ELSEVIER

Canadian Association of Radiologists Journal 62 (2011) 197–202

CANADIAN ASSOCIATION OF RADIOLOGISTS JOURNAL

www.carjonline.org

Ultrasonography / Échographie

Incidence and Significance of Inconclusive Results in Ultrasound for Appendicitis in Children and Teenagers

Jacob L. Jaremko, MD, PhD, FRCPC[a,*], Ann Crockett, RDMS, RVT[a], Diana Rucker, MD, MSc, FRCPC[b], Kenneth G. Magnus, BSc, MB ChB, MMed (RadD)[c]

[a]*Department of Radiology and Diagnostic Imaging, Faculty of Medicine, University of Alberta , Edmonton, Alberta, Canada*
[b]*Department of General Internal Medicine, Faculty of Medicine, University of Alberta, Edmonton, Alberta, Canada*
[c]*Department of Oncological Imaging, Cross Cancer Institute, Edmonton, Alberta, Canada*

Abstract

Purpose: Frustratingly, sonography to assess for appendicitis in children often leads to an inconclusive report (eg, ''suspicious for appendicitis'') or nonvisualization of the appendix. To aid in planning who to image and how to interpret the results, we investigated whether these 2 results were more frequent in teenagers than preteens and the prevalence of appendicitis associated with each result.
Methods: We retrospectively reviewed sonographic and surgical findings in patients <18 years ($n = 189$) referred with clinical suspicion of appendicitis over a 12-month period. Children (≤12.0 years old; $n = 86$) and teens (>12.0 years old; $n = 103$) were compared.
Results: Prevalence of appendicitis was 34% in each group, similar to other centres; 0% for those with negative ultrasound reports (0/35), 10% for nonvisualized appendix (8/84), 68% for inconclusive report (15/22), and 85% for positive ultrasound (41/48). Teens were significantly more likely to have an inconclusive ultrasound. Inconclusive reports were because of borderline findings (eg, appendix size near 6 mm; 9/22), body habitus, bowel gas, or unusual findings due in retrospect to perforation. The rate of nonvisualization of the appendix did not vary significantly with age (42% vs 47%).
Conclusion: An inconclusive result of ultrasound for appendicitis was significantly more frequent in teens than in preteens and carried a high (68%) likelihood of appendicitis. Conversely, a nonvisualized appendix was equally frequent in teens and preteens, and had a low likelihood of appendicitis (only 10% positive). These findings encourage the use of ultrasound in preteens in particular and can assist interpretation of these common results.

Résumé

Objectif: Malheureusement, l'échographie utilisée pour la recherche d'appendicite chez les enfants donne souvent des résultats peu concluants (p. ex., « appendicite probable ») ou ne permet pas de visualiser l'appendice. Afin d'aider à déterminer dans quels cas il serait profitable de faire subir cet examen et à interpréter les résultats, nous avons fait une étude afin (i) d'évaluer si ces deux types de résultats étaient plus fréquents chez les adolescents que chez les préadolescents et (ii) de définir la prévalence des cas d'appendicite associés à chaque type de résultat.
Méthodes: De façon rétrospective, nous avons révisé les résultats d'échographie et de chirurgie de patients de moins de 18 ans ($n = 189$) référés pour recherche d'appendicite, sur une période de 12 mois. Les résultats pour les enfants (12 ans et moins; $n = 86$) et pour les adolescents (plus de 12 ans; $n = 103$) ont été comparés.
Résultats: La prévalence de l'appendicite était de 34 % dans chaque groupe, ce qui est semblable aux résultats des autres centres : elle était de 0 % chez les patients dont les résultats d'échographie sont négatifs (0/35), 10 % chez les patients dont on ne parvenait pas à visualiser l'appendice (8/84), 68 % chez les patients dont les résultats étaient peu concluants (15/22) et de 85 % chez les patients dont les résultats d'échographie étaient positifs (41/48). Il était plus fréquent d'obtenir des résultats d'échographie peu concluants chez les adolescents. Les examens peu concluants l'étaient en raison de résultats limites (p. ex., un appendice de près de 6 mm; 9/22), du phénotype, de gaz intestinaux ou d'anomalies qui étaient en lien avec une perforation. Le taux de non—visualisation de l'appendice ne variait pas de manière significative avec l'âge (42 % contre 47 %).

