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Ultrasound in Emergency Medicine

PREDICTORS OF NONDIAGNOSTIC ULTRASOUND FOR APPENDICITIS

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☐ **Abstract—Background: Ionizing radiation and cost make ultrasound (US), when available, the first imaging study for the diagnosis of suspected pediatric appendicitis. US is less sensitive and specific than computed tomography (CT) or magnetic resonance imaging (MRI) scans, which are often performed after nondiagnostic US. Objectives: We sought to determine predictors of nondiagnostic US in order to guide efficient ordering of imaging studies. Methods: A prospective cohort study of consecutive patients 4 to 30 years of age with suspected appendicitis took place at an emergency department with access to 24/7 US, MRI, and CT capabilities. Patients with US as their initial study were identified. Clinical (i.e., duration of illness, highest fever, and right lower quadrant pain) and demographic (i.e., age and sex) variables were collected. Body mass index (BMI) was calculated based on Centers for Disease Control and Prevention criteria; BMI >85th percentile was categorized as overweight. Patients were followed until day 7. Univariate and stepwise multivariate logistic regression analysis was performed. Results: Over 3 months, 106 patients had US first for suspected appendicitis; 52 (49%) had nondiagnostic US results. Eighteen patients had appendicitis, and there were no missed cases after discharge. On univariate analysis, male sex, a yearly increase in age, and overweight BMI were associated with nondiagnostic US ($p < 0.05$). In the multivariate model, only BMI (odds ratio 4.9 [95% CI 2.0–12.2]) and age (odds ratio 1.1 [95% CI 1.02–1.20]) were predictors. Sixty-eight percent of nondiagnostic US results occurred in overweight patients. Conclusion: Overweight and older patients are more likely to have a nondiagnostic US or appendicitis, and it may be more efficient to consider alternatives to US first for these patients. Also, this information about the accuracy of US to diagnose suspected appendicitis may be useful to clinicians who wish to engage in shared decision-making with the parents or guardians of children regarding imaging options for children with acute abdominal pain.**

☐ **Keywords—appendicitis; body mass index; nonvisualized appendix; ultrasound**

INTRODUCTION

Appendicitis is the leading cause of emergency abdominal surgeries in children (1). There are approximately 295,000 appendectomies performed annually in the United States (2). Nationwide, the annual charges relating to pediatric appendicitis total approximately $800 million (3).

Importance

Delayed diagnosis of appendicitis increases the risk for perforation and other morbidities, including death (4). Diagnostic imaging, such as ultrasound (US), computed tomography (CT) scans, and more recently, magnetic

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resonance imaging (MRI) scans are used to expedite and confirm the diagnosis. Concern exists about the appropriateness of CT scans in children and young adults because of increased awareness of the effects of exposure to ionizing radiation. Non–radiation-based imaging is generally recommended by the American Academy of Pediatrics, the National Cancer Institute, and the American Pediatric Surgical Association (5). As a result, US is considered to be first-line imaging for appendicitis in many centers. Even though the sensitivity and specificity of US is quite high (44–94% and 47–95%, respectively), it sometimes leads to controversial or nondiagnostic studies, especially when the appendix is not visualized (6,7). This often results in the use of a second imaging modality, incurring increased time to diagnose and extra cost. MRI and CT scans are both more sensitive and specific than US (6). As MRI scanning becomes faster and more available and newer generation CT scanner protocols result in decreased dosages of ionizing radiation, it may be advantageous to be able to predict which patients are likely to have an initial nondiagnostic US and obtain a more sensitive and specific study from the beginning. Also, if body habitus or other factors can be shown to influence the accuracy of abdominal US for children with acute abdominal pain suspected to be caused by acute appendicitis, this information, along with the data regarding the probable risks associated with the radiation involved in a CT scan of the abdomen, could be useful toward more precisely formatting a "shared decision-making" discussion regarding imaging choices with the parents or guardians of these children.

Goals of this Investigation

There have been conflicting studies surrounding patient body mass index (BMI) and other factors associated with nondiagnostic US (8–12). The goal of this study was to prospectively evaluate BMI and other potential predictors of nondiagnostic US for appendicitis in children and young adults.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective cohort study of consecutive patients who had suspected appendicitis. The study took place between July 1 and October 31, 2014 at a suburban academic emergency department (ED) with an approximated volume of 60,000 annual visits where radiologists reviewed CT, MRI, and US images 24 hours per day, 7 days per week. Experienced sonographers obtain US images and they are reviewed by radiology residents specializing in either pediatrics or adults, followed by the review of the radiology fellow in real time and then with a final review by the attending radiologist. The study was reviewed and approved by our university's institutional review board with a waiver of informed consent.

Population

All patients presenting to the ED between 4 and 30 years of age who were suspected to have appendicitis as their primary diagnosis and had US as their first imaging study were included. A study investigator then reviewed eligibility by confirming that appendicitis was the primary working diagnosis based upon course of treatment. Patients were excluded if they had CT or MRI scans as their primary imaging study or if they had no imaging.

Variables and Data Collection

Patients were identified using a real-time electronic tracking system that linked US orders to text alerts. Unique identifiers of patients that met eligibility criteria were consecutively recorded into the study database. Predictor and outcome variables were collected from electronic medical records. The clinical variables collected included duration of illness, highest fever, and presence and severity of right lower quadrant (RLQ) pain. Demographic variables included age, sex, and weight. BMI was calculated based on weight and height for age and classified as a dichotomous variable (normal vs. overweight); BMI >85th percentile for age and sex was defined as overweight (13). If a patient had a weight entered in the medical record for that visit but no height was entered, a national average based on a patient's age was used to impute the missing BMI value.

Ascertainment of the Outcome

The outcome of diagnostic versus nondiagnostic US was based on the radiology report, which simply stated whether the appendix was visualized or not. A diagnostic US was defined as an US in which the appendix was visualized, whether it was enlarged or not, whereas a nondiagnostic US was defined as an US examination with no visualization of the appendix. Cases in which there were secondary signs concerning for appendicitis, such as tenderness on examination or free fluid on imaging, but no clear visualization of the appendix, were considered nondiagnostic. Surgical diagnosis of appendicitis was obtained from the operative and pathology notes. Patients discharged without an operation were followed-up at 7 days to confirm the absence of appendicitis. Outcome data were collected from the electronic medical record or via phone follow-up.