



# Clinical Relevance of the Nonvisualized Appendix on Ultrasonography of the Abdomen in Children

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**Objectives** To evaluate the clinical relevance of the nonvisualized appendix on ultrasound imaging in children with right lower quadrant pain.

**Study design** We reviewed 1359 children admitted for abdominal pain between January and December 2013 who had abdominal ultrasound imaging for right lower quadrant pain. Patients who had scans for genitourinary symptoms or intussusception were excluded from the study. When the appendix was not visualized, secondary signs indicating right lower quadrant inflammatory pathology were noted.

**Results** Of all admissions for abdominal pain, 810 had ultrasound scans. Thirty-eight did not evaluate the appendix and 131 were excluded for suspected intussusception, leaving 641 reports for children with a median age of 10.8 years (range, 1.3-21.3); 297 were boys (46.3%). There were 17 of 160 patients with a nonvisualized appendix (10.6%) who underwent appendectomy. Of these, 14 had secondary signs on ultrasound imaging and 3 (1.9%) had normal ultrasound reports. The 3 patients with normal ultrasound imaging had computed tomography imaging confirming appendicitis. There were 51 patients with a partially visualized appendix. The segment of appendix that could be seen was normal in 34 patients, none of whom had appendectomy. The remaining 17 had appendectomy, in whom the appendix seemed to be inflamed in 13 and equivocal in 4, all with histologically confirmed appendicitis. Overall, 232 children underwent appendectomy; 58 had no ultrasound imaging done, and 5 had a histologically normal appendix (overall negative appendectomy rate, 2.2%). Only 35 of 1359 patients (0.03%) had computed tomography scans.

**Conclusion** In patients with a nonvisualized appendix on ultrasound imaging and no evidence of secondary inflammatory changes, the likelihood of appendicitis is less than 2%. Generous use of ultrasonography as an adjunct to clinical examination can achieve low negative appendectomy rates without underdiagnosis of acute appendicitis. (*J Pediatr* 2017;182:164-9).

Acute appendicitis is the most common surgical emergency in children, yet it can be difficult to differentiate from other causes of acute abdominal pain. Heavy reliance has been placed on clinical assessment via serial abdominal examination to reach a diagnosis, but this was frequently associated with high negative appendectomy rates or missed appendicitis.<sup>1</sup> The use of diagnostic imaging, specifically the use of computed tomography (CT), has been advocated for the routine assessment of abdominal pain because it demonstrates high sensitivity and high specificity in the diagnosis of appendicitis.<sup>2</sup> However, detractors cite the risks of unnecessary radiation exposure in children who may be more susceptible to long-term ill effects, including radiation-induced malignancy.<sup>3,4</sup> Some studies report that 20%-40% of CT scans performed in children for the investigation of abdominal pain revealed no intra-abdominal pathology.<sup>5,6</sup>

Ultrasonography, with its absence of radiation, seems to be the ideal imaging modality for children. However, it has its limitations: accuracy depends on the technical skills of the radiologist, services depend on availability of a sonographer who may not be present out of hours, and body habitus of the patient may affect imaging detail.<sup>7,8</sup> In particular, it is difficult to decide how to interpret a study when the appendix cannot be visualized accurately.

Therefore, this study aims to evaluate the clinical relevance of the nonvisualized appendix on ultrasound assessment of abdominal pain in children where acute appendicitis is a differential diagnosis. We also assessed the use of CT imaging and its supportive role in evaluation for acute appendicitis.

## Methods

Our pediatric surgical unit manages acute general surgical admissions in children who are admitted via the children's emergency department which serves

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BMI Body mass index CT Computed tomography

approximately 175 000 patient visits a year. Ethical approval (2014/051/D) was obtained from our institutional ethical review board before the study was carried out.

In this retrospective study, we reviewed the electronic medical records of all pediatric patients admitted with right lower quadrant abdominal pain to the pediatric surgical unit from the emergency department between January to December 2013. We recorded patient demographics, ultrasound findings, operative findings, final diagnosis at discharge, and histologic reports.

### Institutional Protocols

In our institution, office hour (working weekday) ultrasound studies are performed by trained sonography technicians whose scan images are reviewed and reported by specialty certified radiologists. Out of hours scans are available and provided by an onsite radiology resident, supervised by an on-call consultant radiologist with offsite access to images. All ultrasound studies are performed after admission and are not point-of-care studies done in the emergency department. Laparoscopic appendectomy is our surgical technique of choice.

