Evaluation of the Reliability of Pediatric Appendicitis Score and Ultrasonography Findings in the Diagnosis of Acute Appendicitis in Children

Çocuklarda Akut Apandisit Tanısında Pediatrik Apandisit Skoru ve Ultrasonografi Bulgularının Güvenilirliğinin Değerlendirilmesi

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ABSTRACT

Objective: Acute appendicitis is the most common surgical emergency in childhood. Early diagnosis is essential to prevent perforation-related morbidity. In this study, we aimed to evaluate the effectiveness of pediatric appendicitis score (PAS) and ultrasonography (USG) findings in the diagnosis of acute appendicitis.

Material and Methods: Patients who presented with acute abdominal pain and who were followed up or operated with a pre-diagnosis of appendicitis were analyzed retrospectively. The patients were divided into two groups as operated (n = 288) and non-operated (n = 161). PAS value of all patients was calculated and 1-4 negative (low risk), 5-6 suspect (moderate risk), 7 and above were considered positive (high risk). Patients who underwent USG were included in the study. The definitive diagnosis of the patients undergoing surgery was confirmed by histopathological evaluation.

Results: With the pre-diagnosis of acute appendicitis, 449 patients (171 girls, 278 boys) were hospitalized. Appendectomy was performed in 288 (64 %) of the patients. The remaining 161 patients (36 %) who recovered after the observation were discharged without any surgery. Histopathological diagnosis of patients undergoing appendectomy was acute appendicitis in 217 patients (75.3 %), perforated appendicitis in 67 patients (23.2 %) and normal appendix in 4 patients (1.4 %). Patients undergoing appendectomy had a significantly higher PAS value ($p < 0.001$). PAS value was significantly higher in the patients diagnosed with perforated appendicitis ($p < 0.05$). The sensitivity of USG and PAS were 81.59 % and 82.98 %, and their specificity was 88.81 % and 95.03 %, respectively, in the diagnosis of appendicitis. The sensitivity decreased significantly (67.70 %), and the specificity increased (100 %) when the patients with appendicitis in USG and PAS 7 and above were evaluated together. The sensitivity was 32.29 % and the specificity was 83.85 % when USG positivity or high-risk PAS value was used alone.

Conclusion: PAS is a useful clinical guide in determining the risk group for appendicitis and the use of additional imaging, and supports the diagnosis even in the high-risk group without additional imaging. However, in cases of incompatibility between USG and PAS values, we believe that close observation, repeated physical examination and, if necessary, further imaging are necessary to reduce the rate of negative appendectomy.

Key Words: Acute appendicitis, Children, PAS, Ultrasonography

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Conflict of Interest / *Çıkar Çatışması*: On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics Committee Approval / *Etik Kurul Onayı*: For the study, approval was obtained from Kirikkale University, Non-Interventional Research Ethics Committee, with the decision number of 2019.12.21 and the date of 08.01.2020.

Contribution of the Authors / Yazarların katkısı: DERE GUNAL Y: Constructing the hypothesis or idea of research and/or article, Planning methodology to reach the Conclusions, Organizing, supervising the course of progress and taking the responsibility of the research/study, Taking responsibility in patient follow-up, collection of relevant biological materials, data management and reporting, execution of the experiments, Taking responsibility in logical interpretation and conclusion of the results, Taking responsibility in necessary literature review for the study,Taking responsibility in the writing of the whole or important parts of the study, Reviewing the article before submission scientifically besides spelling and grammar, Providing personnel, environment, financial support tools that are vital for the study. ***POLAT D:*** Taking responsibility in patient follow-up, collection of relevant biological materials, data management and reporting, execution of the experiments, Taking responsibility in necessary literature review for the study, Providing personnel, environment, financial support tools that are vital for the study. ***GOKCE E:*** Taking responsibility in patient follow-up, collection of relevant biological materials, data management and reporting, execution of the experiments, Taking responsibility in necessary literature review for the study, Reviewing the article before submission scientifically besides spelling and grammar. ***YORUBULUT S:*** Taking responsibility in logical interpretation and conclusion of the results, Reviewing the article before submission scientifically besides spelling and grammar.

