Pediatr Pract Res 2022; 10(2): 89-96
DOI: 10.21765/pprjournal.1136049

ORIGINAL ARTICLE
ORİJİNAL ARAŞTIRMA

Diagnostic Algorithm in the Pediatric Appendicitis: A Prospective Clinical Study

Çocuklarda Apandisit Tanı Algoritması: Prospektif Klinik Çalışma

Süleyman Arif Bostanci[1], Altan Güneş[2], Doğuş Güney[3], Gökhan Demirtaş[4], Can İhsan Öztorun[3], Ahmet Ertürk[1], Sabri Demir[1], Elif Emel Erten[1], Müjdem Nur Azılı[3], Emrah Şenel[3]

[1]Ankara City Hospital Children's Hospital, Clinic of Pediatric Surgery, Ankara, Turkey
[2]Ankara City Hospital Children's Hospital, Clinic of Pediatric Radiology, Ankara, Turkey
[3]Yıldırım Beyazıt University, Faculty of Medicine, Department of Pediatric Surgery, Ankara, Turkey
[4]Ankara City Hospital, Children's Hospital, Clinic of Pediatric Urology, Ankara, Turkey

ABSTRACT

Objective: We compare the diagnostic approaches: surgeon prediction, surgeon prediction plus ultrasound imagining (US) as the first-line imaging modality, and magnetic resonance imagining (MRI) as the second-line imaging for suspected pediatric appendicitis.

Material and Method: Three hundred sixty-one patients with a clinically suspected appendicitis were prospectively divided into three groups by the type of diagnostic approach.

Results: A total of 51 patients were diagnosed via only the surgeon prediction. Of the patients, 254 only underwent a US examination, and 56 patients underwent both US and MRI. Considering the diagnostic groups, the accuracy of both the "surgeon prediction only" and "surgeon prediction + US + MRI" groups was 100%. The "surgeon prediction + US" group revealed a sensitivity value of 62,4% with an accuracy rate of 59,8%. The sensitivity and specificity of US were 61,0%, 65,5%, respectively. These values were 100% for MRI. The sensitivity, specificity of our institutional algorithm were 100,0%, 94,4%, and the positive-negative predictive values were 94,7%, 100%.

Conclusions: To diagnose appendicitis in children, surgeon's assessment, prudence, and clinical evaluation should be the first method of diagnosis. US is a useful method to support surgeons in ensuring an accurate diagnosis, and MRI can be trusted as an additional method to verify a correct diagnosis.

Keywords: acute appendicitis; children; magnetic resonance imaging; ultrasound.

ÖZ

Amaç: Akut apandisit (AA), çocuklarda tanısı birçok hastalıkla karışabilmektedir. Bu da gecikmiş tedaviye neden olmaktadır. Görüntüleme yöntemleri hekimlere tanıda yardımcı olabilmektedir. Çalışmamızda AA tanısını koymada yaklaşımlar neler olabiliri değerlendiriyoruz. Tanısal yaklaşımları üç gruba ayırdık. Bunlar: birinci basamakta sadece cerrahın muayenesi, ikinci basamak olarak cerrahın muayenesi ile birlikte Ultrason (US), üçüncü basamakta da şüpheli kalınan durumlarda Manyetik rezonans görüntülemenin (MRG) kullanılmasıydı.

Gereç ve Yöntem: Klinik olarak apandisit şüphesi olan üç yüz altmış bir hasta, tanısal yaklaşım tipine göre prospektif olarak üç gruba ayrıldı.

Bulgular: Toplam 51 hastaya sadece cerrah öngörüsü ile tanı konuldu. Hastaların 254'üne sadece US incelemesi yapıldı ve 56 hastaya hem US hem de MRG yapıldı. Tanı grupları dikkate alındığında hem "sadece cerrahın muayenesi" hem de "Cerrahın muayenesi + US + MRI" gruplarının doğruluğu %100 idi. "Cerrahın muayenesi + US" grubu, %59,8 doğruluk oranı ile %62,4'lük bir duyarlılık değeri ortaya koydu. US'nun duyarlılığı ve özgüllüğü sırasıyla %61,0, %65,5 idi. Bu değerler MRG için %100 idi. Kurumsal algoritmamızın duyarlılığı, özgüllüğü %100,0, %94,4, pozitif-negatif tahmin değerleri %94,7, %100 idi.

Sonuç: Çocuklarda apandisit tanısı için cerrahın değerlendirmesi ve klinik değerlendirmesi ilk tanı yöntemi olmalıdır. US, cerrahları doğru tanı koymada desteklemek için yararlı bir yöntemdir ve MRG, doğru tanıyı doğrulamak için ek bir yöntem olarak güvenilir olabilir.

Anahtar Kelimeler: akut apandisit; çocuk; manyetik rezonans görüntüleme; ultrason.

