Clinical Practice Guidelines for Pediatric Appendicitis Evaluation Can Decrease Computed Tomography Utilization While Maintaining Diagnostic Accuracy

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Objectives: The objective of this study was to compare usage of computed tomography (CT) scan for evaluation of appendicitis in a children's hospital emergency department before and after implementation of a clinical practice guideline focused on early surgical consultation before obtaining advanced imaging.

Methods: A multidisciplinary team met to create a pathway to formalize the evaluation of pediatric patients with abdominal pain. Computed tomography scan utilization rates were studied before and after pathway implementation.

Results: Among patients who had appendectomy in the year before implementation (n = 70), 90% had CT scans, 6.9% had ultrasound, and 5.7% had no imaging. The negative appendectomy rate before implementation was 5.7%. In patients undergoing appendectomy in the postimplementation cohort (n = 96), 48% underwent CT, 39.6% underwent ultrasound, and 15.6% had no imaging. The negative appendectomy rate was 5.2%. We demonstrated a 41% decrease in CT use for patients undergoing appendectomy at our institution without an increase in the negative appendectomy rate or missed appendectomy. The results were even more striking when comparing the rate of CT scan use in the subset of patients undergoing appendectomy without imaging from an outside hospital. In these patients, CT scan utilization decreased from 82% to 20%, a 76% reduction in CT use in our facility after protocol implementation.

Conclusions: Implementation of a clinical evaluation pathway emphasizing examination, early surgeon involvement, and utilization of ultrasound as the initial imaging modality for evaluation of abdominal pain concerning for appendicitis resulted in a marked decrease in the reliance on CT scanning without loss of diagnostic accuracy.

Key Words: appendicitis, computerized tomography, CT scan, clinical pathway, ultrasound

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Appendicitis is the most common cause of an acute surgical abdomen in childhood.[1,2] Greater than 100,000 patients are treated in children's hospitals for appendicitis each year; accounting for more than $680 million in hospital charges.[3] Although classic descriptions of the signs and symptoms of acute appendicitis are well known, diagnostic accuracy based on history and physical examination and laboratory analysis often remains difficult in pediatric patients. A child's clinical status can vary drastically across a spectrum of severity depending on the timing of presentation. Less than one third of pediatric patients with appendicitis present with the classic findings of nausea, fever, leukocytosis, and focal right-lower-quadrant pain on examination.[4] Furthermore, history and physical examination may be complicated in young children who are less communicative. Frequently, symptoms of appendicitis are attributed to gastroenteritis or constipation by caregivers and/or primary care physicians. Delay in diagnosis of appendicitis can lead to significant morbidity as complications related to perforation are seen in around 35% of pediatric cases.[5]

The disparity in the clinical presentation of appendicitis has led to wide variations in approach to both diagnosis and treatment. Traditionally, negative laparotomy rates of 20% were considered reasonable by surgeons to prevent missed cases and the associated morbidity of perforation. More recently, efforts have been made to improve rates of diagnostic accuracy through clinical scoring systems such as the Alvarado and Pediatric Appendicitis scores.[6] Unfortunately, most studies prospectively evaluating these scoring systems have shown sensitivity and specificity of around 80%, which is similar to that of an experienced clinician. Because of the limited accuracy of clinical evaluation alone and increased availability of advanced imaging, computed tomography (CT) has become the primary modality for evaluating patients with abdominal pain in many centers. This increased reliance on CT has not come without risk, however. Many clinicians worry that the increased exposure to radiation may contribute to increased risk of malignancy later in life and are, therefore, exploring alternative modalities such as ultrasound (US) to reduce reliance on CT.[7,8]

We hypothesized that reliance on CT scan for the diagnosis of appendicitis would be reduced in our institution with the introduction of a clinical practice guideline (CPG) that focused on early pediatric surgical consultation rather than the use of advanced imaging for the evaluation of abdominal pain. The primary objective of this study was to compare the usage of CT scan for evaluation of suspected appendicitis in a children's hospital emergency department (pediatric emergency department [PED]) before and after the implementation of such a CPG.