How to cite / *Atıf yazım şekli* : Dere Gunal Y, Polat D, Gokce E, Yorubulut S. Evaluation of the Reliability of Pediatric Appendicitis Score and Ultrasonography Findings in the Diagnosis of Acute Appendicitis in Children. Turkish J Pediatr Dis 2020;14;445-451.

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Received / Geliş tarihi : 01.07.2020
Accepted / Kabul tarihi : 24.08.2020
Online published : 16.09.2020
Elektronik yayın tarihi
DOI: 10.12956/tchd.761649

ÖZ

Amaç: Akut apandisit, çocukluk çağında en sık görülen cerrahi acil durumdur. Perforasyonla ilişkili morbiditeyi önlemek için erken tanı şarttır. Bu çalışmada, pediatrik apandisit skoru (PAS) ve ultrasonografi (USG) bulgularının apandisit tanısı koymadaki etkinliklerinin değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntemler: Akut karın ağrısı şikayeti ile başvuran ve apandisit ön tanısı ile yatırılarak takip veya ameliyat edilen hastalar geriye dönük olarak değerlendirildi. Hastalar cerrahi uygulanan (n=288) ve cerrahi uygulanmayan (n=161) olarak iki gruba ayrıldı. Tüm hastaların PAS değeri hesaplandı ve 1-4 arası negatif (düşük risk), 5-6 arası şüpheli (orta risk), 7 ve üzeri olanlar pozitif (yüksek risk) olarak kabul edildi. Çalışmaya USG yapılmış olan hastalar dahil edildi. Cerrahi uygulanan hastaların kesin tanısı histopatolojik değerlendirme ile doğrulandı.

Bulgular: Akut apandisit ön tanısıyla 449 hasta (171 kız, 278 erkek) yatırıldı. Hastaların 288'ine (% 64) apendektomi uygulandı. Gözlem sonrası iyileşen 161 hasta (% 36) ise herhangi bir cerrahi uygulanmadan taburcu edildi. Apendektomi uygulanan hastaların histopatolojik tanıları 217 hastada (% 75.3) akut apandisit, 67 hastada (% 23.2) perfore apandisit ve 4 hastada (% 1.4) normal apendiks idi. Apendektomi yapılan hastaların PAS değeri anlamlı olarak yüksekti (p <0.001). Perfore apandisit tanısı alan hastalarda PAS değeri anlamlı olarak yüksek saptandı (p <0.05). Apandisit tanısında USG ve PAS'ın sırası ile duyarlılıkları % 81.59 ve % 82.98, seçicilikleri % 88.81 ve % 95.03 olarak bulundu. Ameliyat kararı verilirken doğru tanıya ulaşabilmek için USG de apandisit saptanan ve PAS 7 ve üzeri olan hastalar birlikte değerlendirildiğinde duyarlılık belirgin düştü (% 67.70), seçicilik ise arttı (% 100). USG pozitifliği veya yüksek riskli PAS değerlerinden yalnızca birinin olması durumunda duyarlılık % 32.29, seçicilik ise % 83.85 olarak saptandı.

Sonuç: PAS apandisit risk grubunun belirlenmesinde ve ek görüntüleme kullanımıyla ilgili karar vermede yararlı bir klinik rehberdir ve yüksek risk grubunda olan vakalarda ek görüntüleme yapılmadan bile tanıyı desteklemektedir. Bununla birlikte USG ve PAS değerleri arasında uyumsuzluk olan vakalarda negatif apendektomi oranını azaltmak için yakın gözlem, tekrarlayan fizik muayene ve gerekirse daha ileri görüntülemenin gerekli olduğuna inanıyoruz.