Corresponding Author: Süleyman Arif Bostancı
Address: Ankara City Hospital Children's Hospital Clinic of Pediatric Surgery, Ankara, Turkey
E-mail: suleymanbostanci@outlook.com

Başvuru Tarihi/Received: 26.06.2022
Kabul Tarihi/Accepted: 03.07.2022

INTRODUCTION

Acute appendicitis (AA) is a common cause of abdominal pain in children and the most common indication for surgery in the pediatric population.1,2 But its clinical diagnosis remains challenging. Despite investigation, the diagnosis may often be equivocal, which can cause delayed or insufficient management. Imaging modalities are beneficial in supplying timely, accurate diagnosis of AA.3-5 Current American College of Radiology criteria recommend ultrasound (US) as the preferred initial modality, followed by computed tomography (CT) for cases where US is undetermined.6 Appendicitis was formerly diagnosed clinically, based on history, laboratory findings, and physical examination, and a 10–20% rate of negative appendectomy was accepted by surgeons. In the late of 1980s, US gained popularity, and later CT became more prevalent.7,8 With the recently published studies that evaluate the harms of CT-associated radiation, magnetic resonance imagining (MRI) use has increased in recent years. Thanks to the increase in accuracy and availability of diagnostic imaging, the negative appendectomy rate has decreased from 20% to 2% over the past thirty years.4,7 Nowadays, approximately 100% of pediatric patients meet some type of imaging modality to determine a diagnosis of appendicitis; unfortunately, CT constitutes more than 50% of these studies.9 We believe that in addition to the patient's history and laboratory findings, the most important determinant is physical examination findings. Also, surgeon prediction may be followed by US; US should be the first-line imaging method. We believe that MRI, which does not expose the patient to radiation, is applicable in children as an advanced imaging method in equivocal patients despite physical examination and US findings.

The purpose of this study was to prospectively compare the diagnostic approaches: surgeon prediction by physical examination and laboratory findings, surgeon prediction plus US as the first-line imaging modality, and MRI as the second-line imaging after an indeterminate sonographic examination and equivocal findings on physical examination for suspected pediatric appendicitis. We also seek to demonstrate the necessity of advanced imaging modality to diagnose AA in children. We hypothesize that our algorithm, which includes, firstly, a pediatric surgeon's physical examination supported by history and laboratory parameters, secondly, ultrasound, and thirdly (if needed), MRI can accurately predict whether a child has appendicitis or not.

MATERIAL AND METHOD

Our study was approved by the Ethics Committee of Ankara Children Health and Diseases Hematology Oncology Training and Research Hospital (No: 2017-083) and was conducted in accordance with the Helsinki Declaration.

This study is a single-center study that was designed and prospectively performed in pediatric patients evaluated for suspected AA at a tertiary referral children's hospital from January to July 2020. We prospectively planned how to divide patients into groups, but also observe what was done and report the results. This is really not a description of clinical data but a scientific research project. A total of 361 patients (mean age, 11; range, 5–17 years; 143 girls, 218 boys) with abdominal pain suspected of AA were inscribed in this prospective study during a period of six months. Our hospital's medical ethics committee approved the study, and the written consent of the parents was acquired before the MRI examination. Between the mentioned dates, 439 patients were admitted to our clinic with suspicion of AA. 361 patients meeting the criteria were included in the study.

Inclusion criteria: Patients hospitalized in the pediatric surgery clinic with suspicion of AA between the mentioned dates, patients who were operated on for AA or followed with suspected AA, patients between 5 and 18 years old were included. Exclusion criteria: Children younger than five years of age were excluded because of the inability to tolerate an MRI examination without sedation, children in unstable condition or with neurological deficit who intolerance to MRI, children with contraindications to MRI (e.g., metallic implant), children undergoing interval appendectomy were excluded.

Patients were divided into three groups by the type of diagnostic approach. If the diagnosis cannot be made after the physical examination, the patients are examined by the professors. If there is still doubt the diagnosis, ultrasound is performed. If the diagnosis cannot be made despite US, MRI is planned for the patients. In group one, patients who were diagnosed clinically, based on history and physical exam by at least pediatric surgeon specialist or at utmost professor, were named as "surgeon prediction only." These patients are all seen both by senior residents and by attending level surgeons, also in some patients by senior professors. The second group included patients who were diagnosed with AA by surgeon prediction and ultrasound findings together. As MRI is the next step after indeterminate ultrasound in the evaluation of AA at our institute, the third group included patients whose clinical findings and US findings were equivocal, and MRI was performed to decide the clinical course. The prospectively planned division of the patients into groups and observation of the distribution of the participants in concordance with clinical practice is shown in **Figure 1**.