METHODS

In November 2009, a multidisciplinary team including pediatric surgeons, pediatric emergency medicine (PEM) physicians, and pediatric radiologists met at the Medical University of South Carolina (MUSC) Children's Hospital to create a pathway to formalize the evaluation of pediatric patients with abdominal pain concerning for appendicitis. The MUSC Children's Hospital is

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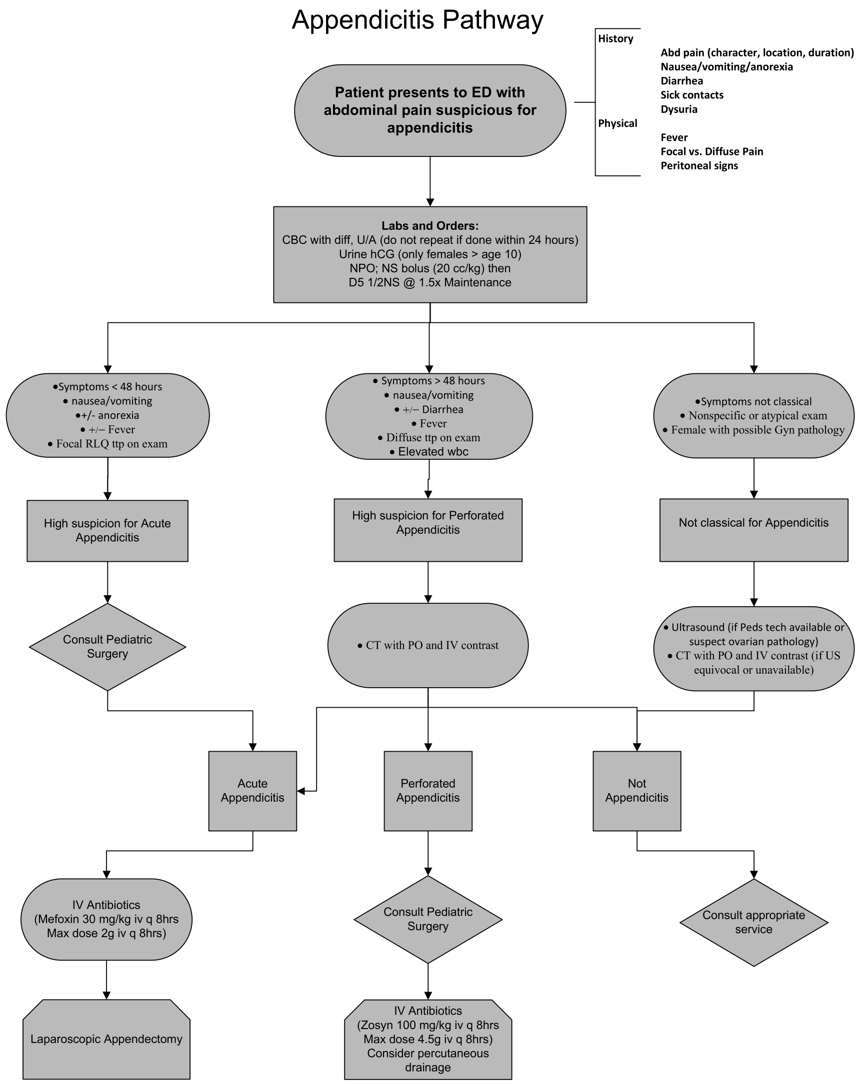

FIGURE 1. Appendicitis evaluation pathway.

an urban tertiary care hospital in Charleston, SC. The goal of this protocol was to encourage early surgical involvement for cases that were highly suggestive of acute appendicitis while recommending US for those patients with equivocal clinical findings and CT scan for findings concerning for perforated appendicitis and abscess. The CPG was introduced in July 2010 (Fig. 1). Before the introduction of this pathway, a formal education process was conducted for both the pediatric surgeons and the PEM physicians.