Anahtar Sözcükler: Akut apandisit, Çocuk, PAS, Ultrasonografi

INTRODUCTION

Appendectomy still forms the basis of treatment (1). While delayed surgical intervention causes serious complications such as perforation, peritonitis, abscess formation, sepsis and bowel obstruction, a rushed surgery decision results in high rates of negative appendectomy (2).

Although the diagnosis of acute appendicitis is made with history, physical examination, and laboratory tests, sometimes it may be difficult to make an accurate diagnosis in children. Clinical symptoms of acute appendicitis may differ in classic or variable symptoms (3, 4). Typical findings classicly found in adults, such as anorexia, nausea-vomiting, and abdominal pain that begins around the umbilicus and radiates to the right lower quadrant, are found in only less than half of pediatric patients (3,5). Most cases present with atypical symptoms and are confused with many non-surgical diseases (5). Furthermore, inadequate communication skills of young children and adjustment problems encountered during physical examination make the diagnosis of acute appendicitis more difficult in children than in adults (3). Therefore, various imaging methods and clinical scoring systems have been used to increase diagnostic accuracy (6,7).

USG is the preferred imaging method in order to confirm the diagnosis and decrease the negative appendectomy rate in patients with suspected appendicitis due to its easy application and availability, low cost, non-invasiveness with no ionizing radiation (8,9). However, it is dependent on the user's experience and its diagnostic value decreases in the presence of pain, intense abdominal gas, obesity and presence of perforation (5,10). It has been reported in the literature that the accuracy rate is between 70 and 95 % (11).

The first scoring system was described by Alvarado in 1986 (12). Then, in 2002, pediatric appendicitis score (PAS) was defined for the diagnosis of acute appendicitis by adapting it to pediatric patients by Samuel (13). PAS consists of six clinical and two laboratory parameters. Since PAS can be easily evaluated, it is widely used as a diagnostic tool in appendicitis (13). In the literature, the sensitivity of PAS in the diagnosis of acute appendicitis has been reported in a wide range from 88.1 to 97.6 % and its specificity from 50 to 98.2 % (14,15). However, there are few studies on the effect of using USG findings with different PAS values on diagnostic accuracy in children with suspected appendicitis.

This study was conducted to reveal the diagnostic value of USG and PAS in pediatric patients with suspected appendicitis and to evaluate the sensitivity and specificity in the diagnosis of appendicitis when used together.

MATERIALS and METHODS

The study protocol was carried out in accordance with the Helsinki Declaration with the approval of the ethics committee. Parents' written consent was obtained. A total of 449 patients who presented with acute abdominal pain and admitted to the Pediatric Surgery clinic with a preliminary diagnosis of acute appendicitis between January 2009 and April 2011 were included in the study. Demographic characteristics (age, gender), initial complaints, physical examination findings, laboratory results, USG findings, surgical findings and histopathological diagnosis information were obtained from the medical records

of the cases in order to calculate PAS. The patients whose data were missing and who had no abdominal USG were excluded. In the presence of more than one abdominal USG, the USG findings at the first presentation of the patients were taken into consideration.

PAS was calculated on a total of 10 points using six clinical and two laboratory parameters for each patient (Table I). According to this scoring system, 1-4 negative (low risk), 5-6 suspect (moderate risk), 7 and above were considered positive (high risk) for appendicitis diagnosis.

The presence of at least one of the primary criteria such as aperistaltic and noncompressible tubular structure associated with cecum, ending with a blind end and a anterior-posterior diameter greater than 6 mm; thickening of the appendix wall (>2 mm); presence of appendicolitis and periapendicular hypoechoic inflammation or of the secondary criteria such as increased echogenicity in peripheral mesenteric fatty tissue in the right lower quadrant; free fluid in the pericecal-periapendicular region and abdominal cavity in the abdominal USG considered positive for acute appendicitis. The absence of the appendix at USG or its diameter below 6 mm and being normal were considered negative.

