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Kuojen Tsao

Shawn D. St Peter
Children's Mercy Hospital

Patricia A. Valusek

Troy L. Spilde

Scott J. Keckler

See next page for additional authors

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Management of Pediatric Acute Appendicitis in the Computed Tomographic Era

KuoJen Tsao, M.D.[1], **Shawn D. St. Peter, M.D.**, **Patricia A. Valusek, M.D.**, **Troy L. Spilde, M.D.**, **Scott J. Keckler, M.D.**, **Abhilash Nair**, **Daniel J. Ostlie, M.D.**, and **George W. Holcomb III, M.D., M.B.A.**
Department of Surgery, The Children's Mercy Hospital, Kansas City, Missouri

Abstract

Background/Purpose—The treatment options for complicated appendicitis in children continue to evolve. Optimal management of complicated appendicitis relies on an accurate preoperative diagnosis. We examined the accuracy of our preoperative diagnosis including computed tomography (CT) and the influence on the management of children with perforated and nonperforated appendicitis.

Methods—Following IRB approval, a 6-year review of all patients that underwent an appendectomy for suspected appendicitis was performed. Treatments included immediate operations and initial nonoperative management (antibiotic therapy ± percutaneous drainage of abscess). Appendicitis was confirmed by histological examination.

Results—One thousand seventy-eight patients underwent appendectomy for suspected appendicitis. Preoperative CT scans were performed in 697 (64.7%) patients: 615 (88.2%) positive for appendicitis; 42 (6.0%) negative; and 40 (5.7%) equivocal. One hundred seventy-three (28.1%) positive CT scans further suggested perforation. Initial nonoperative management was initiated in 39 (22.5%) cases of suspected perforated appendicitis with abscess. The positive-predictive value (PPV) for suspected acute appendicitis based on history and physical examination alone was 90.8%. The PPV for positive CT scan for acute appendicitis was 96.4% with a PPV of 91.9% for positive CT scan for perforated appendicitis.

Conclusions—The correct preoperative diagnosis of appendicitis appears statistically more accurate with CT scan compared to history and physical examination alone (PPV 96.4% *versus* 90.8%, $P = 0.045$). For those with clinically suspicious complicated appendicitis, CT evaluation may direct therapy toward initial nonoperative management. The efficacy of this regimen warrants further investigation.

Keywords

acute appendicitis; perforated appendicitis; CT scan; interval appendectomy; pediatric

INTRODUCTION

In 1958, Orvar Swenson wrote in his textbook *Pediatric Surgery* that "A fundamental feature about acute appendicitis is that there is no medical treatment; only surgical excision is safe" [1]. Although most surgeons would not disagree with that dogma today, the timing

[1]To whom correspondence and reprint requests should be addressed at Department of Pediatric Surgery, University of Texas, Health Science Center–Houston, 6431 Fannin St., Suite 2.524, Houston Texas 77030. Kuojen.Tsao@uth.tmc.edu.

and management of acute appendicitis, especially perforated appendicitis, has changed dramatically. Historically, preoperative imaging was reserved for ambiguous cases based on equivocal history and physical examination. With the increased utilization of computed tomography (CT) in the diagnosis of acute appendicitis in children, the ability to identify complicated appendicitis preoperatively has allowed for the utilization of initial nonoperative therapy [2, 3]. The role of preoperative imaging has extended beyond the mere diagnostic tool for acute appendicitis and become vital in identifying those complicated cases that may be amenable to alternatives to immediate operation. Many institutions, including our own, have opted to selectively treat complicated appendicitis with extended antibiotic therapy with or without percutaneous drainage of abscesses [4–6]. With the mortality from perforated appendicitis extremely low, these adjunctive diagnostic and therapeutic modalities have been used to minimize the morbidity associated with complicated appendicitis. Thus, an accurate preoperative CT scan can play a critical role in the decision-making process in the management of pediatric appendicitis.

As our experience with initial nonoperative therapy has continued grow, we felt the importance to historically evaluate the accuracy of our diagnostic abilities since the management of complicated appendicitis is solely based on these preoperative diagnoses. Thus, we examined our experience with preoperative diagnosis of suspected appendicitis with and without CT scans in the management of acute appendicitis in a tertiary pediatric children's hospital.