After protocol implementation, we sought to measure the impact on our clinical practice. We first conducted a retrospective chart review of all pediatric patients (aged 0–18 years) who underwent surgery for appendicitis at MUSC for the 12-month period before the implementation of the appendicitis clinical pathway (July 1, 2008, to June 30, 2009). Patients were identified using the CPT code for appendectomy (44970). During the 12 months following introduction of the clinical pathway, we continued the aggressive educational push aimed at both the pediatric surgeons and PEM providers to increase awareness and compliance with the new guidelines. We then prospectively collected data on all pediatric surgery consults for suspected appendicitis or focal abdominal pain for the 12 months following pathway implementation (July 1, 2010, to June 30, 2011). Patients were included based on *International Classification of Diseases, Ninth Revision* codes for appendicitis (540, 541, 542) and abdominal pain (789). All patients were evaluated both by the PEM attending physician or nurse practitioner as well as the pediatric surgery team (either resident or attending) in the PED. Patients with an etiology of abdominal pain requiring a surgery other than appendectomy were excluded. Data abstracted from each patient's medical record included general demographic information, imaging modality utilized along with imaging results, presence of

TABLE 1. Demographics of Patients With Appendectomy in Pre-CPG and Post-CBG Groups

	Pre-CPG (n = 70)	Post-CPG (n = 96)
Age, y	10.5	9.9
Female, %	31.4%	39.6%
Negative appendicitis rate	5.7%	5.2%

TABLE 2. Presence of Variables in Patients With Appendicitis Before and After Protocol Implementation

	Before Protocol (n = 66)	After Protocol (n = 92)
White blood cell count >10	49/64 (76.6%)	69/86 (80.2%)
N/V	47/66 (71.2%)	70/92 (76.1%)
Anorexia	41/66 (62.1%)	39/92 (42.4%)
Temperature >37.2°C	27/65 (41.5%)	43/90 (47.8%)
Temperature >38.0°C	14/65 (21.5%)	20/90 (22.2%)
CC: right-lower-quadrant pain	46/66 (70.0%)	52/89 (58.4%)
Exam: focal right-lower-quadrant pain	48/66 (72.7%)	66/92 (71.7%)
Exam: diffuse TTP	18/66 (27.3%)	25/92 (27.2%)

CC indicates chief complaint; N/V, nausea and vomiting; TTP, tender to palpitation.

certain symptoms at presentation (fever, diarrhea, sick contacts, nausea or vomiting, anorexia, and sexual activity), duration of symptoms, complete blood count results, urinalysis results, temperature at presentation (in degrees Celsius), and location of pain on physical examination. Equivocal US scans in which the appendix could not be visualized were considered negative studies. This study was approved by the MUSC institutional review board.

Our initial comparison was between patients who underwent appendectomy before and after protocol implementation. The primary outcome in this analysis was the percent change in CT utilization. A subset analysis of patients evaluated primarily at our institution before any imaging was performed was also conducted. The rate of negative appendectomy was measured in both groups. Secondary analysis included the presence of common symptoms and laboratory findings seen with appendicitis. Lastly, we evaluated the average length of stay (LOS) in the PED for patients who were evaluated with various imaging strategies.

RESULTS

There were 70 patients in the pre-CPG cohort and 96 in the post-CPG group who underwent appendectomy. The demographics of the preimplementation (n = 70) and postimplementation (n = 96) appendectomy patients were very similar.

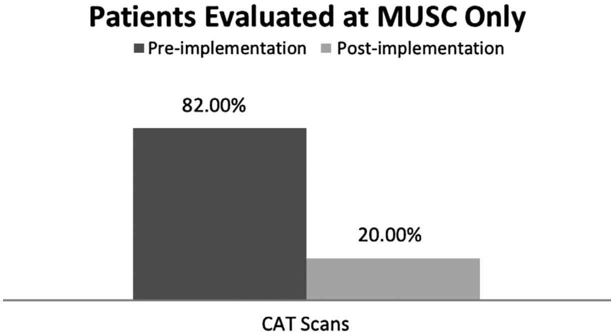

FIGURE 3. Percentage of appendectomy patients evaluated primarily at our institution receiving abdominal CT scan before CPG and after CPG.

