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Emergency Physicians' Point of Care Ultrasonography (POCUS) Competency Assessment for the Diagnosis of Acute Appendicitis in Pediatric Cases

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Abstract

Aim: To evaluate the accuracy of emergency physicians performed point-of-care ultrasonography (EP-POCUS) in diagnosing acute appendicitis (AA) in the pediatric age group who had abdominal pain and compare sonographic findings with those of radiologists.

Materials and Methods: One hundred twenty-three children who had abdominal pain were included in the study. EP-POCUS and radiology department ultrasonography (RADUS) performed on each case. Sonographic findings [non-compressible bowel loops, target sign, edema in the surrounding tissue, appendix diameter, peri-appendiceal abscess, appendicitis positivity (a non-compressible and non-peristaltic blind ending tubular structure >6 mm) and presence of mesenteric lymphadenitis] of the EP-POCUS and RADUS were recorded seperately and compared to evaluate accuracy of the EP-POCUS and RADUS. Definitive diagnoses were determined by pathological evaluation of appendectomy specimens.

Results: Thirty-six (29.2%) patients were diagnosed AA and hospitalized by the surgeon, 30 (24.3%) of which were confirmed pathologically. According to pathological diagnose, the EP-POCUS's sensitivity was 73.3%, specificity was 89.2%, the RADUS's sensitivity was 76.7%, the specificity was 96.8% and significantly consistent with in diagnosing AA (Kappa coefficient: 0.64, $p<0.005$). EP-POCUS accuracy in AA diagnosis did not differ between age groups.

Conclusion: EP-POCUS on pediatric patients acts as an auxiliary and useful approach in AA diagnosis. Training and experience may increase the accuracy rates.

Keywords: Acute appendicitis, bedside ultrasonography, pediatrics, point-of-care ultrasonography

Introduction

Among the causes of abdominal pain in childhood, the most common reason that requires urgent surgery is acute appendicitis (AA) (1-3). The diagnosis is relatively easy in adolescents and adults but somewhat more difficult in children. Lack of typical symptoms and communication skills, may lead to diagnosis delays in childhood appendicitis and consequently increased mortality and morbidity (2).

The difficulties experienced in physical examination in children make it necessary to use additional diagnostic methods. Although the gold standard diagnostic method is computed tomography (CT) (1), ultrasonography (USG) is preferred in pediatric patients to prevent exposure to contrast agents, large amount of radiation, and need to ensure immobility for a long time, (USG) is a cost-effective first-line diagnostic tool with no radiation risk, It can be performed bedside easily in crowded emergency settings. Thin subcutaneous adipose tissue in children is an advantage for application of (USG) not only to diagnose AA but also other pathologies causing abdominal pain such as acute mesenteric lymphadenitis, intussusception, acute cholecystitis, gynecological and urinary pathologies in chidhood.

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Emergency physicians commonly use Point-of-Care Ultrasonography (POCUS) technique that focuses on the highest probability areas with high sensitivity and specificity (2). However, no comparative study includes ultrasonographic signs of AA and compares the signs between radiologists and emergency physicians (EP). Therefore, despite several literature reviews on the efficacy of EP performed Point-of-Care Ultrasonography (EP-POCUS) for AA in the pediatric emergency department (ED), controversy remains. There is a good deal of practices and centers where EPs are routinely performing this scan. This study aimed to evaluate the competence of EP-POCUS in diagnosing AA and compare the sonographic signs with that of abdominal USG performed by a radiologist (RADUS) in the diagnosis of AA in the 0-18 age group who admitted to the Pediatric ED.

Materials and Methods

Study Design

This was a prospective observational study. The ethics committee approval was obtained from Antalya Training and Research Hospital Clinical Research Ethics Committee (decision no: 2/008, date: 24.01.2019). The study did not interfere with the patients' therapeutic and diagnostic procedures, and the patients were not exposed to any risks. The pediatric patients with abdominal pain and physical examination findings resembling AA were studied. Written consent was obtained from the parents of the patients. EP-POCUS was performed on each case by the EP who managed the patient. A physician from the Radiology department also performed abdominal ultrasonofraphy (RADUS) on the same cases. Sonographic findings of the EP-POCUS and RADUS were recorded separately for each patient and compared to evaluate accuracy of the EP-POCUS with regard to RADUS. The sensitivity and specificity of EP-POCUS and RADUS were determined by comparing the diagnoses with pathologic biopsy results.

