[†]Objective is to measure therapeutic efficacy comparing ≥2 interventions.
[‡]Objective is to determine the sensitivity and specificity of diagnostic tests.
[§]Objective is to predict outcome including mortality and morbidity.

Appendix B. Approach to downgrading strength of evidence

	Design/Class		
Downgrading	**1**	**2**	**3**
None	I	II	III
1 level	II	III	X
2 levels	III	X	X
Fatally flawed	X	X	X

Appendix C. Likelihood ratios.

LR (+)	LR (-)	
1.0	1.0	Useless
1-5	0.5-1	Rarely of value, only minimally changes pretest probability
10	0.1	Worthwhile test, may be diagnostic if the result is concordant with pretest probability
20	0.05	Strong test, usually diagnostic
100	0.01	Very accurate test, almost always diagnostic even in the setting of low pretest probability