- Group 1 (Surgeon prediction only)→51 patients
- Group 2 (Surgeon prediction + US)→254 patients
- Group 3 (Surgeon prediction + US + MRI)→56 patients

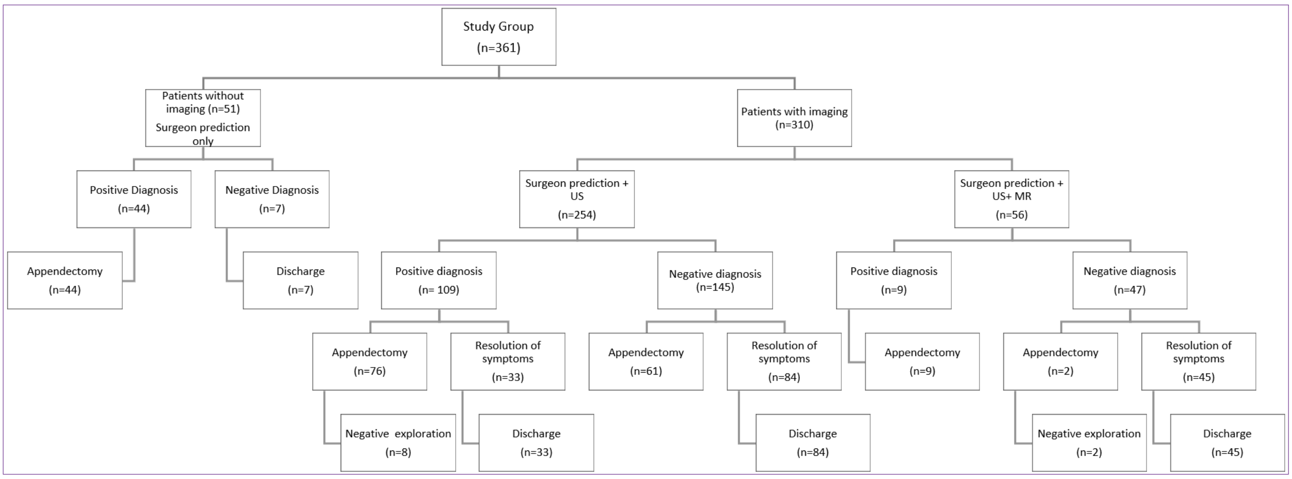

Figure 1. The details of the study group

Ultrasound findings were considered positive if the appendix diameter was larger than 6 mm and there were inflammatory changes, such as increased periappendiceal mesentery echogenicity, periappendiceal fluid, appendicolith, or fluid collection. MRI was performed without intravenous (IV) contrast and anesthesia sedation. T2 and diffusion-weighted imaging were performed in three planes (axial-sagittal-coronal) to the pelvic region. Imaging took about 15 minutes. Appendix localization, size, wall thickness, signs of periapendicular inflammation, and fluid were evaluated and interpreted by the pediatric radiologist. If the diagnosis was negative, appropriate follow-up planning and treatment were performed. If the diagnosis was positive, the operation was performed. The operation notes and pathology reports of the patients were recorded, and MRI-US accuracy rates and their superiority to each other were evaluated. Patients who were not considered for AA were discharged, and any of their complaints were re-evaluated urgently. Even if there was no complaint, at the outpatient clinic control one week later, it was recorded whether there was a delayed or missed diagnosis.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp. Inc., Armonk, NY, USA). The significance level (p-value) was set at 0.05 in all statistical analyzes. Descriptive statistics were given as mean ± standard deviation and median with minimum-maximum values for continuous variables depending on their distribution. Numbers and percentages were used for categorical variables. The normal distribution of the numerical variables was analyzed by the Kolmogorov-Smirnov test.

In comparing two independent groups, the Mann-Whitney U test was used where numerical variables had no normal distribution. To compare the differences between categorical variables, Pearson Chi-Square and Fisher's Exact tests were used in 2x2 tables.

Sensitivity, specificity, positive and negative predictive values, and overall accuracy were calculated for the development of AA based on the final decision of the diagnostic treatment groups and imaging techniques.

RESULTS

Demographic and clinical features of the study groups are given in **Table 1**. A total of 361 patients underwent diagnostic evaluation for appendicitis during the study period. The mean age was 11.4 ± 3.3 years. The female-to-male ratio was 0.66. A total of 51 patients (14.1%) were diagnosed via only the physical examination and laboratory findings by surgeon prediction. In the remaining 310 patients (85.9%), at least one type of imaging technique was performed. For diagnostic purposes, 310 US and 56 MRI examinations were performed. Of the patients, 254 only underwent a US examination, and 56 patients underwent both US and MRI.

The groupings for the diagnostic approach are detailed in **Table 1**. In the majority of the cases (70.4%), the diagnostic evaluation was performed via the surgeon prediction plus US. Of those patients with additional imaging, 56 (15.5%) underwent MRI.