Study Population

The study group consisted of patients with abdominal pain and physical examination findings resembling AA under the age of 18 who admitted to the Yellow Triage Zone of Antalya Training and Research Hospital Pediatric Emergency Service between the dates 15.11.2018 and 01.04.2019. Unstable patients, patients with trauma history and findings, and those who underwent abdominal imaging at other medical centers before referral to the pediatric ED were excluded from the study. Also, patients without a pre-diagnosis of AA were excluded. The study group was classified into three age groups as preschool period (0-5 years old), school period (6-12 years old) and adolescence (13-18 years old) to simplify the ages.

The estimated sample size was calculated based on other studies using POCUS for similar indications. After sample size calculation, it was estimated that at least 123 volunteers were required to detect statistically significant differences, admitting a type I error rate of 0.05 and a power of 80%.

The physicians who performed POCUS received 16-hour training (8 hours of theoretical course and 8 hours of practicals) on implementation of POCUS to detect acute appendicitis. The training was organized by the Emergency Medicine Physicians Association of Turkey (EPAT). Emergency physicians and radiologists were informed about the study in advance.

Of the cases taken into consideration; age, gender, symptoms, vital signs, physical examination findings, leukocyte count, EP-POCUS, and RADUS findings [non-compressible bowel loops, target sign, edema in the surrounding tissues, appendix diameter, peri-appendiceal abscess, appendicitis positivity (a non-compressible and non-peristaltic blind ending tubular structure >6 mm), presence of mesenteric lymphadenitis], discharge, operation, and pathological results were recorded.

Patients with suspected AA findings, 0-18 years of age and performed RADUS were included in the study.

Study Protocol (EP-POCUS Technique)

EP-POCUS measurements were made by Mindray DC-T6 US device and RADUS measurements by the radiologist with Toshiba SSA-660A ultrasound device. EPs and radiologists used the same probe, a 7.5-MHz linear probe, and the same compression technique.

First of all, the EP performed clinical questioning and physical examination for abdominal pain, and EP-POCUS was applied before the diagnostic tests. Then, the same performers noted the sonographic findings into the data collection form. Finally, RADUS was performed with using the same technique.

The EP-POCUS was performed in a standardized manner. If the patient can localize the pain well, the imaging protocol started from that localization. In other conditions, the POCUS performer using the graded compression method started at the umbilicus level, in the transverse plane with a linear probe. The probe was moved towards the ascending colon to the lateral abdominal wall. When the ascending colon was identified, follow the ascending colon's lateral edge by moving the probe inferiorly until the cecum's end. The probe was moved medially, and the iliac artery, vein, and psoas muscle were identified. The pelvis and umbilicus were scanned by seeing the psoas muscle and iliac vessels at the same image plane. Afterward, the probe was given a sagittal position to sagittal scanning, and the long axial imaging of the end of the cecum was identified. During the scanning, the cecum was compressed with probe against the psoas muscle.

The physician tried to visualize the appendix to evaluate the non-compressible bowel loops, target sign, edema in the surrounding tissue, appendix diameter, peri-appendiceal abscess, appendicitis positivity (a non-compressible and non-peristaltic blind ending tubular structure >6 mm) and presence of mesenteric lymphadenitis. The EP-POCUS findings were recorded in the study form. The positive indications for AA diagnosis were appendiceal diameter above 6 millimeters and nonperistaltic and noncompressible tubular structures. Absence of target sign, peri-appendiceal abscess, and secondary inflammatory findings, such as mesenteric lymphadenitis, non-compressible bowel loops, and edema in the surrounding tissue and appendiceal diameter equal or under 6 millimeters, or inability to visualize appendix were considered as unfavorable for AA. The consulting pediatric surgeon made the clinical management decision of the patient.