* Address for correspondence: Jacob L. Jaremko, MD, PhD, FRCPC, Department of Radiology and Diagnostic Imaging, Faculty of Medicine, University of Alberta, 8440-112 Street, 2A2.41 WMC, Edmonton, Alberta T6G 2B7, Canada.
E-mail address: jjaremko@ualberta.ca (J. L. Jaremko).

0846-5371/$ - see front matter
doi:10.1016/j.carj.2010.03.009

Conclusion: Il est beaucoup plus fréquent d'obtenir des résultats peu concluants à l'échographie pour recherche d'appendicite chez les adolescents que chez les préadolescents. Les patients dont les résultats sont peu concluants sont très susceptibles de souffrir d'une appendicite (68 %). Inversement, la non—visualisation de l'appendice est aussi fréquente chez les adolescents que chez les préadolescents et est liée à une faible probabilité d'appendicite (seulement 10 %). Les conclusions de cette étude encouragent l'usage de l'échographie chez les préadolescents en particulier et peuvent aider à interpréter les résultats peu concluants, qui sont fréquents.

Key Words: Ultrasound; Pediatric; Appendicitis (diagnosis)

Appendicitis remains a difficult clinical diagnosis in children or adults, for which imaging assistance is frequently sought. About 1 of 3 children with symptoms clinically suspicious for appendicitis has a positive diagnosis [1]. Because perforation of the appendix, which is common (20%), results in increased morbidity and mortality, a negative laparotomy rate in the 20% range remains acceptable in adults and children [2]. Both ultrasound and computed tomography (CT) have shown high sensitivity (SN) and specificity (SP) for appendicitis in controlled trials, especially when combined with each other (eg, CT after inconclusive ultrasound) [3,4]. However, results in the community are poorer for both modalities [2,5]. Consequently, in many centres, only about half of the patients with appendicitis receive any imaging at all [6], and surgeons frequently ignore imaging results discordant with their clinical impression [5].

Because of radiation dose concerns with CT, ultrasound is generally preferred to investigate children with possible appendicitis. Sonography in this setting is intended to provide a positive or negative result (''appendicitis'' or ''normal appendix'') but frequently results in either an inconclusive report (eg, ''suspicious for appendicitis'') or nonvisualization of the appendix. The clinician may have difficulty interpreting these results, and, knowing that ultrasound is likely to produce one of these outcomes, may be reluctant to image the next child who presents with lower abdominal pain. To assist in determining which patient to image and to aid in the interpretation of the ultrasound results, we asked 2 related questions: (1) Is an inconclusive result or nonvisualization of the appendix more common in ultrasound for appendicitis in teenagers than in preteens? and (2) What is the prevalence of appendicitis associated with these 2 results?

SN of ultrasound for acute appendicitis varies widely in prospective and retrospective studies, ranging from 78%–94% in children, to as low as 34% in adults. SP is reportedly higher and less variable in children, near 89%–98% [1, 7]. In other words, if the appendix is seen and is abnormal, then acute appendicitis is likely, but an unseen appendix does not completely exclude appendicitis. The frequency with which the appendix is seen is user dependent, especially because a normal appendix can closely mimic a small bowel loop. One group detected the appendix in an impressive 99% of 877 adult patients [4], and a careful scan detected the appendix in 82% of children without acute abdominal pain [8], but most other groups suggest that only between 6%–25% of normal appendices are detected in children with abdominal pain [3,9,10].