METHODS

After obtaining IRB approval (no. 06 03-061X), the medical records of all children undergoing appendectomy for suspected acute appendicitis between January 1, 2000 and January 1, 2006 at Children's Mercy Hospital were retrospectively analyzed. Preoperative diagnoses of acute appendicitis were based on history and physical examination alone or history, physical examination, and CT scan. The decision for obtaining a CT scan was made by variety of healthcare personnel: pediatrician, emergency medicine practitioner, or surgeon. All CT scans were officially reviewed by a pediatric radiologist and included diagnosis of positive for acute appendicitis with or without evidence of perforation, negative for appendicitis, or equivocal. The final postoperative diagnoses of acute appendicitis including perforation were confirmed histologically by a pediatric pathologist.

All patients were treated by immediate appendectomy or initial nonoperative therapy which included antibiotic therapy with or without percutaneous drainage of abscess. All initial nonoperative therapy patients eventually underwent an interval appendectomy. Intra-abdominal abscesses on CT scan were evaluated by a pediatric radiologist to determine its amenability to percutaneous drainage. The decision for immediate operation *versus* initial antibiotic therapy was determined by one of six staff pediatric surgeons.

The study included all patients under the age of 18 years that underwent appendectomies for suspected appendicitis. Patients undergoing incidental appendectomies were excluded. Patients that underwent interval appendectomies were also excluded because their operative and histological findings would not be reflective of the initial diagnosis due to the delay to surgery. Data points collected include age at time of diagnosis, gender, performance of preoperative CT scan, results of preoperative CT scan, operative findings, and pathology results.

Bivariate analyses were performed to compare patient characteristics. χ^2 analysis was used for categorical variables. Significance was defined as $P \leq 0.05$.

RESULTS

During the 6-year period, a total of 1078 children were identified that underwent immediate appendectomy for suspected appendicitis. The mean age was 10.1 ± 3.7 years. The mean weight was 37.1 ± 5.7 kg. A preoperative CT scan was performed in 697 patients (64.7%). The remaining 381 patients underwent appendectomy for presumed acute appendicitis based on history and physical examination alone. For patients that went onto immediate operation without a CT scan, appendicitis was confirmed by histology in 346 patients. This resulted in a positive-predictive value (PPV) of history and physical examination alone of 90.8%. Perforated appendicitis was confirmed in 117 patients (30.7%).

In the cohort that underwent preoperative CT (697 patients), 615 (88.2%) CT scans demonstrated positive signs of appendicitis, 42 (6.0%) were negative, and 40 (5.7%) were equivocal. Of those with a positive CT scan, 593 (96.4%) were found to have appendicitis confirmed by histology, resulting in a PPV of 96.4%. Of the 42 patients with a negative CT for appendicitis, 15 (35.7%) were negative for appendicitis based on histology. This resulted in a negative-predictive value of 35.7% for negative CT scans.

Perforated appendicitis was preoperatively diagnosed in 173 cases based on CT scan. Based on histology, 159 (91.9%) were confirmed as perforated, and 14 (8.1%) were negative for perforation. The PPV for perforated appendicitis on CT scan was 91.9% (Table 1). Initial nonoperative management followed by interval appendectomy was initiated in 39 (22.5%) cases of perforated appendicitis based on CT scan. The diagnosis of appendicitis was confirmed by histology in all patients in this group.

Overall, the confirmation of appendicitis by pathology was made in 992 (92.0%) cases. Of these confirmed cases of appendicitis, 646 (65.1%) underwent a preoperative CT scan in which 593 (91.8%) of those scans were positive, 27 (4.2%) were negative, and 26 (4.0%) were equivocal. The sensitivity of the preoperative CT scan is 91.8%.

Based on the PPV, the diagnosis of acute appendicitis with CT was statistically more accurate than history and physical examination alone ($P = 0.045$).

DISCUSSION

The diagnosis of acute appendicitis has been traditionally taught as a clinical decision based on history and physical examination. The routine utilization of radiographic imaging in cases of low or high clinical suspicion has not demonstrated to be efficacious for the patient and has often resulted in altered management without benefit or cost-effectiveness [7, 8]. Subsequently, in most pediatric practices, the use of preoperative imaging to make a diagnosis is reserved for patients with equivocal assessments. Despite this general consensus, the routine utilization of CT scan in the evaluation and diagnosis of acute appendicitis has increased dramatically [2, 3]. As a result, the ability to diagnose early appendicitis and evaluate for complicated appendicitis (perforated or abscessed) has also increased.

