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The Accuracy of Computed Tomography (CT) and Ultrasound (US) in the Diagnosis of Acute Appendicitis in Pediatrics: A Retrospective Comparative Study

Daehwan Kim, Kyuwhan Jung*, Sio Ann Cherry, Hyejin Jang and Mi-Ok Yoon

Seoul National University Bundang Hospital, Republic of Korea

***Corresponding author:** Kyuwhan Jung, Ph.D., Associate Professor, Seoul National University Bundang Hospital, Seongnam - 463-707, Republic of Korea, Tel: 82-10-9389-0296; E-mail: chungq@snubh.org

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Abstract

Purpose: The aim of this study was to determine if US is an accurate imaging modality in determining the preoperative diagnosis of acute appendicitis compared to CT and to assess the accuracy of US as the primary imaging modality.

Methods: A retrospective review of all US and CT evaluations for appendicitis from January 2003 to December 2012 was conducted in our institution. All patients who underwent appendectomy were included. From these patients, we documented who underwent ultrasonography or CT scan for their preoperative workup and noted the diagnoses made based on the imaging modality done. We retrospectively documented the subjects' demographic data (age, sex, body weight, type of operation and pathologic finding).

Results: There were 1117 consecutive patients in our study. Among them, 65 patients were excluded because of lack of preoperative imaging and record of the body weight. A total of 1052 patients were evaluated. Of these patients, 25 (2.3%) patients had a negative appendectomy, 14 patients (2.6%) performed US and 11 patients performed CT for preoperative imaging workup. There was no statistical difference between those who underwent US and CT with negative appendectomy. The ROC curve was constructed based on the pathologic result of appendectomy. The AUC for US and CT was 0.666 and 0.778, respectively. However, the difference between them was reduced after adjusting sex, age and BW, as US (0.739) and CT (0.801) for which there is no statistical difference (p=0.366). The relevance of diagnosis was acceptable using co-efficient analysis which constructed based on a pathology result, both US and CT (p<0.001).

Conclusions: The diagnostic accuracy of preoperative US did not decrease the accuracy on diagnosis of acute appendicitis in children when compared with CT. US is a sensitive test and is useful on diagnosis of acute appendicitis in children, with the advantage of avoiding radiation exposure.

Keywords: Appendicitis; US; CT; Children

Introduction

Acute appendicitis is the one of the most common surgical emergencies, the incidence rate is almost 10% [1,2]. Especially in children, the diagnosis is often challenging, due to their symptoms and sign are nonspecific compared to adults [3]. Making an accurate diagnosis is of utmost importance to pediatric surgeons and pediatricians providing care, hence preoperative imaging is now widely accepted by most surgeons and emergency medicine physicians in the workup of acute appendicitis. Imaging studies, either US or CT, are used in conjunction with clinical examination, the primary method for diagnosis. Among several cross sectional imaging modalities, CT is the most preferred method owing to its considerable diagnostic accuracy, and ability to identify other anatomic or surgical pathologies which might require hospitalization and surgery [4-6].

Recently, low-dose CT has been used to lessen the radiation exposure according to the principle of "As Low as Reasonably Achievable" [5]. Growing children with highly actively-dividing cells are more sensitive to radiation exposure than adults. They are at high risk for increased cumulative dose absorption even in the same radiation conditions because of smaller body physique and age. In addition, female patients may especially be more sensitive, almost twice, to radiation effect than male [7-9]. Recent practice in the United States has led to 10-30% decrease in the initial workup with CT scan being replaced by other modalities such as US [9,10].

We retrospectively analyzed the diagnostic advantage of US and CT; cross-sectional imaging, as currently practiced at a tertiary referral hospital located at the metropolitan area. This study was designed to evaluate the diagnostic usefulness of US as first choice of imagine workup for acute appendicitis.

Methods

Patients

A retrospective review of all patients diagnosed with acute appendicitis from January 2003 to December 2012 was conducted at single tertiary referral medical center located at the metropolitan area.

We reviewed the 1,117 children (under 18) who had undergone appendectomy. We documented whether US or CT was performed as a first choice diagnostic tool. We analyzed age, sex, body weight, diagnosis date, operation date, result of imaging study, type of operation, pathologic report and postoperative course including complications.

Modality: US

Criteria for the diagnosis of acute appendicitis includes identification of a non-compressible, fluid-filled, blind-ended tubular structure in the right lower quadrant, with ultrasonography features indicating intestinal origin, and a diameter equal or greater than 6 mm [10,11]. Experienced pediatric sonographers performed US during weekdays with all exams interpreted by a radiology resident and attending radiologist. Senior radiology residents performed and interpreted US during nights and weekends. Ultrasound radiology reports were classified as positive, indeterminate or negative. Negative reports included those in which there was no appendix seen on US.

Modality: CT

Most CT examinations were obtained by using 16- or more detector-row machines were used with tube potential of 120 kVp and modulated tube current. Transverse CT images were reconstructed with a section thickness of 3-5 mm. CT scans were performed with intravenous contrast. Criteria for the diagnosis of appendicitis included an enlarged, fluid-filled tubular structure arising from the cecum, with wall enhancement and stranding of the pericecal fat indicative of inflammatory change; occasionally an appendicolith was also seen [11,12]. Criteria for diagnosis of acute appendicitis on the CT evaluation were almost same as US. The cut-off value for the dilated tubular structure was an internal diameter of greater or equal to 6mm [10,11]. The CT scan results are categorized into five grades (1; definitely absent-2; probably absent-3; indeterminate-4; probably present-5; definitely present) [5]. We retrospectively categorized the CT result into 3 grade (absent: 1, indeterminate: 2-3, present: 4-5).