SN and SP are both decreased by an inconclusive ultrasound report. Reports are often worded with terms such as ''suspicious for acute appendicitis'' or ''borderline findings may represent acute appendicitis,'' which convey the difficulty in assessing the right lower quadrant on an ultrasound but does less to modify pretest probability than a definite ''yes'' or ''no'' report. A Toronto study identified numerous inconclusive reports (43/317) when real-world cases performed by on-call general radiologists and senior residents were retrospectively reviewed [10]. The investigators noted that ultrasound diagnosis can be difficult in early appendicitis (when findings are subtle); in late appendicitis, when perforation has occurred and the appendix is decompressed or destroyed; and when the appendix is retrocecal. The Toronto study did not stratify the inconclusive reports by age, but, in a study from Cleveland, ultrasound was less sensitive in children older than 10 years of age compared with younger children (71% vs 84%) [11]. One obvious contributing factor would be the generally more-slender body habitus of younger children, which is favorable for ultrasound. Importantly, younger children more frequently present with atypical or vague symptoms than older children do, which increases the potential importance of imaging in the diagnosis of appendicitis in younger children [12].

When combined, these observations suggest but do not directly demonstrate that an indeterminate sonographic result or nonvisualized appendix might be more common in older than younger children. If true, then this could impact clinical decision protocols, which might, then, more routinely include ultrasound of younger children than of teenagers. We performed a retrospective study to test this hypothesis and to estimate the prevalence of appendicitis implied by each sonographic result in a routine pediatric hospital practice.

Methods

The study was approved by the health ethics research board at our institution. We performed a retrospective review of the electronic medical records of patients examined in the radiology department, located in a Canadian tertiary care hospital that serves a catchment area of more than 1.5 million people. We included all pediatric patients (younger than 18 years old) who were referred for ultrasound because of clinical suspicion of appendicitis during the year 2007. The

decision to perform ultrasound was made clinically by the referring emergency physician or surgeon. For each patient, we recorded age, sex, white blood cell, and neutrophil counts (the latter 2 recorded as abnormal when more than 13×10^9 or 10×10^9 cells/mm^3, respectively), ultrasound results, and the results of any subsequent (within 72 hours) CT or abdominal surgery, including the associated pathologic specimens. Any surgery within the next month was also noted. Ultrasound was performed as per usual clinical practice in our department. In general, this included a scan by an ultrasound technologist and a check scan by a pediatric radiologist, with or without a radiology resident if performed 8 AM to 5 PM Monday to Friday, or a scan by the on-call ultrasound radiologist (in most cases not a pediatric radiologist) on evenings or weekends. The available equipment and probes were selected by the scanning team, most commonly, a Philips IU22 unit (Philips Electronics NV, Eindhoven, The Netherlands), with C5-2 curved-array and L12-5 linear-array probes.

The original radiologist reports were retrospectively reviewed. Reporting radiologists followed the usual criteria to determine whether appendicitis was present, seeking the classic findings of a 6-mm or larger diameter aperistaltic, noncompressible hyperemic structure generally found near the cecum [12], in conjunction with secondary findings that suggest local inflammation (such as free fluid or collection, enlarged lymph nodes, echogenic fat), and clinical factors. Based on the wording of the ultrasound report, the sonography results were coded as the following: ''Appendicitis'' (appendix seen and abnormal), ''Inconclusive'' (findings worrisome for, but not definitely diagnostic of, appendicitis), ''Appendix Not Seen'' (no findings to suggest appendicitis, but no appendix seen to confirm this), or ''Normal'' (normal appendix seen). Other sonographic findings, such as the presence of enlarged lymph nodes, free fluid, loculated fluid collection, adnexal lesion (such as an ovarian cyst), or intussusception, were also recorded. Statistics were calculated by using SPSS v. 9 (SPSS Inc., Chicago, IL). Standard descriptive statistics were obtained where relevant. We estimated SN, SP, positive predictive value (PPV), negative predictive values (NPV), and accuracy from sonographic vs surgical results, with the conservative assumption that all patients who did not have surgery in our region within 1 month of ultrasound did not have appendicitis.