Radiologists on duty performed RADUS for all study patients. None of the patients had CT scan.

A blinded physician reviewed the EP-POCUS and RADUS findings and pathology reports. The parents of the discharged patients were called by the physician three weeks later after the examinations were performed to determine that they had undergone appendicitis surgery later.

The exact diagnosis of AA was made according to pathology results. In contrast, exact no appendicitis diagnosis was made upon negative pathology reports or recuperating the patients' symptoms during three weeks follow-up time.

Measures

This study aimed to evaluate the competence of EP-POCUS in diagnosing AA and compare the sonographic signs with that of RADUS in the diagnosis of AA in the 0-18 age group who admitted to the Pediatric ED.

The primary outcome measures were the consistency between EP-POCUS and RADUS findings for the diagnosis of AA. Besides, the diagnostic value, sensitivity and specificity of EP-POCUS for AA in the pediatric ED were evaluated in the study.

Statistical Analysis

The analyses were performed using SPSS for Windows 22 package (IBM Corp., Armonk, NY, USA) program. Descriptive statistics were shown as mean ± standard deviation for continuous and discrete numerical variables, number of cases, and (%) for categorical variables. Chi-square test was used for categorical variables. False positive, false negative, sensitivity, specificity, positive predictive value (PPD), negative predictive value (NPD), for sonographic evaluations and kappa coefficient for compatibility were calculated. Although there is no consensus on how to decide borders and ranges and most researches divide Kappa coefficient into five groups, we divided the range into three groups acoording to the Fleiss' kappa statistic which is a well-known index for assessing the reliability of agreement between raters." Compatibility was considered perfect for Kappa coefficients greater than 0.75, moderate for the values between 0.75 to 0.40, and poor for the values less than 0.40. P values less than 0.05 was accepted to show statistical significance.

Results

In the study, five different EPs performed POCUS in the ED and four different radiologists performed RADUS. Thirty-nine (29.3%) of the patients were hospitalized, 87 (70.7%) of them were discharged from the ED. One patient was discharged from hospital without having an operation. Thirty-five patients underwent an operation, and AA was confirmed in 30 of them by pathological evaluation. Laparotomy was negative in five patients, in which EP-POCUS and RADUS were negative in different three of them. Sixty-nine (56.1%) of the study patients were male, and 54 (43.9%) were female. Of the patients included, seven (5.7%) were under the age of 6, 60 (48.8%) were between the ages of 6-12, 56 (45.5%) were between the ages of 12-18 (Table 1).

The false-positive results obtained by emergency physicians were mostly found in evaluation of the appendix diameter and diagnose of the presence of appendicitis. The highest value for false negativity was determined as the presence of mesenteric lymphadenitis. False positivity, false negativity, and kappa coefficient of EP-POCUS findings of the patients included in the study are shown in Table 2. When EP-POCUS findings were evaluated individually, the highest consistency was evaluating the edema in the surrounding tissue (kappa: 0.88). When EPs were evaluated to determine the presence of AA with POCUS, the false negativity value was 8, the false positivity value was 9, and the kappa coefficient was 0.64.

Table 1. Demographic characteristics of the patients

Variables	n	%
Gender		
Female	54	43.9
Male	69	56.1
Ages in years		
0-6	7	5.7
6-12	60	48.8
12-18	56	45.5
Total	123	100.0

n: Number of patients

According to the pathological reports, EP-POCUS's sensitivity was 73.3% and specificity was 89.2%. Their sensitivity in detecting the presence of appendicitis was 80.8%, their specificity was 88.7%, PPD was 65.6%, and NPD was 94.5%. When the findings of EP-POCUS were examined one by one, it was found that the highest specificity was the edema in the circumference of the intestines (100%), and then the non-compressible bowel loops (90.6%) (Table 2). According to the pathological results, the RADUS evaluation's sensitivity was 76.7%, and the specificity was 96.8% (Table 3). There was a moderate consistency between EP-POCUS and RADUS results [Kappa coefficient: 0.64, p=0.001 95% confidence interval (CI)].