Table 1. Demographic and clinical features of the study groups.

Variable	
Age (year) †	11.4 ± 3.3
Sex ‡	
Female	143 (39.6)
Male	218 (60.4)
Diagnostic groups ‡	
"Surgeon prediction only"	51 (14.1)
"Surgeon prediction + US"	254 (70.4)
"Surgeon prediction + US + MRI"	56 (15.5)
Imaging techniques ‡	
US	310 (85.9)
MRI	56 (15.5)

†: mean ± standard deviation, ‡: n (%). US: ultrasound, MRI: magnetic resonance imaging.

The median diameter of the appendix vermiformis was 7 mm in 195 patients whose appendix could be imaged during US. Mesenteric lymphadenopathy was the most common ultrasonographic finding, detected in 119 patients (46.9%). Increased periappendiceal mesenteric echogenicity was detected in 71 patients (28%). Periappendicular fluid collection was detected in 69 patients (27.2%), and the number of patients with appendicolith detected on US was 26 (10.2%). Based on the ultrasonographic findings, 109 patients (42.9%) were diagnosed with AA. There were nine patients (16.1%) whose diagnoses were AA according to MRI.

Treatment outcomes are given in **Table 2**. In the overall study groups, the rate of AA was 50.4%. Although 169 (46.8%) patients did not receive operation, surgical treatment was needed in 192 patients (53.2%). In 182 patients, appendectomy was performed. Complicated AA was diagnosed in 45 patients (24.7%) who underwent appendectomy. There were ten cases with negative exploration in which surgical treatment was applied. There was no significant impact of age and sex distribution on the development of AA (p=0.809 and p=0.505).

Table 2. Treatment outcomes of the study groups.

Variables	
Final diagnosis (n=361) ‡	
Acute appendicitis	182 (50.4)
Other diagnoses/non-specific abdominal pain	179 (49.6)
Final outcome (n=361) ‡	
Conservative management / Discharged	169 (46.8)
Surgical treatment	192 (53.2)
Appendectomy	182
Negative exploration	10
Severity of AA (n=182) ‡	
Complicated	45 (24.7)
Non-complicated	137 (75.3)
Length of hospital stay (day) β	2 [1 – 7]

‡: n (%), β: median (min-max).

The mean length of hospital stay was two days in the study group. In patients with AA, the mean length of hospital stay was longer than in patients without AA. The difference between the two groups was statistically significant (2 ± 1.1 days vs. 1.8 ± 1.1 days) (p=0.012).

There was no significant difference in the length of hospital stay between the groups based on the diagnostic approaches (2 days [1-6] for "Surgeon prediction only", 2 days [1-7] for "Surgeon prediction plus US" and 2 days [1-6] for "Surgeon prediction plus US plus MR") (p=0.073).

The comparison of the groups based on the diagnostic approaches in patients with and without AA revealed that the rate of AA was 86.3% in the "Surgeon prediction" group (p<0.001). In the "Surgeon prediction plus US" group, the rate of not having AA was 49.2%. However, the use of US as the only imaging method caused a substantial increase in this rate of 55.5%. In patients in which both imaging techniques (US plus MRI) were used, there were significantly more patients without AA (p<0.001). The use of MRI caused the detection of significantly more patients without AA (p<0.001) (**Table 3**).

Table 3. Comparison of the groups based on the diagnostic approaches in patients with and without AA.

	Final diagnosis of AA		P
	No (n=179)	Yes (n=182)	
Diagnostic groups ‡			
"Surgeon prediction only"	7 (13.7)	44 (86.3)	<0.001*
"Surgeon prediction + US"	125 (49.2)	129 (50.8)	0.828
"Surgeon prediction + US + MRI"	47 (83.9)	9 (16.1)	<0.001*
Imaging technique ‡			
US	172 (55.5)	138 (44.5)	<0.001
MRI	47 (83.9)	9 (16.1)	<0.001

‡: n (%). US: ultrasound, MRI: magnetic resonance imaging. * Pearson Chi-Square test, ** Mann Whitney U test

There were significant differences in the diameter of the appendix vermiformis, mesenteric lymphadenopathy, and periappendiceal mesenteric echogenicity in patients with and without AA (**Table 4**). The diameter of the appendix vermiformis was significantly larger in patients with AA (p=0.003). The presence of mesenteric lymphadenopathy was more frequently detected in patients without AA (p<0.001). In 56.1% of the patients with AA, periappendiceal mesenteric echogenicity was seen, whereas this rate was significantly lower in other diagnoses (43.9%). The difference was significant (p=0.019).

Table 4. Comparison of the ultrasonographic imaging findings in patients with and without AA (n=310).