The definitive diagnosis of patients undergoing surgery was confirmed histopathologically. Accordingly, the presence of edema in the appendix wall and polymorphonuclear leukocytes along mucosa, submucosa or the entire wall was evaluated as acute appendicitis; the presence of necrosis in the appendix wall and / or the surgeon's indication that a hole in the appendix wall was seen were evaluated as perforated appendicitis; no pathological evidence of inflammation of the appendix or only reactive follicular hyperplasia was considered normal appendix.

The diagnostic performance of USG and PAS were evaluated separately according to the histopathological results of the cases. In addition, 2 groups were created to evaluate the effect of using USG and different PAS values on sensitivity and specificity: Patients with appendicitis in USG, i.e. USG positive and PAS 7 and above, were included in Group 1 (USG + and PAS ≥7) and Group 2 included patients with USG positive but PAS < 7 or USG negative but PAS 7 and above (USG + but PAS < 7 or USG - but PAS≥7).

For the study, approval was obtained from Kirikkale University, Non-Interventional Research Ethics Committee, with the decision number of 2019.12.21 and the date of 08.01.2020.

Statistical analysis

SPSS 21 package program was used for statistical analysis of the data. Categorical variables are expressed as numbers and percentages. Continuous measurements are summarized as mean ± standard deviation (median and minimum-maximum where necessary). Chi square test or Fisher's exact probability test was used to compare categorical variables. In comparing continuous measurements between groups, distributions were checked, Student T test was performed for parameters with normal distribution according to the number of variables, and Mann-Whitney U test for parameters without normal distribution. Results with $p < 0.05$ were considered statistically significant. The effect of USG and PAS values in determining the diagnosis was examined according to Binary logistic regression analysis. According to the histopathological results, sensitivity, specificity, positive and negative predictive values and diagnostic accuracy rates were calculated separately in order to determine the diagnostic performance of USG and / or PAS.

RESULT

Of the 449 patients included in the study, 171 were girls (38.1 %), 278 were boys (61.9 %), and the mean age was 10.34 ±2.97 years (4-17 years). Appendectomy was performed in 288 (64 %) of these patients with a preliminary diagnosis of acute appendicitis, and 161 (36 %) were discharged without surgery and they were observed to recover completely within the follow-up period. Demographic and clinical features of all patients are given in Table II. There was no significant difference between the mean ages of the operated and the non-operated groups ($p > 0.05$). The rate of boys in the surgical group was significantly higher ($p<0.05$). According to the histopathological evaluation, 217 (75.3 %) of 288 patients who underwent surgery were reported as acute appendicitis, 67 (23.2 %) as perforated appendicitis and 4 (1.4 %) as normal appendix. The mean of the calculated PAS values was 7.61±1.15 (4-10) in acute appendicitis, 8.00±1.04 (5-10) in perforated appendicitis, and 6.00±1.41 (5-8) in patients with normal appendix in histopathological evaluation. PAS value was significantly higher in perforated appendicitis ($p=0.003$). The mean time from onset of complaints to hospital admissions in the patients undergoing surgery was 2.31±2.72 days (1-30 days). This period was 1.54 ±1.12 days (1-10 days) in acute appendicitis, 4.87±4.41 days

Table I: Pediatric Appendicitis Score (PAS).

Clinical variables	PAS
Fever (38 °C and above)	1
Poor appetite	1
Nausea – vomiting	1
Pain during cough/percussion/jumping	2
Tenderness in the riht lower quadrant	2
Displaced pain	1
Increased leukocyte count (≥ 10.000 / mL)	1
Left shift in neutrophils (≥ 75 PMNL)	1
Total	10

Table II: Demographic and clinical features of all patients.