Analysis

The study population was divided into two groups based on whether a US or CT were performed as an initial imaging study. Key outcome measures for the performance of the first imaging workup (CT or US) were sensitivity compared with finial pathologic reports. Criteria for a positive acute appendicitis were based on pathologic analysis. The diagnostic accuracy of CT or US was assessed by receiver operating characteristics (ROC) curve analysis. A ROC curve is obtained by plotting the sensitivity (fraction of true positives, y-axis) against 1-specificity (fraction of false negatives, x-axis). The area under the curve (AUC) is a direct measure of the diagnostic accuracy of the test. An AUC value 50 % indicates the ability of a test to significantly discriminate between positive and negative cases with regard to the pathologic finding. We used the DeLong's test to compare the areas under two or more correlated ROC curves. A confidence interval is constructed using DeLong's variance estimate. A p value<0.05 (two-sided tests) was considered statistically significant. All calculations were performed with statistical software (PASW statistics 18 for Windows).

Definition

Negative appendectomy was defined as removal of uninflamed appendices. The uninflamed appendices were determined based on pathologic report. Also, appendiceal perforation was defined based on surgical record and pathologic report [5,13-15]. The patient's Body weight (BW) was categorized into ten sections by the Adolescents Growth Chart [16], as the obesity is a factor related with accuracy of US [10,17].

Result

The 1,117 children were included in our study. Among them, 65 patients were excluded due to missing body weight in 2 patients, and absence of preoperative imaging study in 63 patients, (missing images done in other hospital, the workup refusal of guardians). After, 65 patients who had no preoperative imaging study or body weight were excluded, 1,052 patients were identified as study groups (615 boys and 437 girls). The mean age of study group was 11.18 ± 5.65 (range; 1 month - 18 years) years. US and CT was performed in 521 patients and 531 patients, respectively. Those patients where 2 imaging modalities, first imaging was US followed by CT scan, was performed were grouped to the US group. There is statistically significant difference between US group and CT group based on age. The average age is 9.28 years about US groups, while 13.04 on CT groups. There are no statistically significant difference on sex, body weight and uninflamed appendices. The total number of uninflamed appendices during this study was 25 (2.3%). Normal appendix was found 14 cases (2.6%) in US, while 11 cases (2.0%) had a normal appendix in the diagnosed as appendicitis with CT (Table 1).

	US (n=521) [%]	CT [%] (n=531) [%]	P value
Age (year)[a]	9.28±3.33	13.04±3.83	0.001
Sex (Male/Female)	302/219	313/218	0.755
BMb	5.85	5.88	0.772
NA[c] (%)	14 (2.6)	11 (2.0)	0.581

Table 1: Demographic and clinical characteristics in the patients with US group and CT group. (aData are mean ± standard deviations, b:Body weight was categorized into ten sections by the Adolescents Growth Chart, c:negative appendectomies).

The Delong's test for ROC curve was constructed based on the pathologic result of appendectomy. The AUC for US and CT was 0.666 and 0.778, and there was no statistical differences between them (p=0.102) (Model 1). The diagnostic value in CT was slightly higher, but the difference was reduced after correcting sex, age and BW. (Model 2) (represented by an AUC for US = 0.739 and for CT=0.801). Also, there was no statistical difference (p=0.366). We attained a high degree of diagnostic accuracy using co-efficient analysis which constructed based on a pathology result, both US and CT (p<0.001).

Discussion

There has been a great debate in the clinical and imaging evaluation of pediatric patients with an acute abdomen. Most of this has resulted from the great strides accomplished with US or CT imaging [18]. There is a tendency that CT scan as preoperative workup chosen

frequently more than US because of operator independency, sensitivity and specificity, accuracy. Despite concerns over radiation exposure in children [18]. Advances in imaging techniques and the move towards more timely and accurate diagnosis and management decisions have made CT and US central adjuncts in the diagnosis of appendicitis in children at most institutions [19]. The accuracy of pediatric US in the literature varies from 44% to 94% and specificity from 47% to 95%. Sensitivity of pediatric CT is 87%-100% and specificity from 89%-98%. As previous studies, it shows the high diagnostic accuracy of CT, as well the slight superiority [18,19].

Results from this study show that we may be underestimating the value and benefit of ultrasound in the preoperative workup in appendicitis. Our results show that US is not inferior to CT. And the difference in terms of diagnostic accuracy was not statistically significant. Accuracy of diagnosis was increased when adjusting for patient's age, sex and BW, using US and CT. Also, the slightly difference between US and CT has been more reduced. There was an acceptable rate of both US and CT uninflamed appendices in this study. Considering that children are more sensitive to radiation exposure and more vulnerable for cumulative absorbed dose than adults [7-9], as our principal concern was direct benefit to the patient. US as the primary imaging workup is accurate.

There were several limitations in this study. First, the assessors forming the reference standard for appendicitis, the study coordinator and site pathologists, could empirically predict very low uninflamed appendices rate, which may have misled them to customarily judging indeterminate cases as positives. Second, it was often unclear from our retrospective review how wet reports made afterhours were changed or overwritten by the abdominal radiologists next morning, as not all the sites had a strict policy to keep the original wet reports. Therefore, the reported diagnostic sensitivity from the final reports may have been overestimated than that from the initial reports. And There was a tendency to implement US as an initial diagnostic tool especially to younger children concerning over radiation exposure. Third, as our inclusion criteria covered only patients who underwent appendectomy. A prospective study included randomized controlled trial is required to assess whether US replaced CT as a diagnosis tool of acute appendicitis. Therefore, we recommend a selective diagnostic protocol using ultrasound as the initial imaging modality.

Acknowledgments

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