	Final diagnosis of AA		P
	No (n=172)	Yes (n=138)	
US findings			
Diameter of the appendix vermiformis (mm) β	7 [2 – 14]	7.7 [2 – 14]	0.003**
Mesenteric lymphadenopathy ‡	81 (66,4)	41 (33,6)	<0.001*
Periappendiceal mesenteric echogenicity ‡	36 (43,9)	46 (56,1)	0.019*
Periappendicular fluid collection ‡	46 (62,2)	28 (37,8)	0.142*
Appendicolith ‡	14 (48,3)	15 (51,7)	0.412*

‡: n (%), β: median (min-max). US: ultrasound. *. Pearson Chi-Square test, **. Mann-Whitney U test

The distribution of ultrasonographic findings in patients with non-complicated and complicated AA is given in **Table 5.** There were significant associations between the diameter of appendix vermiformis, periappendiceal mesenteric echogenicity, and periappendicular fluid collection and the development of complicated AA. The diameter of the appendix vermiformis was significantly larger in patients with complicated appendicitis (10 mm vs. 7 mm) (p<0.001). Periappendiceal mesenteric echogenicity and periappendicular fluid collection were more frequently detected in complicated appendicitis cases (p=0.003 and p<0.001).

Table 5. Comparison of ultrasonographic findings in patients with non-complicated and complicated AA (n=138).

	Non-complicated AA (n=105)	Complicated AA (n=33)	P
Diameter of the appendix vermiformis (mm)	7 [2 – 14]	10 [7 – 13]	<0.001**
Mesenteric lymphadenopathy ‡	30 (28.6)	11 (33.3)	0.375*
Periappendiceal mesenteric echogenicity ‡	27 (25.7)	19 (57.6)	0.003*
Periappendicular fluid collection ‡	10 (9.5)	18 (54.5)	<0.001*
Appendicolith ‡	11 (10.5)	4 (12.1)	0.759*

‡: n (%), β: median (min-max). *. Pearson Chi-Square test, **. Mann-Whitney U test

The treatment modality correlated with the final clinical and radiological diagnosis in 97.2% of the cases (351 out of 361 patients); there were ten cases of negative appendectomy. The sensitivity and specificity of our institutional algorithm were 100.0% and 94.4%, and the positive and negative predictive values were 94.7% and 100%.

In 33 of the 109 patients diagnosed with AA using "surgeon prediction + US" were not confirmed as having AA (33 false positive results), and 61 of the 145 patients not diagnosed with AA were confirmed as having AA (61 false negative results). Nine of the 56 patients diagnosed with AA using physical "surgeon prediction + US + MRI" were confirmed as having AA (zero false positive results). Also, two patients not diagnosed with AA by MRI were confirmed as not having AA (no false negative results) (**Figure 1**).

The diagnostic accuracy of the diagnostic treatment groups and imaging techniques are given in **Table 6**. Considering the diagnostic groups, the accuracy of both the "surgeon prediction only" and "surgeon prediction + US + MRI" groups was 100%. The "surgeon prediction + US" group revealed a sensitivity value of 62.4% with an accuracy rate of 59.8%.

Table 6. Diagnostic accuracy of the groups based on diagnostic approaches and imaging techniques.

Variables	Sensitivity	Specificity	Accuracy	PPV	NPV
Diagnostic groups					
"Surgeon prediction only"	100	100	100	100	100
"Surgeon prediction + US"	62.4	57.9	59.8	52.7	67.2
"Surgeon prediction + US + MRI"	100	100	100	100	100
Imaging technique					
US	61.0	65.5	63.9	52.2	73.3
MRI	100	100	100	100	100

PPV: Positive predictive value, NPV: Negative predictive value

The sensitivity and specificity of US were 61.0% and 65.5%, respectively. The positive and negative predictive values were 52.2% and 73.3%, respectively. However, these values were 100% for MRI.

DISCUSSION

The best method for diagnosing AA is still controversial despite it being the most common surgical emergency in children.10 At our tertiary referral pediatric hospital, patients whose history, physical examination, and laboratory findings are insinuating appendicitis are treated directly with surgery without any imaging modality. If the patients have equivocal findings, they were kept going to imaging. At our institution, sufficiently high clinical suspicion is enough in pediatric patients with suspected appendicitis to be treated directly with surgery without imaging. Ultrasound is the first-line imaging method used in 85.8% of cases, while CT was never used because of the radiation burden. It is known that even one CT examination has an increased incidence of radiation-induced malignancy in children.11,12 Also, approaching zero CT use for evaluation of pediatric appendicitis is possible through a multidisciplinary approach without affecting clinical outcomes, as shown in a recently published study.13 We realized that many patients who were referred to our institution had CT imaging without US. Therefore, we decided to plan this prospective study to encourage the reduction of CT.