It was necessary to collapse the 4 sonographic diagnostic categories (Appendicitis, Inconclusive, Appendix Not Seen, Normal) into 2 (Test Positive, Test Negative) to compute SN, SP, and related indices. This could reasonably be done in 2 ways: method A: only those patients with ultrasound result ''Appendicitis'' were considered Test Positive, all 3 other results Test Negative; and method B: ''Appendicitis'' or ''Inconclusive'' considered Test Positive, and ''Appendix Not Seen'' or ''Normal'' considered Test Negative. A recent study with similar diagnostic categories used method B [13]. We present results from both methods. Relevant values were calculated for the whole study population, then in groups stratified by age older than and younger than 12.0 years old, which was the mean age in our data set. We used χ^2 tests to assess for significant differences in calculated values when appropriate by using a 1-tailed level of significance, $P = .05$.

Results

The number of patients totaled 189, with a mean (SD) age of 12.0 ± 3.9 years (range, 2.6–17.7 years). There were 78 boys and 112 girls. Fifty patients (26.5%) had elevated white blood cell or neutrophil counts. Ultrasound reports noted free fluid in 80 (42.3%) and prominent or enlarged lymph nodes in 59 of patients (31.2%). There were 64 cases of surgically proven appendicitis (prevalence, 34%). Ultrasounds of these patients had 41 correct positive diagnoses, 15 inconclusive reports, 8 nonvisualized appendices, and no false-negative reports. In addition, 5 patients had surgery negative for appendicitis, with the following results: perforated Meckel diverticulum, resected (1); hemorrhagic left ovarian cyst (not suspected on ultrasound), resected (1); perforated duodenal ulcer, repaired (1); lymphoid hyperplasia of terminal ileum (1); and normal findings (1). Thus, nontherapeutic surgery occurred in 2.9% (2/69). No fatalities were recorded. One surgical complication was noted: a bulbar urethral tear related to perioperative Foley catheter placement, which required subsequent urologic repair.

Just under half of the patients ($n = 86$; Table 1) were younger than 12 years of age. The prevalence of appendicitis was unchanged between the children (≤12 years) and teenagers (>12 years), at 34% each. The prevalence of surgically diagnosed appendicitis in patients with ultrasound report ''Normal'' was 0% (0/35); ''Appendix Not Seen,'' 10% (8/84); ''Inconclusive,'' 68% (15/22); and ''Appendicitis,'' 85% (41/48) (Figure 1).

The following statistically significant differences were observed. Children were more likely to have an elevated white blood cell count or sonographically obvious enlarged lymph nodes, and teenagers were more likely to be girls (68% vs 47%) or to have an adnexal lesion (13% vs 0%). Significantly more inconclusive ultrasound reports were generated in teenagers than in preteens (16% vs 7%, $P < .05$). Only 3 of the 22 inconclusive reports (14%) were in children ≤10 years of age, who made up 32% of our patients (61/189). Children older than 12 years had significantly more CTs after the ultrasound examination (15% vs 4%). Of the 3 children <12 years who had CT, 2 had inconclusive ultrasound reports (1 positive on CT for appendicitis), and 1 had no visible appendix on ultrasound (CT was normal).

Overall, 18 of 189 patients had a CT (9.5%). Of these, 6 of 18 were performed after ''Inconclusive'' ultrasound (5/6; 83% positive on CT for appendicitis), 10 of 18 after ultrasound with a result of ''Appendix Not Seen'' (0/10 positive on CT for appendicitis), 1 after an ultrasound that showed normal appendix and bowel changes (a CT showed normal appendix and Crohn's disease), and 1 in a patient with ultrasound that showed appendicitis (CT also positive for appendicitis). This last patient actually had confirmatory ultrasound at our site after a positive CT performed

Table 1
Clinical and sonographic characteristics of preteen and teenage patients undergoing ultrasound for acute appendicitis

