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Reducing computed tomography scans for appendicitis by introduction of a standardized and validated ultrasonography report template

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ABSTRACT

Purpose: Computed tomography (CT) for the diagnosis of appendicitis is associated with radiation exposure and increased cost. In an effort to reduce the diagnostic use of CT scans, we implemented a standardized ultrasound report template based on validated secondary signs of appendicitis.
Methods: In September 2012, as part of a quality improvement project, we developed and introduced a four category standardized ultrasound report template for limited right lower quadrant abdominal ultrasounds. Outcomes for patients undergoing ultrasound or CT scan for appendicitis between 9/10/2012 and 12/31/2013 (Period 2, n = 2033) were compared to the three months prior to implementation (Period 1, n = 304).
Results: In Period 1, 78 of 304 (25.7%) patients had appendicitis versus 385 of 2033 (18.9%) in Period 2 ($p = 0.006$). Non-diagnostic exams decreased from 48% to 0.1% ($p < 0.001$). Ultrasound sensitivity improved from 66.67% to 92.2% ($p < 0.001$). Specificity did not significantly change (96.9% to 97.69%, $p = 0.46$). CT utilization for appendicitis decreased from 44.3% in Period 1 to 14.5% at the end of Period 2 ($p < 0.001$).
Conclusions: Implementation of a standardized ultrasound report template based on validated secondary signs of appendicitis nearly eliminated non-diagnostic exams, improved diagnostic accuracy, and resulted in a striking decrease in CT utilization.

Acute appendicitis is the most frequent cause of acute abdominal surgery in children [1]. The total lifetime cumulative incidence rate of appendicitis is 9% and has been increasing annually [2]. The diagnosis of appendicitis is most prevalent during the second decade of life, specifically between the ages of 10 and 14 [2]. Despite the frequency of appendicitis, diagnosis can be challenging [3,4].

Both ultrasound and CT have been reported to improve diagnostic accuracy in appendicitis [5]. CT scan rates for the diagnosis of appendicitis have been increasing nationally [6,7]. Although CT is reported to have a higher sensitivity than ultrasound, ongoing concerns have been raised about the radiation exposure and increased costs associated with CT [8,9]. Projections estimate that a solid cancer will result at a rate of 25.8 to 33.9 cases per 10,000 abdominal CT scans for girls and 13.1 to 14.8 cases per 10,000 abdominal CT scans for boys [10]. Strategies to increase the utility of ultrasound as a diagnostic tool for appendicitis are desirable to reduce radiation exposure and decrease costs, but ultrasound has challenges as well. Appendix visualization rates vary and ultrasound exhibits significant user dependency [11–13].

Others have sought to decrease CT rates by establishing diagnostic protocols using pediatric appendicitis scores and surgeon assessment [3,14]. Increased use of magnetic resonance imaging (MRI) has been proposed [15], but MRI is also associated with challenges including cost, time and potential need for sedation to obtain an accurate study.

We designed and implemented a standardized ultrasound reporting template based on validated secondary signs of appendicitis in order to increase the diagnostic accuracy of the ultrasound exam and to simultaneously decrease CT utilization.

1. Materials and methods

1.1. Template design

A collaborative group from the quality improvement, pediatric surgery, and pediatric radiology departments met in 2012 to discuss a standardized ultrasound reporting template for appendicitis. The current literature was reviewed to design a template with maximal sensitivity and specificity. A maximal outer diameter of <7 mm and a maximal appendiceal wall thickness of <1.7 mm with graded compression were considered normal [16]. Secondary signs were defined as hyperechogenic periappendiceal fat, fluid collection consistent with an appendicular abscess, and local dilation and hypoperistalsis of the

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bowel consistent with focal peritonitis [17]. Other sonographic findings including hyperemia of the appendix, free fluid, lymphadenopathy, and appendicoliths were included as part of the template for assessment but were not considered secondary signs in the analysis. Radiologists were asked to classify patients into four categories: 1. Normal appendix; 2. Appendix not visualized or partially visualized without secondary signs of appendicitis; 3. Appendix not visualized or partially visualized with secondary signs of appendicitis; 4. Acute appendicitis [17]. Category 1 and 2 reports were considered negative for appendicitis while Category 3 and 4 reports were considered positive.