The preimplementation cohort average age was 10.5 years, and male-to-female ratio was 48:22 (68.6%/31.4%) versus 9.9 years with gender ratio of 58:38 (60.4%/39.6%) in the postimplementation cohort (Table 1). Clinical signs and symptoms in the patients with appendicitis were similar before and after CPG implementation (Table 2). There were no significant differences in the populations, with the exception of a larger percentage of patients with anorexia and focal right-lower-quadrant abdominal pain in the preimplementation group (62.1% vs 42.4% and 70.0% vs 58.4%, respectively). The number of negative appendectomies pre-CPG was 4 (5.7%), and in the post-CPG cohort, there were 5 negative appendectomies (5.2%).

Among patients who had appendectomy in the year before implementation of the pathway (n = 70), 63 (90%) had CT scans, 5 (6.9%) had US, and 4 (5.7%) had no imaging. In patients undergoing appendectomy in the postimplementation cohort (n = 96), 46 (48%) underwent CT, 38 (39.6%) underwent US, and 15 (15.6%) had no imaging (Fig. 2). Therefore, we demonstrated a 42% (Fig. 2), decrease in CT use for all patients undergoing appendectomy without an increase in the negative appendectomy rate. A subset analysis comparing the rate of CT scan use in all patients undergoing appendectomy who were evaluated primarily at our institution (n = 105) was also performed. In those patients, none of whom received imaging at a transferring institution, the reduction in CT use was even larger. In this group of patients, CT scan utilization decreased from 82% (37/45) to 20% (12/60). This represents a 76% reduction

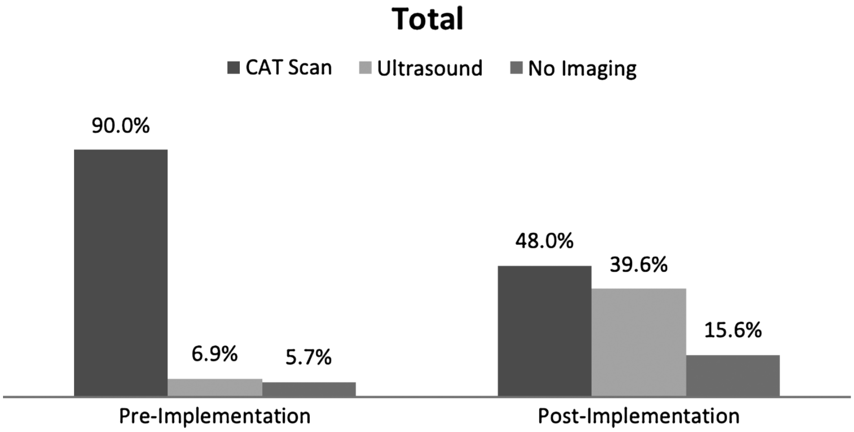

FIGURE 2. Imaging rates for appendectomy patients before CPG and after CPG.

TABLE 3. Effectiveness of Imaging Modalities Among Patients Undergoing Surgical Consults for Possible Appendicitis After Pathway Implementation

	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Abdominal CT scan	100%	86.7%	95.8%	100%
Abdominal US	63.9%	92.6%	92%	65.8%

in CT use for evaluation of appendicitis in our facility after CPG implementation (Fig. 3).

Because there was a marked decrease in CT scan utilization and subsequent increase in US performance with no change in the negative appendectomy rate, we sought to evaluate the efficacy or each of these advanced imaging modalities in our institution. All post-CPG patients in whom a surgical consultation for suspected appendicitis was performed were included in this analysis. Surgical consults for focal abdominal pain that were not found to have appendicitis were not tracked before protocol implementation and therefore not available for review. There were 134 surgical consultations in the post-CPG cohort. There was only 1 case of delayed appendicitis diagnosis (0.7%) among the 134 patients undergoing surgical consultation after pathway implementation. Computed tomography was obtained in 61 patients (45.5%) and had a sensitivity of 100% and a specificity of 86.7%. Sixty-three (47.0%) of these patients underwent US with a sensitivity of 63.9% and specificity of 92.6% (Table 3). Those who were initially evaluated at an outside facility and had imaging performed before transfer (n = 42) received CT scan 95% of the time. The imaging rates for this post-CPG implementation group who were not imaged at an outside institution before transfer (n = 92) were as follows: CT, 22.8%; US, 66.3%; no imaging, 21%; and both CT and US, 9.8% (Fig. 4).