Although four (3.2%) of the discharged patients re-applied to different hospitals, no appendectomy was performed. In the EP-POCUS evaluation, 24 of the 36 patients hospitalized were evaluated in favor of AA.

Eight of the 91 discharged patients were diagnosed with AA in the EP-POCUS evaluation.

According to pathology results, there was no significant difference between the age groups and the EP-POCUS evaluation (p=0.18).

Discussion

In the pediatric age group, evaluation of abdominal pain, a frequent reason for admission in the ED, is difficult due to communication limitations, anamnesis, and physical examination. Differential diagnosis of abdominal pain, USG is preferred primarily because fast, easy to apply, and has no radiation effect. In the literature, there are many studies on the diagnostic confirmation effectiveness of EP-POCUS performed in the ED.

In the meta-analysis made by Lee and Yun (4), in 2018, POCUS evaluation was more successful in pediatric patients than in adults in diagnosing AA. Less subcutaneous adipose tissue in the pediatric patient group was found to facilitate imaging of the appendix compared to adults. However, in the study of Nicole et al. (5), POCUS was found inconsistent in the pediatric patient group according to the RADUS evaluation. In studies evaluating the diagnosis of AA in the current literature, the sensitivity of POCUS administration was expressed in a wide range of 40% to 94%.

In a retrospective study by Fox et al. (6) in 2007, EPs' competencies to diagnose AA with POCUS were evaluated. In this study, EP-POCUS was compared with RADUS. As a gold standard, RADUS, abdominal CT, and pathology reports were accepted. In this study, which was conducted on 155 cases, the EP-POCUS assessment's sensitivity was 39%, and the specificity was 90%. In our study, the EP-POCUS's sensitivity was 66%, and the specificity was 91% for the patients who underwent an appendectomy.

In the study conducted by Elikashvili et al. (7) in 2014, the effectiveness of EP-POCUS for diagnosing AA was evaluated. EPs who will make the evaluation were given a 30-minute vocal and 30-minute practical training, and a standard was established in terms of findings. Findings were compared with

Table 2. Test characteristics and concordance of EP-POCUS and RADUS findings (n=123)

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Kappa coefficient	p*
Edema in surrounding tissue	80.0	100.0	100.0	98.3	0.880	<0.001
Non-compressible appendix	81.5	90.6	71.0	94.6	0.685	<0.001
Appendix diameter >6 mm	81.5	89.6	68.8	94.5	0.666	<0.001
Presence of appendicitis	80.8	88.7	65.6	94.5	0.640	0.001
Any ultrasonography finding considering AA	74.0	87.7	80.4	83.1	0.625	<0.001

*Chi-square test.
EP-POCUS: Point-of-care ultrasonography performed by emergency physician, RADUS: Abdominal ultrasonography performed by radiologist, PPV: Positive predictive value, NPV: Negative predictive value, AA: Acute appendicitis, n: Number of patients

Table 3. Accuracy of EP-POCUS and RADUS according to pathology reports of the patients (n=123)

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Kappa coefficient/p*
EP-POCUS	73.3	89.2	68.8	91.2	0.612/<0.001
RADUS	76.7	96.8	88.5	92.8	0.769/<0.001

*Chi-square test.
EP-POCUS: Point-of-care ultrasonography performed by emergency physician, RADUS: Abdominal ultrasonography performed by radiologist, PPV: Positive predictive value, NPV: Negative predictive value, n: Number of patients

EP-POCUS, RADUS, and CT performed in the ED. While in the study conducted by Elikashvili et al. (7), RADUS, and CT were the gold standard, appendectomy and RADUS evaluations were accepted in our study. As a result of the study; In EP-POCUS evaluation, sensitivity was 60%, and specificity was 94%, while in RADUS evaluation, sensitivity was 62.5% and specificity was 99.3%. In our study, sensitivity was 66%, and specificity was 91% in the EP-POCUS evaluation, while 77% and specificity were 100% in the RADUS evaluation. Compared to the patients who underwent an appendectomy in our study, the sensitivity and specificity of patients were found to be close to each other. It was emphasized by Elikashvili et al. (7) that the experience of the practitioner was the most critical criterion affecting the outcome of the study. Although the practitioners received standard basic ultrasonography training in our study, no data was provided about their experience. However, it was concluded that the sensitivity and specificity values depending on the experience could change positively.

