Journal of Pediatric Surgery 50 (2015) 923–927

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

The non-diagnostic ultrasound in appendicitis: is a non-visualized appendix the same as a negative study?

Brian Cohen [a], Jordan Bowling [b], Peter Midulla [a], Edward Shlasko [a], Neil Lester [c], Henrietta Rosenberg [c], Aaron Lipskar [a,*]

[a] Division of Pediatric, General, and Thoracic Surgery, Icahn School of Medicine at Mount Sinai, New York, NY, USA
[b] Department of Surgery, Icahn School of Medicine at Mount Sinai, New York, NY, USA
[c] Department of Radiology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

ARTICLE INFO

Article history:
Received 2 March 2015
Accepted 10 March 2015

Key words:
Appendicitis
Abdominal ultrasound
Non-diagnostic ultrasound
Negative predictive value

ABSTRACT

Purpose: The purpose of this retrospective study was to investigate outcomes in children who underwent a non-diagnostic ultrasound (US) evaluating for appendicitis and to identify predictors of a negative diagnosis.
Methods: An IRB-approved retrospective chart review was performed on patients age 0–18, who underwent an abdominal US evaluating for acute appendicitis from 2004 through 2013. Clinical data and specified outcomes were recorded, and exams were categorized into non-diagnostic studies and further separated into studies where the appendix was non-visualized.
Results: Of the 1383 studies included for analysis, 876 were non-diagnostic for acute appendicitis (63.34%) with 777 specifically because the appendix was non-visualized. Seven hundred forty of the 876 non-diagnostic studies and 671 of the 777 non-visualized studies were ultimately considered true negatives, corresponding to a negative predictive value (NPV) of 84.47 and 86.36%, respectively. In patients with WBC $<7.5 \times 10^9$/L, the NPV of non-diagnostic and non-visualized studies increased to 97.12 and 98.86%, respectively. Patients with WBC $<11.0 \times 10^9$/L have similarly high NPVs of 95.59 and 96.99% (non-diagnostic and non-visualized).
Conclusion: Based on the high NPV of a non-diagnostic US in children without leukocytosis, these patients may safely avoid further diagnostic imaging for the workup of suspected appendicitis.

Acute appendicitis is the most common abdominal emergency worldwide and appendectomies are the most common emergency surgery in the pediatric population [1]. The foundation of the diagnosis of appendicitis is clinical assessment, however, history and physical examination alone have low sensitivity and specificity [2], and adjunctive imaging studies have become relatively commonplace in the workup of right lower quadrant pain. Even with significant advances in imaging modalities, the question of what imaging, if any, should be used to aid in diagnosis, persists [3,4].

Early diagnosis is critical in preventing perforation, abscess formation, and postoperative complications [5]. This consideration must be weighed against the risks inherent in unnecessary appendectomies, as well as the health and financial costs of excessive imaging. There were early reports advocating that computerized tomography (CT) scan be the gold standard for diagnosis of appendicitis [6], citing the high sensitivity offered by the CT exam vs. other modalities. Due to increasing concern regarding the risk of radiation exposure, there is significant interest both in the media as well as in the surgical literature regarding the avoidance of CT scans. Many tertiary care centers around the country are therefore using ultrasound (US) as the first imaging modality, and there have been studies that proposed US followed by selective CT or magnetic resonance imaging (MRI) when the US study is non-diagnostic [7–9]. Research regarding the negative predictive value (NPV) of a non-diagnostic CT scan has been reported [10], however, there are minimal data regarding the meaning of a non-diagnostic US. The purpose of this study is to investigate outcomes in children who underwent a non-diagnostic US and identify predictors of a negative diagnosis after an equivocal study.

We hypothesized that a non-diagnostic US, especially in conjunction with specific clinical parameters such as the absence of leukocytosis, the absence of obesity, and the study being performed between normal work/fully staffed hours (9 am and 5 pm), are highly predictive of a truly negative appendicitis diagnosis.

1. Methods

1.1. US technique and diagnostic criteria

Following voiding, a linear 12-5 transducer was used (linear 9-3, and/or curvilinear 9-4, 5-2 or 5-1 MHz for obese patients) for evaluation of the right lower quadrant in transverse and sagittal directions using a graded compression technique to search for the appendix. A positive study was reported upon identification of a blind-ending, tubular,

* Corresponding author at: Icahn School of Medicine at Mount Sinai, Division of Pediatric, General, and Thoracic Surgery, 5 East 98th Street, 15th Floor, Box 1259, New York, NY, 10029. Tel.: +1 212 241 1602.
E-mail address: aaron.lipskar@mountsinai.org (A. Lipskar).