	No. (%) patients ≤12.0 y old (n = 86)	No. (%) patients >12.0 y (n = 103)	All patients (%) (n = 189)	Significance[a]
Boys	45 (52.3)	33 (32.0)	78 (41.3)	*
Elevated white blood cell or neutrophil count	31 (36.0)	21 (20.4)	52 (27.5)	*
US "Appendicitis"	25 (29.1)	21 (20.4)	46 (24.3)	
US "Inconclusive"	6 (7.0)	16 (15.5)	22 (11.6)	*
US "Appendix Not Seen"	36 (41.9)	48 (46.6)	84 (44.4)	
US "Normal Appendix"	18 (20.9)	17 (16.5)	35 (18.5)	
Free fluid on US	36 (41.9)	44 (42.7)	80 (42.3)	
Enlarged nodes on US	36 (41.9)	23 (22.3)	59 (31.2)	
Adnexal lesion on US	0 (0.0)	13 (12.6)	13 (6.9)	
Mesenteric adenitis on US	8 (9.3)	2 (1.9)	10 (5.3)	
Abscess on US	4 (4.7)	4 (3.9)	8 (4.2)	
CT performed	3 (3.5)	15 (14.6)	18 (9.5)	
Surgery performed	30 (34.9)	39 (37.9)	69 (36.5)	
Surgery positive for appendicitis	29 (33.7)	35 (34.0)	64 (33.9)	

CT = computed tomography; US = ultrasound.
[a]Asterisk indicates significant difference between age ≤12 y and age >12 y, at $P < .05$, 1-tailed, when using the χ^2 test.

elsewhere (and did have appendicitis at surgery). Of the 12 CTs with a normal appendix, findings were the following: no other abnormality (10), omental infarct (1), free air from perforated duodenal ulcer (1).

The sonographic true-positive rate for appendicitis was not significantly different between age groups, and, if inconclusive results were also considered to be positive, then the rate was nearly identical (30% children vs 29% teens). Inconclusive reports were evenly split between male and female patients (11 each).

Because method A and method B of computing SN, SP, and related indices differed in handling of "Inconclusive" ultrasound results, and most of these (68%) were positive for appendicitis, treating "Inconclusive" results as negative (method A) led to a high number of false negatives and low SN, whereas SN and accuracy were improved by treating "Inconclusive" results as positive (method B). For method A, we had overall SN = 0.67, SP = 0.96, PPV = 0.90, NPV = 0.85, accuracy = 0.86. Method A gave poorer results in teens (n = 103, SN = 0.57, SP = 0.97, PPV = 0.91, NPV = 0.81, accuracy = 0.83) than children <12 years old (n = 86: SN = 0.79, SP = 0.95, PPV = 0.88, NPV = 0.90, accuracy = 0.90), because most of the inconclusive results were in teens. For method B, overall SN = 0.88, SP = 0.89, PPV = 0.80, NPV = 0.93, accuracy = 0.88. Unlike method A, method B was only slightly less accurate in teens (SN = 0.86, SP = 0.88, PPV = 0.79, NPV = 0.92, accuracy = 0.87) than children <12 years old (SN = 0.90, SP = 0.89, PPV = 0.81, NPV = 0.94, accuracy = 0.90).

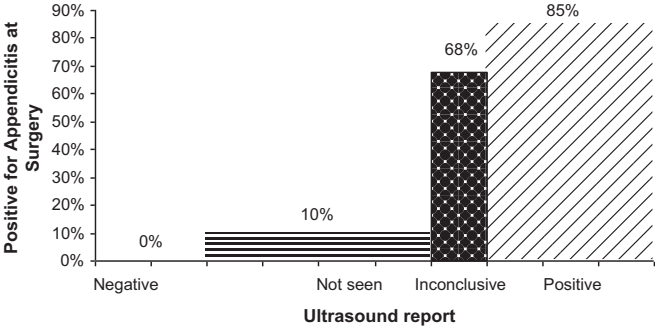

Figure 1. Relation between sonographic and surgical findings in acute appendicitis. Note: width of bars indicates the relative frequency of each type of ultrasound report.