	Operated group (n=288)	Non-operated group (n=161)	p
Age (year)	10.46±2.93 (4-17)	10.13±3.03 (4-17)	0.271
Gender			
Girl	98(34 %)	74(46 %)	0.015
Boy	190(66 %)	87(54 %)	
Duration of application to the hospital (day)	2.31±2.72	2.18±2.62	0.072
Pediatric appendicitis score (PAS)	7.73±1.15 (1-7)	3.72±1.49 (4-10)	<0.001
Hospital stay (day)	4.84±2.55 (1-15)	2.28±0.85 (1-5)	<0.001

Table III: Distribution of PAS values and USG among the groups that are operated and not operated.

		PAS 1-4	PAS 5-6	PAS≥7	Total (n)
Non-operated group	USG (-)	95	40	8	143
	USG (+)	15	3	-	18
Operated group	USG (-)	-	1	52	53
	USG (+)	2	38	195	235
Total (n)		112	82	255	449

Table IV: Distribution of PAS and USG findings according to the histopathological results of operated group.

Histopathologic Results		PAS 1-4	PAS 5-6	PAS≥7	Total (n)
Normal appendix	USG (-)	-	-	1	1
	USG (+)	-	3	-	3
Acute appendicitis	USG (-)	-	1	39	40
	USG (+)	2	29	146	177
Perforated appendicitis	USG (-)	-	-	12	12
	USG (+)	-	6	49	55
Total (n)		2	39	247	288

(1-30 days) in perforated appendicitis and 1.00±0.00 days (1-1 days) in those with normal appendix. The mean hospital admission time of the patients with perforated appendicitis increased significantly ($p<0.05$). The mean hospital stay was 4.0±1.8 days in the patients with acute appendicitis and 7.5 ±2.6 days in the patients with perforated appendicitis. The length of hospital stay was significantly longer in the patients with perforated appendicitis ($p<0.001$).

PAS values of all patients were calculated. The distribution of PAS values between the groups is given in Table III. Surgery was performed in 247 of 255 patients with a PAS value of 7 and above, and in only one of them, the appendix was histopathologically normal. Surgery was performed in 41 of 194 patients with a PAS value below 7, and appendix was histopathologically normal in 3 of them. Appendicitis was not observed in children with low risk score (PAS 1-4) and negative USG. Of 41 patients with moderate risk (PAS 5-6) and negative USG, 1 patient was operated on, and histopathologically diagnosed as acute appendicitis. Of 41 patients with moderate risk (PAS 5-6) and positive USG, 38 were operated, and 3 of them had normal appendix (Table III, Table IV). Surgery was performed in 53 of 196 patients whose abdominal USG findings were negative in terms of appendicitis due to positive examination findings during follow-up. Among these 53 patients acute appendicitis was detected in 19 and perforated appendicitis in 6 of 25 patients with a normal appendix below 6 mm diameter in USG, histopathologically. Histopathology of the remaining 28 patients with unvisible appendix and / or negative secondary appendicitis symptoms in USG, revealed acute appendicitis in 20 patients, perforated appendicitis in 7 patients, and normal appendix in 1 patient. Surgery was performed in 235 of 253 patients whose USG findings are compatible with appendicitis. Surgery was performed in 216 patients with an uncompressible inflamed appendix with 6 mm in diameter and above, and 3 of them were normal, histopathologically (Table V). A statistically significant relationship was observed between PAS values and USG findings ($p < 0.001$).

According to the binary logistic regression analysis, USG findings and PAS values had a statistically significant effect in determining the diagnosis of acute appendicitis (PUSG < 0.001,

Table V: USG findings.

USG findings	Non-operated group	Operated group	Total (n)
Appendix diameter < 6mm and normal	102	25	127
The appendix is unvisible, but there are no signs of secondary appendicitis	41	28	69
The appendix is unvisible, but there are signs of secondary appendicitis	6	19	25
Appendix diameter > 6mm, noncompressed, inflamed appendix	12	216	228
Total (n)	161	288	449

Table VI: Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), false negativity (FN), false positivity (FP) and accuracy rates of USG, PAS, Group 1, Group 2 in the diagnosis of acute appendicitis.