The average LOS in the PED for patients being evaluated for acute appendicitis with surgical consultation requiring no imaging (in hours) was 3.3, whereas it was 4.8 (45.5 percent increase), 5.9 (78.8 percent increase), and 7.7 (133.3 percent increase) for those requiring US, CT, and both US and CT, respectively (Fig. 5).

DISCUSSION

In the PED, appendicitis remains a clinical diagnosis. In many institutions, CT has become the primary diagnostic modality to evaluate patients with potential appendicitis because of the greater than 95% sensitivity and specificity and its operator independence. Studies from some children's hospitals report very low rates of negative appendectomy with expanded use of CT scans,[9,10] whereas other studies have shown little improvement in diagnostic accuracy with increased CT scan utilization.[11] On a population level, CT scans have not been shown to decrease the rate of negative appendectomy in children.[12,13] Currently, more than 70 million CT scans are obtained each year in the United States.[14] Concerns about the risks of malignancy associated with low-dose radiation from CT have become more prevalent in recent years based on reports that estimate a 1/1000 lifetime mortality from a single CT scan in a child.[7] Pediatric patients are at greater risk than adults from a given amount of radiation because they are inherently more radiosensitive and because they have more years of life during which a radiation-induced malignancy could develop.[7] Previous studies have shown a greater reliance on CT scan in children evaluated for appendicitis in emergency departments that primarily take care of adults when compared with pediatric-specific emergency departments.[8] In addition to radiation exposure, CT imaging may lead to increased hospital charges.[15] To save cost and decrease radiation exposure, many centers have increased US utilization as an alternative to abdominal CT. In our institution, the charge for performance and interpretation of a pediatric CT of the abdomen and pelvis with contrast ($5728/$830, respectively; $6558 total) is approximately 6 times that of an abdominal US ($852/$231, respectively; $1083 total). Unfortunately, US has limitations as well. Ultrasound has excellent specificity, greater than 90% in many studies,[21] but overall poor sensitivity, which varies significantly with operator experience and patient body habitus. Observation with serial abdominal examination remains a viable alternative to advanced imaging as few patients progress to perforation during a brief observation period, and 23-hour admission for observation remains less expensive than CT scan in most institutions.[16] Despite these alternative options and increased recognition of risk of CT, use of CT continues to rise.

To reduce the reliance on CT scan for the diagnosis of appendicitis at our hospital, a multidisciplinary team made up

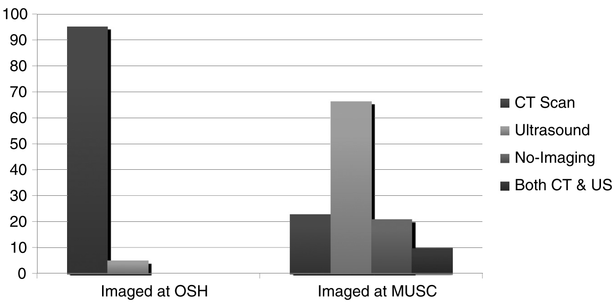

FIGURE 4. Imaging modalities for post-CPG patients imaged at outside hospital versus those imaged only at our institution.

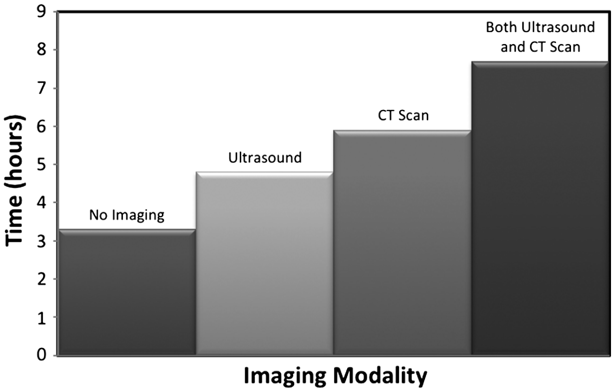

FIGURE 5. Average LOS for patients by advanced imaging modality.