The 22 inconclusive ultrasound reports were reviewed individually and were found to be associated with the following: appendix visible but with borderline findings, such as diameter 5–7 mm or enlargement without hyperemia or enlarged but compressible (n = 9); bowel gas partially obscuring the appendix (n = 2); obese patient with poor visualization (n = 2); no visible appendix, but suspicious findings such as guarding during ultrasound examination (n = 3); misdiagnosis of appendix as a gynaecologic structure (n = 2); unusual findings associated in retrospect with a perforated appendix (n = 3); and classic findings reported but radiologist reluctant to firmly diagnose appendicitis (n = 1). Of the inconclusive cases, 15 of 22 (68%) went on to surgery, and all of these were positive for appendicitis.

Gynaecologic diagnoses were made sonographically in 13 patients, all girls >12 years old (13/70 [19%]): 1 patient with multiple follicles suspicious for polycystic ovarian syndrome, 1 hydrosalpinx, and 11 patients with ovarian cysts. Of those with cysts, 3 had a normal appendix, 7 had no appendix seen, and there was 1 "Inconclusive" case, with findings reported as an 8-cm ovarian cyst, borderline appendix, and signs of pyelonephritis. This patient went on to surgery, which revealed appendicitis with abscess.

Discussion

The prevalence of appendicitis in our study was 34% and was unaffected by age. This finding is similar to the 31%

reported in a recent large meta-analysis in children [1]. A total of 12% of our ultrasound results were inconclusive, and nearly half (44%) of our patients had no visible appendix, similar to the 14% and 47% proportions observed in Toronto [10]. Although our study is limited to 1 centre, these findings suggest a similarity between referral and diagnostic patterns at our institution and elsewhere.

Preteen children and teenagers presented to our department with suspected appendicitis in nearly equal numbers but represented 2 somewhat different populations. Although the prevalence of appendicitis was remarkably similar in the 2 groups, most (16/22) of the inconclusive ultrasound reports were in teenagers. No single clear factor explains this. The teenagers were more frequently girls and were more likely to have a gynaecologic diagnosis such as an ovarian cyst. The appendix is more difficult to find in teenagers, who are larger, with deeper abdominal structures and a larger abdominal volume to cover in the search, but this more likely explains the slight increase in proportion of ''Appendix Not Seen'' (47% vs 42%) with age than the increase in ''Inconclusive'' results. Given that most ''Inconclusive'' results were in patients who did have appendicitis, it may be somehow more difficult to distinguish an inflamed appendix from bowel in the teenagers. Radiologists may also have been more reluctant to make a firm diagnosis on ultrasound in teenagers when knowing that a CT would be more easily performed with less perceived radiation risk than in younger children.

Few studies have stratified children with suspected appendicitis by age, but our results are compatible with a prior study that found poorer sonographic sensitivity in children aged >10 years than in younger children [10]. Similarly, another study where ultrasound detected pediatric appendicitis with exceptionally high accuracy (98%) was primarily done in young male children, because the older patients in the area, especially teenage girls, were generally sent to a nearby hospital for assessment instead [14].

At least 1 investigator favors CT in older children because of poorer ultrasound accuracy [10]. We did note increased CT utilisation in teenagers in our study, but rates were still relatively low, at 15% (teen) vs 4% (child). Reported rates of CT use in pediatric appendicitis range from 1.7% [15] to 92% [16]. Disadvantages of CT include radiation risks and the likelihood that heavy reliance on CT will adversely affect the quality of ultrasound studies at an institution, because busy staff avoid taking the extra time and effort to scan carefully for the appendix. As a possible example of this, the outlier study identified in a meta-analysis [1] with a very low ultrasound SN for pediatric appendicitis (SN = 0.45) was in a centre with a high rate of CT use (61%) [17].

The rates of nonvisualization of the appendix with no secondary findings of appendicitis (42%–47%) were similar, regardless of age, and likely represented the presence of a normal appendix in most patients. In this ''Appendix Not Seen'' group, only 10% were subsequently positive for appendicitis, and all 10 CTs were negative. A comparable recent study had no cases of appendicitis in the equivalent category, 0% [13]. We agreed with the conclusion of that study that, if the appendix is not seen and there are no secondary findings to suggest nearby inflammation, then this has clinical meaning similar to finding a normal appendix. It, therefore, is difficult to justify CT in this category.