A staged imaging algorithm was implemented at our institution prospectively if the surgeon's clinical decision was equivocal. Ultrasound (as the initial modality) followed by MRI (as an advanced modality) were performed in pediatric patients suspicious of AA. Our staged algorithm of surgeon's prediction, followed by ultrasound, followed by MRI in patients with equivocal findings, was 100% sensitive and 94.4% specific for AA. This algorithm has a similar impact to the US and unenhanced MRI algorithm described in 2017 by Dibble et al., which was 98.2% sensitive and 97.1% specific.14

In this study and many other studies, the reason for the need for further advanced imaging modality is equivocal ultrasound findings. However, in our prospective study, we performed MRI in patients whose surgeon prediction by clinical findings was equivocal despite ultrasound predicting appendicitis. Also, even if MRI gave a negative result, if the suspicion of the surgeon proceeded because of the equivocal physical examination findings, we performed a diagnostic laparoscopy (**Figure 1**). In other words, indeed, our study mostly presents the sensitivity specificity of the surgeon's prediction.

We believe that despite technological improvements, appendicitis can be diagnosed clinically with a meticulous history and detailed physical examination.15,16 Clinical scores such as the Alvarado, pediatric appendicitis score, or pediatric appendicitis risk calculator are also helpful, but they have limited ability to identify patients who warrant appendectomy.17,18 Nevertheless, these scores may have utility in identifying children who may benefit from diagnostic imaging and/or surgical consultation by providing a standard approach. We do not use any of these scoring systems in our clinic. Although we could clinically diagnose only 14.1% of patients in our cohort, the diagnostic specificity and sensitivity of "surgeon prediction only" was 100%. Kelly et al. reported in their study that 983 appendectomies were performed of whom only 189 had preoperative ultrasound, and the rest of the patients (80.7%) had no imaging modality.19 The rate of negative appendectomy is remarkably higher than the literature in this study. The overall negative appendectomy rate is 32%, and this rate rises to 46% within the clinically equivocal group that underwent ultrasound. The authors accept the need for advanced imaging because of the markedly higher rate of negative appendectomy by saying "CT may well have been underutilized in this cohort".19 Our negative appendectomy rate is 5.2%, which is an acceptable value for the recent literature.4,20

With the popularization of the nonoperative management of simple appendicitis, many studies have pointed to the value of clinical diagnosis. Yu et al. reported in their prospective study in which they aimed to evaluate the accuracy of pediatric surgeons' prediction of appendicitis severity in children, they found that surgeon prediction was very sensitive (95%) for diagnosing simple appendicitis.21 The accuracy of pediatric surgeons' prediction of diagnosis of appendicitis is very high in our study but in a small portion of patients.

Today, the first preferred imaging method for patients with suspected appendicitis is ultrasound. From a prospective, 10-center study (N = 965) of children aged 3–18 years with acute abdominal pain concerning appendicitis showed that ultrasound sensitivity and specificity were 72% and 97%, respectively, in diagnosing appendicitis.22 Kelly et al. reported in their retrospective study overall, the sensitivity of ultrasound for AA (used in 19% of cases as the first-line imaging) was 72.55% and specificity was 77.01%.19 In our study, "surgeon prediction + US" was used in 70.4% of the study cohort, and US sensitivity and specificity were 62.4% and 57.9%, respectively. Surgeon prediction is always the first diagnostic value to our knowledge.

The accuracy of US is dependent on factors including the patient's body habitus, US technician experience, patient ability to tolerate the US, and the sonographer's experience performing appendix US.23,24 There are limited large cohort pediatric studies evaluating secondary sonographic findings that can be predictive of appendicitis. Malia et al. evaluated the findings in patients who underwent ultrasound with suspected appendicitis. They recorded nine specific ultrasound findings in patients whose appendix was visible: appendix diameter, compressibility, increased vascularity, presence of appendicolith, inflammatory changes, fluid near the appendix, lower abdominal fluid, tenderness revealed by sonographer, and one or more lymph nodes (≥5 mm in diameter). According to the results of the regression analysis, they found that all patients with a visualized appendix, the likelihood of surgical pathology positive for AA was significantly greater if the appendix diameter was 7 mm or greater, an appendicolith was present, inflammatory changes were seen, or the white blood cell count was greater than 10,000/μL. A duration of abdominal pain of three or more days was significantly less likely to be associated with appendicitis in this model.25 In our study, we recorded the five specific US findings—diameter of the appendix vermiformis, presence of mesenteric lymphadenopathy, increased periappendiceal mesenteric echogenicity, periappendicular fluid collection, and presence of appendicolith. Appendicitis diameter was significantly larger in patients with AA than in those without AA. Also, in patients with AA, increased echogenicity in the periapendicular mesentery was significantly higher. The presence of periappendicular fluid or appendocholitis was not predicted for AA. In addition, mesentery lymphopathy was found to be significantly higher in patients without appendicitis. It was noted that the diameter of the appendix was 10 mm and above in complicated patients (perforated appendicitis), and the presence of periappendicular fluid was significantly higher in addition to periappendicular mesentery echo increase. The rate of utilization of MRI after ultrasound varies in the literature. Dibble et al. reported a utilization rate of 13% equivocal US findings versus our rate of 15.5%.14 The rate of utilization of MRI was 53%, as reported in Thieme et al.'s study. In their study, US was performed by trainees in radiology, probably resulting in a higher rate of uncertain results.26 Dillman et al. reported an MRI utilization rate of 15%, which is the same as our rate. Although Dillman et al. compared the effectiveness of CT and MRI after undetermined US findings, the sensitivity and specificity of MRI were similar to ours at 94.4% and 100%, respectively.27