	PAS (%)	USG (%)	Group 1 (USG + and PAS ≥ 7) (%)	Group2 (USG + but PAS<7 or USG - but PAS ≥7)
Sensitivity	82.98	81.59	67.70	32.29
Specificity	95.03	88.81	100	83.85
PPV	96.76	92.88	100	78.15
NPV	75.74	72.95	63.38	40.91
FN	24.25	27.04	36.61	59.10
FP	3.23	7.11	0	21.84
Accuracy rate	87.30	84.18	79.28	50.78

bUSG = 4.11; PPAS < 0.001, bPAS = 5.04).

For an accurate diagnosis of acute appendicitis, sensitivity, specificity, positive predictive values and negative predictive values are given in Table VI in groups where USG and PAS values are used separately and together.

DISCUSSION

Although appendicitis is the most common cause of acute abdomen requiring urgent surgical intervention in the pediatric age, it is sometimes difficult to make an accurate and timely diagnosis. Unnecessary or late operations due to difficulties in diagnosis are one of the important problems encountered in children with suspected appendicitis. In the literature, it has been reported that 20-25 % of the operated patients are operated unnecessarily or 23-73 % of them have complicated appendicitis (16,17). This suggests that some auxiliary methods are needed to lead to early diagnosis.

Despite the development of imaging techniques, an excellent diagnostic method for appendicitis is not yet available. The distinctive features of acute appendicitis is still based on the patient's clinic and a careful physical examination. However, imaging methods in addition to the clinical examination have been shown to improve the accuracy of the diagnosis and reduce the progression of the disease and the rate of negative appendectomy (8,9,18).

USG is the first imaging method used in children with appendicitis based on history, physical examination and laboratory results (19, 20). However, since USG findings may vary depending on the experience of the user, sensitivity in the literature has been reported in the range of 76.4-93.1 % and specificity in the range of 80.0-92.2 % for the diagnosis of acute appendicitis (11, 21). In our study, the sensitivity of USG was 81.59 % and the specificity was 88.81 %, in accordance with the literature. However, the false negative rate was 27.04 %. Similarly, high false negativity rates have been reported by other authors (11, 22, 23). The high rate of false negativity may be due to the absence of normal or inflamed appendix in USG, or measurement errors, particularly in focal appendicitis. If the non-inflamed proximal part of the appendix is measured, the appendicitis may be overlooked. It is important to show the appendix in the longitudinal and transverse plane to minimize this error (11, 24, 25).

Some clinical scoring systems have been developed to reduce the time required for appendicitis diagnosis and the number of inappropriate appendectomies (12,13,26). The first of these is the Alvarado scoring system, which is frequently used especially in the adult population (12). The Alvarado scoring system is evaluated with a total of 10 points over eight parameters. There is evidence that the negative laparotomy rate decreases in patients with an Alvarado score of 7 or above (12). Samuel adapted the Alvarado score to children and developed PAS (13). Both scores have been developed without any complexity to be calculated manually. Recently, a new electronic health

record integrated pediatric appendicitis risk calculator (pARC) has been developed to evaluate the likelihood of appendicitis in children (27). The variables included in pARC are; sex, age, duration of pain, guarding, pain migration, maximal tenderness in the right-lower quadrant, and absolute neutrophil count. The authors reported that pARC provides a continuous risk assessment for appendicitis for children over 5 years old (27).