Although nonoperated patients generally received no further follow-up, the electronic medical record covers all regional hospitals, and it is likely that few, if any, of this subset of patients would have had subsequent surgery within a few days outside the region. Still, results in this subgroup, and all of the SN and SP calculations, should be interpreted with caution.

Our SN and SP were on the low end of published ranges, in particular lower than some recent prospective studies [13,18]. Other investigators have noted that sonographic SN (SN = 50%–100%) varies much more than SP (SP = 88%–99%) [12]. A recent meta-analysis reported ultrasound assessment of appendicitis to be highly accurate and slightly more sensitive in children (SN = 86%–90%, SP = 92%–95%) than in adults (SN = 78%–87%, SP = 90%–96%) [1]. If our relatively frequent inconclusive results were classified as negative (method A), then we had low SN, SN = 0.67 (method A). Following the methods described in [13], it is more natural to consider the inconclusive results as positive (method B), giving SN = 0.88, SP = 0.89, much closer to ranges in the meta-analysis. This is also clinically sensible, given that 68% of our inconclusive results were, in fact, positive for appendicitis.

Our relatively low SN, SP, and accuracy, all because of the presence of inconclusive ultrasound results, are explained by noting that ultrasound in our study was performed by a mix of general radiologists, pediatric radiologists, and senior residents, without standardized protocols, whereas controlled and/or prospective trials typically have the benefit of more rigorous review by experienced pediatric radiologists who can devote greater effort to minimizing inconclusive results [2]. Our 12% rate of inconclusive results is similar to the 14% observed in a study in Toronto with similar inclusion criteria [10]. Likely for similar reasons, CT scanning for appendicitis in adults is also substantially less accurate in community use than in controlled trials [5].

We concur with investigators of Wiersma et al [13] that 4 diagnostic categories are necessary to describe ultrasound results, rather than the traditional 3 (positive, negative, equivocal). Our ''Normal,'' ''Appendix Not Seen,'' and ''Appendicitis'' categories closely match their ''Normal appendix,'' ''Appendix not depicted, no secondary signs of appendicitis,'' and ''Depiction of inflamed appendix'' categories, respectively. Both studies also have a category that indicates findings worrisome for appendicitis, without definite diagnosis. In our study, this is the ''Inconclusive'' category, which is broader than the ''Appendix not depicted (hyperechoic mesenteric fat, fluid collection, or local dilated bowel loop present)'' category in Wiersma et al [13], because it includes cases in which the appendix was visible but borderline (eg, enlarged but compressible or normal size but hyperemic) and cases in which secondary signs other than the specific ones listed in Wiersma et al [13], such as focal

guarding on probe placement, larger than expected quantity of free fluid, or congested adjacent ovary, were sufficiently worrisome for the radiologist to issue an inconclusive report.

In our study population, an ''Inconclusive'' ultrasound result doubled the likelihood of having appendicitis from 34% pretest to 68% posttest, whereas a positive ultrasound only moderately further increased the likelihood of appendicitis to 85%. Nearly half (9/22) of the inconclusive results in our study were because of borderline findings (eg, diameter of appendix near 6 mm). Sonographic findings in appendicitis, including the 6-mm threshold for appendix diameter, vary in reliability and have been thoroughly studied in adults [19]. The high prevalence of appendicitis in the group with borderline findings and improvement in SN when inconclusive results were considered equivalent to positive results suggest that, in many cases, borderline findings might best be interpreted by the clinician as likely positive.

A greater proportion of teenagers than children referred for ultrasound for appendicitis in this study were girls (68% vs 47%). Although we can only speculate as to reasons for referral, it is likely that ultrasound was ordered in more teenage girls than boys because of the wider variety of possible differential diagnoses for right lower quadrant pain in postpubertal girls than boys. In our study, 13% of the teenagers and 0% of the preteens had an adnexal lesion as the likely cause of pain. Increased diagnostic uncertainty in women because of the wider differential diagnosis is thought to account for the higher negative appendectomy rates in adult women than in men, as in a study in adults in which 4058 appendectomies (mean age 31 years) resulted in false-positive rate of 8.3% for men, and 22.8% for women [2].