Two meta-analyzes reported MR imaging sensitivities of 96% and 96.5% and specificities of 96% and 96.1% for recognition of AA in children.28,29 Recently Dibble et al. found that unenhanced MRI was 87.5% sensitive and 98.4% specific after equivocal US findings; 16 of 77 patients who underwent MRI had appendicitis.13 We found that MRI was 100% sensitive and 100% specific in our study.

Two MRI results were evaluated as normal by a pediatric radiologist with no findings of appendicitis. However, these two children underwent exploratory laparoscopy due to progressively worsening right lower quadrant pain and signs of peritonitis. The final pathology report described a normal appendix in both patients.

The other eight negative explorations were interpreted as AA with a significantly enlarged appendix measuring greater than 7 mm. The patients underwent laparotomy because of clinical suspicion for AA. Surgical findings included a normal appendix.

Moore et al. and Dibble put forward that an algorithm of US followed by MRI might be the most effective imaging algorithm for pediatric abdominal pain.14,30 Although some authors have suggested that MRI may be appropriate as a first-choice test, our study demonstrated acceptable results with US alone but an even higher diagnostic efficiency when the surgeon prediction, US and MRI staged algorithm was used, with an MRI utilization rate of only 15%.28 We believe that the most important predictor is the surgeon's decision, which can be supported with ultrasound, and in equivocal cases can be supported with MRI as an advanced imaging modality, respectively. MRI as the first-line modality for suspected pediatric appendicitis may have been efficient throughout institutions with that capability, and a recent study by Petkovska et al. found unenhanced MRI to be 97.0% sensitive and 99.5% specific for AA in patients aged 3–50 years.31

Our study has some limitations. The relatively small number of patients is one of the limitations. Larger groups are needed for the evaluation of AA with MRI. Second is the lower limit of age 5 years old; this cohort does not reflect the general pediatric population that lends to the most clinically challenging group to diagnose acute appendicitis.

CONCLUSION

To diagnose appendicitis in children, surgeon's assessment, prudence, and clinical evaluation should be the first method of diagnosis. US is a useful method to support surgeons in ensuring an accurate diagnosis, and MRI can be trusted as an additional method to verify a correct diagnosis. When MRI is available, the role of CT in the assessment of suspected pediatric appendicitis should be minimized, and CT should be reserved for only the most challenging cases like children younger than five years old age.

ETHICAL DECLARATIONS

Ethics Committee Approval: Our study was approved by the Ethics Committee of Ankara Children Health and Diseases Hematology Oncology Training and Research Hospital (No: 2017-083) and was conducted in accordance with the Helsinki Declaration.

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. Am J Epidemiol 1990;132(5):910-25.
2. Burjonrappa S, Rachel D. Pediatric appendectomy: optimal surgical timing and risk assessment. Am Surg 2014;80(5):496-9.
3. Kim K, Lee CC, Song KJ, Kim W, Suh G, Singer AJ. The impact of helical computed tomography on the negative appendectomy rate: a multi-center comparison. J Emerg Med 2008;34(1):3-6.
4. Raja AS, Wright C, Sodickson AD, et al. Negative appendectomy rate in the era of CT: an 18-year perspective. Radiology. 2010;256(2):460-5.
5. Akın M, Kaba1 M, Yıldız A, et al. Assessment of the pediatric patients with appendiceal mass secondary to perforated appendicitis who were treated by conservative treatment and elective interval appendectomy. Sisli Etfal Hastan Tip Bul. 2019;53(1):1-6.
6. Smith MP, Katz DS, Lalani T, et al. ACR Appropriateness Criteria® Right Lower Quadrant Pain--Suspected Appendicitis. Ultrasound Quarterly. 2015;31(2):85-91.
7. Kaiser S, Mesas-Burgos C, Söderman E, Frenckner B. Appendicitis in children--impact of US and CT on the negative appendectomy rate. Eur J Pediatr Surg-Zeitschrift fur Kinderchirurgie. 2004;14(4):260-4.
8. Puylaert JB. Acute appendicitis: US evaluation using graded compression. Radiology. 1986;158(2):355-60.
9. Kotagal M, Richards MK, Flum DR, Acierno SP, Weinsheimer RL, Goldin AB. Use and accuracy of diagnostic imaging in the evaluation of pediatric appendicitis. J Pediatr Surg 2015;50(4):642-6.
10. Ferguson DM, Anderson KT, Tsao K. Diagnostic Imaging for Pediatric Appendicitis. In: Hunter CJ, ed. Controversies in Pediatric Appendicitis. Cham: Springer International Publishing; 2019:29-45.
11. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet (London, England). 2012;380(9840):499-505.