In the study of Sivitz et al. (8), in 2014, patients diagnosed with AA and who underwent RADUS were evaluated. Before the study, EPs were verbally and practically given POCUS training on AA. The EP-POCUS, and the RADUS was compared. In the study, which included 264 pediatric patients, the EP-POCUS's sensitivity at the bedside was 85%, and the specificity was 93%. In our study, the sensitivity was found to be 66% and was lower than this study. The reason for this is that, in our study, EPs who performed POCUS received a total of 16 hours of theoretical and practical training, at a basic and advanced level, and did not have specific training for the diagnosis of AA.

In the prospective study conducted by Doniger et al. (9) in 2016, 40 patients admitted due to abdominal pain between the ages of 2 and 18 were compared with the confirmation of the diagnosis of AA by comparing their POCUS and other radiological methods. The sensitivity of 93.8% and 85.7% of EP-POCUS were determined. In RADUS evaluation, sensitivity was 81.25%, while specificity was 100%. As a result of this study, it was suggested that POCUS evaluation has an acceptable diagnostic value. However, the patients' physical characteristics may create obstacles in the procedure (9). In our study, the sensitivity of EP-POCUS was low compared to this study, and we did not make an additional evaluation in terms of personal physical properties.

As a result of our study findings, the diagnosis was moderately compatible (kappa=0.64). To the best of our knowledge, there is no comparison of ultrasonography findings between EP-POCUS and RADUS in pediatric patients was found in the literature. Since appendicitis ultrasonography findings were similar in pediatric and adult patients, studies for adult patients in the literature were reviewed for compliance. In the study conducted by Gungor et al. (10). In 2017, on 264 adult patients, EP-POCUS appendix circumference was detected in 69% of patients. Another data in the same study, EP-POCUS sensitivity and specificity were 92.3% and 95.8%, while RADUS sensitivity and specificity were 76.9% and 97.8%, respectively. In diagnosing AA, the kappa coefficient between EP-POCUS and RADUS was 0.66 with moderate compliance. In our study, the kappa coefficient between EP-POCUS and RADUS in AA diagnosis was moderately compatible with 0.64. It was similar to the study on these adults in the literature (Table 2).

Study Limitations

The nature of POCUS is highly operatory dependent. Therefore, the accuracy of POCUS may alter regard in the performer's experience.

The study was a single centre study with five EPs and four radiologists involved and may not be externally valid to other centres.

Doctors performing POCUS were not blinded to the patients' history and physical examination, which may have influenced their interpretation of the ultrasound.

Anatomical variation of the appendix (appendix showing various variations, especially retrocecal), fat mass of the patient and excessive amount of intestinal gas in the abdomen may affect to the interpretation of the ultrasound.

The uncontrolled adequacy of ultrasonographic images in both EP-POCUS and RADUS groups (physicians decided by themselves).

The "inter-rater agreement" between five EPs and four radiologist prior the study with a smaller sample size different from study group did not tested.

Conclusion

When the data of this study and similar studies in the literature are analyzed, it was seen that the bedside EP-POCUS had an auxiliary and accelerating effect on early diagnosis in pediatric patients. The fact that the physician is trained and experienced in this regard will increase the diagnosis's success rate.

Ethics

Ethics Committee Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Antalya Training and Research Hospital, decision no: 2/008, date: 24.01.2019).

Informed Consent: Informed consent was obtained from all the parents of the participants.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and/or Medical Practices: H.A., Ö.F.K., Concept: H.A., M.K., Ö.F.K., Design: H.A., M.K., Data Collection and/or Processing: H.A., Ö.F.K., Analysis and/or Interpretation: M.K., A.K., Literature Search: Ö.F.K., A.K., Writing: H.A., A.K.

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