PAS is a simple scoring system based on history, physical examination findings and laboratory results, developed to facilitate diagnosis of acute appendicitis in children. Samuel reported the sensitivity of PAS as 100 %, specificity as 92 %, negative appendectomy rate as 4.9 %, and complicated appendicitis rate as 29 % (13). PAS is recommended for children over 4 years of age as it is considered that young children cannot express their complaints fully and accurately (13,28). However, Erturk et al. (29) found that the sensitivity of PAS (95.9 %) was high in children under 6 years of age. They also found that the sensitivity of PAS decreased with age. In the study in which Schneider et al. (6) evaluated 588 cases, when PAS 6 and above were accepted as positive, its sensitivity was reported as 82 % and specificity as 65 %. PAS sensitivity was found to be 97.6–100 % and specificity as 96–92 % in two studies that accepted PAS values of seven and above as significant for surgery (13,28). In the study of Tasar et al. (20), when the cut-off value was taken as 8, PAS sensitivity was 58.0 % and specificity was 94.9 %. PAS and USG were evaluated together to increase sensitivity, but sensitivity was still low (44.4 %), and specificity was unchanged (94.9 %). According to these results, they thought that PAS alone can be used safely in excluding acute appendicitis. In our study, when the cut-off value was taken as 7, PAS sensitivity was 82.98 %, specificity was 95.03 %, positive predictive value was 96.76 % and negative predictive value was 75.74 %. These results show us that PAS can be similarly used to exclude acute appendicitis alone, and especially PAS with high risk can strengthen the diagnosis of acute appendicitis. Bhatt et al. evaluated the usefulness of the clinical scoring system in the diagnosis of pediatric appendicitis and reported that PAS excluded the diagnosis in the low-risk group and supported the diagnosis in the high-risk group, whereas radiology was required in the medium-risk group (14). In previous studies, the confirmed appendicitis rate was reported as 0–2 %, 8–48 % and 78–96 % in low, medium and high risk groups, respectively (14, 28, 30). Similarly, in our study, the confirmed appendicitis rate was 1.8 % in the low-risk group (PAS 1-4), 43.9 % in the medium-risk group (PAS 5-6) and 96.3 % in the high-risk group (PAS ≥ 7). These results may be due to the fact that the PAS assessment is performed only by two pediatric surgeons with similar experience. Aydin et al. reported the confirmed appendicitis rate of 1.5 % in the low-risk group and 65.1 % in the high-risk group. They reported that this difference may be due to the lack of experience of emergency physicians evaluating PAS that led to inaccurate high scores (31).

In our study, sensitivity was 67.70 % and specificity was 100 % in Group 1, in which patients with a PAS value of 7 and above and with a positive USG in terms of acute appendicitis. While the diagnosis was correct in 99.5 % of the patients who were operated in the presence of both USG positivity and the clinical score of 7 and above, 36.61 % of the patients could not be diagnosed due to the low sensitivity although they had appendicitis. In such a case, while the negative appendectomy rate decreases, the risk of perforation due to delayed diagnosis will increase. If PAS is less than 7 and USG is positive or USG is negative but PAS≥7, it is difficult to rule out appendicitis. Therefore, these patients should be hospitalized and monitored closely. We think that the operation decision in such patients should be made according to the patient's clinic and repeated physical examination findings and, if necessary, recurrent USG results. So that, in our study the negative appendectomy rate was 1.4 % (4 patients) and this is among the lowest rates reported in the literature. On the other hand, while avoiding negative appendectomies, surgeons may experience increased complicated appendicitis. Complicated appendicitis rate has been reported in the literature between 29 and 49 % (13, 32, 33). In our study, the perforation rate was 23.2 %. Although the admission time of these patients was significantly high, we did not encounter perforation during follow-up.

The limitations of this study are using the data obtained by retrospective file scanning and the evaluation of USG findings at different times by different radiologists. However, the sensitivity and specificity of USG were found to be compatible with the literature. In a prospective study in which USG of patients with suspected appendicitis will be performed by an experienced Radiologist, the contribution of USG in diagnosing appendicitis can be better demonstrated.

In conclusion, PAS is a useful clinical guide in determining the risk groups of appendicitis and in making decisions regarding the use of additional imaging. PAS supports diagnosis even in cases with high risk group without additional imaging. In cases with PAS in the moderate risk group, there is a need for imaging with USG as an auxiliary examination. However, if there is an incompatibility between USG and PAS values, we believe that close observation, repeated physical examination and, if necessary, further imaging are necessary to reduce the rate of negative appendectomy.

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