In our study, the PPV for acute appendicitis with history and physical examination alone was 90.8%. This resulted in an approximate 10% negative laparotomy or laparoscopy rate. This false-positive rate is consistent and acceptable to traditional surgical teachings. In comparison, in the cohort that underwent a preoperative CT, the PPV was 96.4%. Although the difference in PPV does not appear to be drastically different compared to history and physical exam alone, it could be presumed that a large portion of these patients underwent CT scan because of an equivocal clinical assessment and, without a CT diagnosis, could have potentially attributed to a greater negative exploration rate.

Overall, the mortality from appendicitis in children remains extremely low. However, the morbidity from acute appendicitis lies within those who present with gross perforation or abscess [9]. Operative complications for these cases are well known. Thus, an initial nonoperative approach has been introduced within many institutions including our own. With advances in broad-spectrum antibiotics and aggressive radiographic intervention, the initial nonoperative treatment of complicated appendicitis has been shown to be efficacious [10–12]. The incidence of perforation at time of presentation has been reported to be from 30 to 60% [10]. During the study period, the perforation rate was 28.1% in the CT-positive group with an overall rate of 34.3%. The evaluation of perforated appendicitis with CT had a PPV of 91.9%. This was lower than the overall PPV for all appendicitis (96.4%) but slightly higher than history and physical examination alone (90.8%). Unfortunately, this study could not capture the predictive ability of history and physical exam alone in diagnosing perforated appendicitis and, thus, could not assess the true comparative accuracy of CT scan. Such predictors based on history and physical exam alone remain difficult to assess and warrant stringent prospective data collection.

The preoperative diagnosis of complicated appendicitis may direct therapy toward potential initial nonoperative therapy. In this study, nonoperative therapy was initiated in 39 patients (22.5%) who had a positive CT scan for abscess or perforation. Because this clinical pathway was determined by surgeon preference, the percentage of positive CT scans of complicated appendicitis which were amenable to antibiotic therapy or interventional radiology was impossible to determine. Several nonrandomized, retrospective studies involving nonoperative therapy for complicated appendicitis have illustrated the benefits and failures of therapy [9, 12].

In addition to the retrospective nature of this study, there are several limitations that need to be acknowledged [1]. The utilization of preoperative CT scan in the evaluation of abdominal pain may or may not be determined based on equivocal assessments. Patients that may have a high or low clinical suspicion of acute appendicitis may have undergone a CT scan for another indication. In addition, in our institution, the decision of preoperative imaging is often made prior to assessment by the surgical team [2]. The diagnosis of perforation is based on pathological examination, which may differ and be inconsistent throughout the study period. The pathological diagnosis of perforation may not correlate with clinical perforated appendicitis. Currently, in our institution, perforated appendicitis is defined as a hole in the appendix or stool in the abdomen. This strict correlation has been consistent throughout our institution and patients have been managed postoperatively based on this definition [3]. During the study period, the decision for immediate appendectomy or initial antibiotic therapy with potential percutaneous drainage of abscess was based on surgeon preference.

The evaluation of the pediatric patient for suspected appendicitis has been facilitated by the ease and availability of the CT scan. Although most clinicians would advocate a limited utilization of preoperative radiographic imaging with the vast majority of diagnoses made by clinical assessment, the role of preoperative CT scan may be expanded beyond the mere diagnostic purposes of acute appendicitis. Because the continued interested and practice of initial nonoperative therapy, accurate preoperative diagnosis of complicated appendicitis is necessary. Thus, CT scan may serve as a valuable adjunct in the evaluation of suspected *complicated* appendicitis. We feel that the true efficacy of the CT scan is in identifying children with advanced disease. Such diagnoses may direct patients with clinically suspicious perforated appendicitis toward an initial nonoperative therapy. The benefits and efficacy of initial nonoperative therapy, which includes extended antibiotic therapy and/or percutaneous drainage of abscesses, warrant further investigation in a randomized, controlled fashion.

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TABLE 1

Accuracy of Diagnosis for Appendicitis

	Appendectomies	Histologically confirmed appendicitis	Positive-predictive value (%)
No CT scan	381	346	90.8
+CT for appendicitis	615	593	96.4
+CT for perforated appendicitis	173	159	91.9