Conclusion

For every 3 children with suspected acute appendicitis, 1 is positive, but this diagnosis remains difficult with or without imaging guidance. This retrospective study at a Canadian tertiary hospital showed that inconclusive ultrasound reports are significantly more common in teenagers than in preteens, whereas rates of nonvisualization of the appendix vary little by age. Clinicians interpreting scan results may find it helpful to recognize that (1) ultrasound for appendicitis is still highly accurate in pediatric patients of all ages, even outside clinical trial setting and that CT should only rarely be necessary, and (2) the ultrasound report is not a ''yes/no'' answer but should fall into 1 of 4 categories, each with a clear implication for management: positive, negative, ''inconclusive'' (alternatively termed ''worrisome''), which has a high probability of appendicitis, and ''no appendix seen, no secondary findings,'' which strongly suggests a normal appendix and does not usually require further imaging.

References

[1] Doria AS, Moineddin R, Kellenberger CJ, et al. US or CT for diagnosis of appendicitis in children and adults? A meta-analysis. Radiology 2006;241:83–94.
[2] Flum DR, McClure TD, Morris A, et al. Misdiagnosis of appendicitis and the use of diagnostic imaging. J Am Coll Surg 2005;201:933–9.
[3] Kaiser S, Frenckner B, Jorulf HK. Suspected appendicitis in children: US and CT: a prospective randomized study. Radiology 2002;223:633–8.
[4] Lee JH, Jeong YK, Park KB, et al. Operator-dependent techniques for graded compression sonography to detect the appendix and diagnose acute appendicitis. AJR Am J Roentgenol 2005;184:91–7.
[5] Huynh V, Lalezarzadeh F, Lawandy S, et al. Abdominal computed tomography in the evaluation of acute and perforated appendicitis in the community setting. Am Surg 2007;73:1002–5.
[6] Cobben LP, Bakker OJ, Puylaert JB, et al. Imaging of patients with clinically suspected appendicitis in the Netherlands: conclusions of a survey. Br J Radiol 2009;82:482–5.
[7] Brennan GD. Pediatric appendicitis: pathophysiology and appropriate use of diagnostic imaging. CJEM 2006;8:425–32.
[8] Wiersma F, Sramek A, Holscher HC. US features of the normal appendix and surrounding area in children. Radiology 2005;235:1018–22.
[9] Kaneko K, Tsuda M. Ultrasound-based decision making in the treatment of acute appendicitis in children. J Pediatr Surg 2004;39:1316–20.
[10] Ang A, Chong NK, Daneman A. Pediatric appendicitis in ''real-time'': the value of sonography in diagnosis and treatment. Pediatr Emerg Care 2001;17:334–40.
[11] 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;175:977–80.
[12] Taylor GA. Suspected appendicitis in children: in search of the single best diagnostic test. Radiology 2004;231:293–5.
[13] Wiersma F, Toorenvliet BR, Bloem JL, et al. US examination of the appendix in children with suspected appendicitis: the additional value of secondary signs. Eur Radiol 2009;19:455–61.
[14] Lander A. The role of imaging in children with suspected appendicitis: the UK perspective. Pediatr Radiol 2007;37:5–9.
[15] Hernandez JA, Swischuk LE, Angel CA, et al. Imaging of acute appendicitis: US as the primary imaging modality. Pediatr Radiol 2005; 35:392–5.
[16] York D, Smith A, Phillips JD, et al. The influence of advanced radiographic imaging on the treatment of pediatric appendicitis. J Pediatr Surg 2005;40:1908–11.
[17] Garcia Pena BM, Mandl KD, Kraus SJ, et al. Ultrasonography and limited computed tomography in the diagnosis and management of appendicitis in children. JAMA 1999;282:1041–6.
[18] Peletti AB, Baldisserotto M. Optimizing US examination to detect the normal and abnormal appendix in children. Pediatr Radiol 2006;36: 1171–6.
[19] 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;230:472–8.