of pediatric surgeons, PEM physicians, and pediatric radiologists developed a clinical pathway for the evaluation of abdominal pain in our PED. This pathway was designed to limit CT scan utilization, increase US usage for equivocal cases, and encourage early pediatric surgical involvement. Computed tomography utilization rates before and after protocol introduction were compared for all patients who underwent appendectomy. Implementation of this CPG, which emphasized experienced clinical examination before a decision about additional imaging, resulted in a significant decrease in CT scan utilization. Before the protocol, 90% of all patients who underwent appendectomy had a CT scan before surgery, whereas only 48% underwent CT scan after protocol implementation. This represents an overall reduction of CT usage of 42%. Our negative appendectomy rate was similar to that published in other recent studies, which range from 3.6% to 6.7%.[2,8,16–19] Our findings suggest that emphasis on the clinical experience of the emergency physician and early surgical consultation instead of a CT first and call second approach is effective. Of note, in the subset of patients who were evaluated with advanced imaging for abdominal pain initially at outside institutions before referral, the CT scan rate was 95%, and 5% underwent US. In contrast, patients initially evaluated at our children's hospital underwent US 65% of the time, and 25% received no advanced imaging. This subset of patients potentially represents a selection bias toward the "nonclassic" presentation of appendicitis; however, a 4-fold higher rate of CT scan suggests a reliance on CT that is higher at outside institutions than at our children's hospital. A similar trend was reported in a recent study by Neff and Ladd.[20] We believe that these data support early referral to a children's hospital for evaluation of possible appendicitis. This represents an interesting and important area for further study.

Importantly, our CPG, which emphasized early surgical consultation without CT scan or scoring systems in patients whose initial clinical evaluation was consistent with appendicitis, did not alter diagnostic accuracy. The rate of negative appendectomy based on histology was stable, 5.7% before and 5.2% after protocol implementation. As CT scan utilization decreased, rate of US use was increased. Specificity of US was relatively high (92.6%), but sensitivity was relatively low (63.9%). Despite a low prevalence of patients with a combination of variables classically associated with acute appendicitis and the relatively low sensitivity of US, the combination of evaluation by fellowship-trained pediatric ED physicians and pediatric surgeons maintained diagnostic accuracy while avoiding many unnecessary CT scans. Interestingly, the proportion of patients with focal right-lower-quadrant pain and anorexia, 2 variables commonly associated with appendicitis, was higher in the pre-CPG group. This supports our conclusion that the CPG was effective.

Limitations of this study include those inherent to any retrospective review including incomplete data gathering/recording and lack of standard documentation practices by physicians. It is also important to note that this study was performed during a time in which there was an increased awareness of and concern for radiation exposure in clinical settings, and our results might be influenced by this change in addition to our practice guideline. The small sample size in both our preimplementation and postimplementation groups makes generalizability of our findings challenging and made subset analysis of sensitivity/specificity of US and clinical variables used to diagnose appendicitis difficult. We were able to analyze only data from our institution and were, therefore, unable to compare our CT scan rate for appendicitis evaluation with that of our referring institutions to confirm our suspicion that CT rate is much higher in referring hospitals. We evaluated only the patients who underwent appendectomy before the implementation of the pathway instead of all patients evaluated for abdominal pain via surgical consult. This limited our ability to effectively measure the utility of the clinical variables in our protocol. Finally, there was a proportion of US in which the appendix was not visualized; these were categorized as negative rather than nondiagnostic, which likely affected our sensitivity/specificity calculations.

Implementation of a clinical evaluation pathway emphasizing clinical examination, early pediatric surgeon involvement, and selective utilization of US as the initial advanced imaging modality for evaluation of abdominal pain concerning for appendicitis resulted in a marked decrease in the reliance on CT scan without loss of diagnostic accuracy. We recommend increased awareness regarding the potential dangers associated with radiation-induced malignancy from CT utilization. In children where there is significant suspicion for appendicitis, transfer to a children's hospital before imaging has many potential benefits including earlier surgical intervention, decreased cost, and decreased exposure to radiation.

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