Three criteria were required for a compliant ultrasound report: the template had to be used by the radiologist, one of the four categories had to be selected, and the category selected had to match the information in the report. A sample ultrasound template consistent with Category 1 is shown in Fig. 1. Non-diagnostic exams were defined as ultrasound reports where the description was insufficient to make or exclude the diagnosis of appendicitis. An IRB exemption was granted for this quality improvement project (IRB# 13–00734).

1.2. Patients

From 9/10/2012 to 12/31/2013 (Period 2, n = 2033) records from all patients undergoing abdominal ultrasound evaluation in our emergency department (ED) were prospectively reviewed. Only ultrasounds performed for suspected appendicitis were included in the analysis. Patients enrolled in a concurrently running study on the non-operative management of appendicitis were excluded. Demographic data, ultrasound reports, and diagnostic accuracy were compared to the period prior to implementation of the template from 6/1/2012 to 9/9/2012 (Period 1, n = 304). All CT scans obtained in our ED for evaluation of appendicitis during Periods 1 and 2 were also reviewed. All patients undergoing imaging for suspicion of appendicitis were used to calculate the CT utilization rate. Final diagnosis was determined by histopathology and defined as transmural inflammation of the appendix [18,19].

1.3. Statistical analysis

Descriptive statistics were calculated, including frequencies, percentages, means, and standard deviations. To statistically compare Periods 1 and 2, chi-square tests were performed for categorical variables. Fisher's Exact Test was used when the variable was dichotomous and the number of data points was below 5. T-tests were used to make group comparisons for continuous variables. Measures of test accuracy including sensitivity, specificity, and predictive values were determined by standard methods. Results were tracked using statistical process control (SPC) methodology with control charts (p-charts) per established quality improvement practices. Compliance was defined as ultrasound reports that used the template and selected a category per established guidelines.

1.4. Normal work flow

Initial clinical evaluation of all patients with abdominal pain is performed by our ED physicians. ED physicians make the determination to obtain imaging. Ultrasound is our primary diagnostic imaging modality and is preferentially ordered but is not mandated. The ED physicians had full license to order both initial and secondary imaging for appendicitis prior to surgical consultation. ED Physicians could involve surgery in the decision if they wished but this was not mandated during the time of the study and surgery involvement prior to ordering imaging was inconsistent.

2. Results

2.1. Patient demographics/epidemiology

Demographic data between Periods 1 and 2 were similar. The rate of appendicitis among patients undergoing ultrasound decreased from 25.7% (78/304) in Period 1 to 18.9% (385/2033, p = 0.006) in Period 2. At the same time, the average number of ultrasound exams per month increased from 92.3 in Period 1 to 129.4 in Period 2. Despite differences in appendicitis rates the negative appendectomy rate (NAR) was unchanged (Period 1 = 8.23% vs. Period 2 = 8.76%, p = 0.8).

2.2. Diagnostic accuracy

The sensitivity and negative predictive value (NPV) of our ultrasound exams improved to greater than 90% after the template, and non-diagnostic exams were nearly eliminated (Table 1). The specificity and positive predictive value (PPV) of ultrasound also improved but not significantly (Table 1). Compliance to the template led to a lower NAR, lower CT utilization rate, and higher specificity (Table 2). The rate of non/partial visualization was unchanged between Periods (55.9% vs. 54.1%, p = 0.55).

The predictive values of ultrasound varied for each template category. The NPV of Categories 1 & 2 and the PPV of Category 4 were high. Category 3 was our poorest performing category with a PPV of 76% (Table 3). Falsely positive Category 3 patients had a female predominance (12/17 or 70.6%, p = 0.137).

Figure 1

Appendix: The appendix is identified in the right lower quadrant.
Appendix size: The appendix is less than 7 mm in outer diameter measuring 4.2 mm.
Wall thickness: Normal, less than 1.7 mm in thickness measuring 0.8 mm
****Appendicolith:** No appendicolith was identified.
Perforation: None
***Abscess:** None
****Fluid:** There is no free fluid.
***Periappendiceal fat:** The periappendiceal fat is normal.
****Vascularity:** Normal vascularity was observed without hyperemia.
****Mesenteric lymph nodes:** No pathologically large lymph nodes were observed.
***Adjacent bowel loops:** Peristalsing normal appearing bowel loops were observed.
Additional abnormalities: None

Impression: Normal appendix.

Fig. 1. Sample Category 1 standardized right lower quadrant limited ultrasound report template. Primary criteria include appendiceal size and wall thickness. * Approved secondary signs. ** Additional signs not considered approved secondary signs.