Upon discharge, all patients are contacted at 3 days to evaluate the persistence of their symptoms. We assumed no missed surgical pathologies if there were no physical complaints on follow-up telephone contact. For this study, this helped to confirm that there were no cases of missed appendicitis.

### Exclusion Criteria

We excluded the following patients from analysis: (1) those who had ultrasound imaging for genitourinary symptoms; (2) those who had ultrasound imaging for suspected intussusception—in our institution, when intussusception is the provisional diagnosis, an ultrasound examination is done to exclude the presence of intussusception, and does not include a full and detailed study of the entire abdomen and viscera; and (3) those whose ultrasound reports made no mention of the appendix, that is, we could not tell from the report whether or not it had been looked for and assessed by the sonographer.

### Definitions

Nonvisualized on ultrasound examination was defined as an appendix that was sought for on ultrasound imaging but could not be seen. Fully visualized on ultrasound examination was defined as an appendix that could be followed from its caeca attachment to its tip. Partially visualized on ultrasound examination was defined as an appendix that could be assessed for part of its anatomy but incompletely.

Abnormal appearance on ultrasound examination was defined as when the appendix was reported as inflamed, usually accompanied by any of the following features: appendiceal diameter of 8 mm or greater, hyperemic appendiceal wall, echogenic thickened periappendiceal fat, presence of an appendicolith, and noncompressibility of the appendix. Normal appearance on ultrasound examination was defined as when the appendix was reported definitively as normal in appearance, usually measuring 6 mm or less in diameter, with normal vascularity and echogenicity (Figure 1, A). Equivocal appear-

ance on ultrasound examination was defined as when the appendix could not be categorized definitively as either abnormal or normal. Examples include borderline appendiceal diameter measuring 7 mm with no other features of appendicitis or a noncommittal report from the radiologist such as 'unable to exclude early appendicitis.'

Ultrasound features or 'secondary signs' suggesting appendicitis or inflammatory pathology in the right lower quadrant (Figure 1, B-D) were defined as presence of thickened echogenic periappendiceal/intra-abdominal fat or extraluminal fluid collection. Diagnosis at discharge was defined as appendicitis (those who had appendectomy) or not appendicitis (those who did not have appendectomy).

In this study, a pediatric surgeon reviewed all ultrasound reports and categorized them into clearly abnormal, clearly normal, and equivocal cases. A pediatric radiologist then re-evaluated the findings and both achieved a consensus.

Statistical analysis was performed using IBM SPSS 19 software (SPSS Inc, Chicago, Illinois). The  $\chi^2$  test was used for categorical variables and the Mann-Whitney *U* test for non-parametric continuous variables with a  $P < .05$  taken as level of significance. ANOVA and pairwise comparisons were also performed to compare across groups. Data for continuous variables are reported as median values and ranges.

## Results

There were 1359 admissions for abdominal pain during the study period. After a review of all records, there were 810 children who had ultrasound imaging for right lower quadrant pain that were not done for genitourinary pathology. Of the 810, 131 were for suspected intussusception, and 38 did not mention evaluating the appendix, leaving 641 reports for analysis (Figure 2; available at [www.jpeds.com](http://www.jpeds.com)). In these 641 patients, the median age was 10.8 years (range, 1.3-21.3) and there were 297 boys (46.3%) (Table I).

In 160 patient reports, the appendix could not be visualized. Of these, 17 patients underwent appendectomy. Fourteen of the 17 had ultrasound findings suggestive of associated intra-abdominal inflammation, 13 of whom had histologically proven appendicitis and 7 of whom had perforated appendicitis. The remaining 3 patients (1.9%) had otherwise normal ultrasound reports and progressed to CT imaging, which diagnosed appendicitis; all 3 had histologically proven appendicitis.

In other words, when the appendix cannot be visualized on ultrasound examination, and secondary signs are present, the sensitivity in diagnosing appendicitis is 82.4% and specificity is 99.3%, with high positive predictive value of 93.3% and high negative predictive value of 97.9% (Table II).

The appendix was visualized fully in 430 children. Of these, 140 had appendectomy with an accurate diagnosis achieved in 99.3% of cases. There were 2 appendices reported as normal on histology. Both these patients had ultrasound reporting an abnormal appendix. When the appendix was visualized fully, sensitivity and specificity were high at 98.4% and 100%, respectively (Table II).

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