http://dx.doi.org/10.1016/j.jpedsurg.2015.03.012
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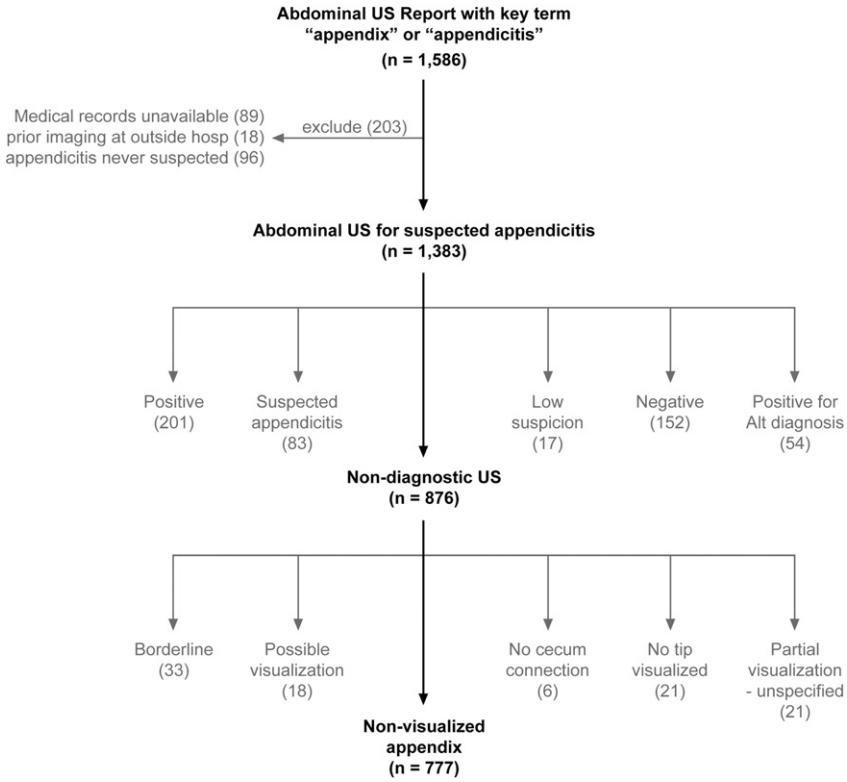

Fig. 1. Breakdown of US result categories—the bold center line represents data on which the majority of analysis was performed.

non-compressible structure in the right lower quadrant measuring >6.5 mm in diameter and showing connection to the cecum. Other signs indicating towards a positive study included appendiceal hyperemia, abnormal echogenicity of surrounding fat, or free fluid in the area. In addition, the pelvis and lower abdominal quadrants were evaluated with the bladder as well distended as possible to identify localized or free fluid collections, an appendix that extends into the pelvis, the right ovary, as well as other pathology. In our institution, a pediatric radiologist and pediatric radiology technologist were both present between the hours of 9 am and 5 pm, whereas an on-call radiology resident performed the studies during "off-hours". We based our analysis on the time of the study instead of directly recording who performed the exams.

1.2. Study design and population

After obtaining approval from the internal review board (IRB # 13-1902-00001-01-PD), we performed a retrospective chart review for all patients, age 0–18, who underwent an abdominal US evaluating for appendicitis between January 2004 and December 2013 in a single tertiary academic medical center. A total of 1586 studies were identified after patients underwent an abdominal US (ordered as either an "US Abdomen Complete" or "US Abdomen Limited") in which the US report mentioned the key terms, "appendix" or "appendicitis". From this group, 203 studies were excluded if the patient's medical records were unavailable for review, if they had prior imaging done at an outside hospital, or if it was deemed that appendicitis was never suspected according to the US report.

1.3. US result definitions

After reviewing the remaining US reports, an additional 54 studies were excluded because the US was conclusive for an alternative diagnosis (intussusception, ovarian cyst, etc.). Studies were then categorized as positive or negative when an ultrasound was conclusive for acute appendicitis. If there were signs indicating towards appendicitis, but the report fell short of calling it a conclusive study (because of a failure to trace the appendix back to the cecum, failure to fully visualize the tip, etc.) the study was categorized as "suspected appendicitis". A similar label of "low suspicion" was used when the US report fell short of a negative study, but still described most of a normal-appearing appendix. The remaining reports were all categorized as non-diagnostic. The non-diagnostic US studies were further broken down into the following categories: borderline (diameter between 6 and 7 mm, conflicting diagnostic criteria, etc.), no connection to the cecum visualized, no tip visualized, partial visualization (unspecified), possible visualization (questionable structure which may represent an appendix or a bowel loop, etc.), and non-visualized (neither a normal nor abnormal appendix was seen). The breakdown of categories is shown in Fig. 1 along with the number of studies that fell into each group. Patient's medical records were reviewed for all non-diagnostic studies.

1.4. Data collection and outcome definitions

For each electronic medical record that was reviewed, the following information was collected: date of birth, date of service, time of service, gender, weight, temperature, and WBC count.

It was also recorded whether the patient had a CT scan, any associated CT findings, whether they went to surgery, any operative findings, whether they had a repeat US, and any associated US findings. For the purposes of this study, multiple ultrasounds were treated as separate data points. If a repeat US was conclusive, it was categorized as such, whereas the original non-diagnostic scan remained as a separate, non-diagnostic data point. Pathological findings were used to record if the patient was ultimately diagnosed with acute appendicitis. If a patient had no CT scan or a negative CT, no surgery or a negative appendectomy, and no conclusive repeat US, then they were presumed to not have acute appendicitis (true negatives). Two patients with non-diagnostic ultrasounds developed appendicitis at future visits (5 months and 4 days and 5 months and 10 days after their equivocal scans); they