12. Mathews JD, Forsythe AV, Brady Z, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. BMJ (Clinical research ed.). 2013;346:f2360.
13. Anderson KT, Bartz-Kurycki M, Austin MT, et al. Approaching zero: Implications of a computed tomography reduction program for pediatric appendicitis evaluation. J Pediatr Surg 2017;52(12):1909-15.
14. Dibble EH, Swenson DW, Cartagena C, Baird GL, Herliczek TW. Effectiveness of a Staged US and Unenhanced MR Imaging Algorithm in the Diagnosis of Pediatric Appendicitis. Radiology. 2018;286(3):1022-29.
15. Hardin DM, Jr. Acute appendicitis: review and update. Am Fam Physician. 1999;60(7):2027-34.
16. Kalliakmanis V, Pikoulis E, Karavokyros IG, et al. Acute appendicitis: the reliability of diagnosis by clinical assessment alone. Scand J Surg 2005;94(3):201-6.
17. Alvarado A. A practical score for the early diagnosis of acute appendicitis. Ann emerg med 1986;15(5):557-64.
18. Samuel M. Pediatric appendicitis score. J Pediatr Surg 2002;37(6):877-81.
19. Kelly BS, Bollard SM, Weir A, et al. Improving diagnostic accuracy in clinically ambiguous paediatric appendicitis: a retrospective review of ultrasound and pathology findings with focus on the non-visualised appendix. Br J Radiol 2019;92(1093):20180585.
20. Kim JR, Suh CH, Yoon HM, et al. Performance of MRI for suspected appendicitis in pediatric patients and negative appendectomy rate: A systematic review and meta-analysis. JMR 2018;47(3):767-78.
21. Yu YR, Rosenfeld EH, Dadjoo S, et al. Accuracy of surgeon prediction of appendicitis severity in pediatric patients. J Pediatr Surg 2019;54(11):2274-8.
22. Mittal MK, Dayan PS, Macias CG, et al. Performance of ultrasound in the diagnosis of appendicitis in children in a multicenter cohort. Acad Emerg Med 2013;20(7):697-702.
23. Nielsen JW, Boomer L, Kurtovic K, et al. Reducing computed tomography scans for appendicitis by introduction of a standardized and validated ultrasonography report template. J Pediatr Surg 2015;50(1):144-8.
24. Nordin AB, Sales S, Nielsen JW, Adler B, Bates DG, Kenney B. Standardized ultrasound templates for diagnosing appendicitis reduce annual imaging costs. J Surg Res 2018;221:77-83.
25. Malia L, Sturm JJ, Smith SR, Brown RT, Campbell B, Chicaiza H. Predictors for Acute Appendicitis in Children. Pediatr Emerg Care 2019.
26. Thieme ME, Leeuwenburgh MM, Valdehueza ZD, et al. Diagnostic accuracy and patient acceptance of MRI in children with suspected appendicitis. Eur Radiol 2014;24(3):630-7.
27. Dillman JR, Gadepalli S, Sroufe NS, et al. Equivocal pediatric appendicitis: unenhanced MR imaging protocol for nonsedated children-a clinical effectiveness study. Radiology. 2016;279(1):216-25.
28. Duke E, Kalb B, Arif-Tiwari H, et al. A Systematic Review and Meta-Analysis of Diagnostic Performance of MRI for Evaluation of Acute Appendicitis. AJR 2016;206(3):508-17.
29. Moore MM, Kulaylat AN, Hollenbeak CS, Engbrecht BW, Dillman JR, Methratta ST. Magnetic resonance imaging in pediatric appendicitis: a systematic review. Pediatr Radiol 2016;46(6):928-39.
30. Moore MM, Gustas CN, Choudhary AK, et al. MRI for clinically suspected pediatric appendicitis: an implemented program. Pediatr Radiol 2012;42(9):1056-63.
31. Petkovska I, Martin DR, Covington MF, et al. Accuracy of Unenhanced MR Imaging in the Detection of Acute Appendicitis: Single-Institution Clinical Performance Review. Radiology. 2016;279(2):451-60.