

Evaluation of a new scoring system for early diagnosis and management of acute appendicitis in pediatric patients

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Background

Acute appendicitis is a common surgical emergency among infants and children. The diagnosis of acute appendicitis in young children remains a big challenge, as most of such patients present late, with complications. However, unnecessary surgery should be avoided. Over years, many scoring systems have been introduced for helping the diagnosis of acute appendicitis such as Alvarado score, the Pediatric Appendicitis Score (PAS), and Appendicitis Inflammatory Response score.

Patients and methods

In the period between 3/2018 and 9/2019, 130 infants and children till the age of 16 years, with acute right iliac pain, were included in this study. These patients were evaluated using three diagnostic scores: Acute Pediatric Appendicitis Score (APAS), PAS, and Alvarado scores.

Results

Logistic regression analysis yielded a model comprising nine variables, all being statistically significant ($P < 0.001$). Moreover, we found a significant correlation between the management findings and four APAS items, including anorexia, right lower quadrant tenderness, cough/percussion tenderness, and positive ultrasound findings, as they showed the highest significant values statistically and were very predictive regarding the management of the cases, with the ultrasound examination showing the most accuracy value between all the items. The accuracy of APAS score to differentiate between both surgical appendicitis and conservative appendicitis groups was 99.2%, sensitivity was 100%, specificity was 98.04%, positive predictive value was 98.7%, and negative predictive value was 100%, whereas the accuracy of PAS score was 95.3%, and the accuracy of Alvarado score was 91.3%.

Conclusion

APAS score is a significant diagnostic tool for diagnosis of acute appendicitis in pediatrics. The study also provides a solid comparison among APAS, PAS, and Alvarado scores. APAS score is the first score in well-known literature to introduce ultrasound examination as a routine investigation among the suspected children with acute appendicitis with an accuracy of ~95.38%.

Keywords:

appendicitis, laparoscopy, scoring system

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Introduction

Acute appendicitis is a common surgical emergency among infants and children (1–2% in pediatric surgical admissions) [1,2].

Appendicitis is an acute inflammatory process involving the appendix. It is the number one surgical emergency and one of the most common causes of abdominal pain, particularly in children. It should be considered in any patient with acute abdominal pain without prior appendectomy. The diagnosis must be made as quickly as possible because with time, the rate of rupture increases [3–5].

The cause of appendicitis is an obstruction of the appendix, either from inflammation of the wall or a fecalith [6,7].

Despite the availability of advanced diagnostic imaging, the diagnosis of acute appendicitis in young children remains a big challenge, as most of such patients present late, with complications, for

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example, abscess formation, generalized peritonitis, and sepsis. The delay in the diagnosis of acute appendicitis has been attributed to nonspecific presentations, overlap of symptoms with many other common childhood illnesses, inability of the child to express, and difficult abdominal examination in this age group [8]. However, unnecessary surgery should be avoided. The proportion of appendices that are normal on histologic studies identifies this problem with a negative appendectomy rate of 10–30% [9].

Over years, many scoring systems have been introduced for helping the diagnosis of acute appendicitis such as Alvarado score in 1986, who constructed a 10-point clinical scoring system, also known by the acronym MANTRELS [10]; Christian in 1992 with five point simple scoring system [11]; Samuel in 2002, who published another scoring system specific to the pediatric age group, the Pediatric Appendicitis Score (PAS) [12]; and also the recently introduced Appendicitis Inflammatory Response score [13].

In our study, we evaluate a new scoring system, Acute Pediatric Appendicitis Score (APAS), for helping the diagnosis of acute appendicitis in the pediatric age group. APAS score is based on symptoms, signs, and other different diagnostic tools in a simple manner. The study also evaluates the accuracy of our score in management plan of the cases. The study also compares the results of APAS score and other previous scores, Alvarado score and PAS.

Patients and methods

In the period between 3/2018 and 9/2019, all the infants and children till the age of 16 years with acute right iliac pain (130 patients) were admitted to the Emergency Pediatric Surgery Unit, Tanta University Hospitals. Informed consent was taken from parents of all patients before participation in the study. Any unexpected risks that appeared during the course of the research was cleared to the participants or guardians with the approval of the Ethical Committee on time. A uniform prospective data form was completed, which included the following: first, demographic data (age and sex); second, duration of symptoms, such as anorexia and nausea, vomiting, or refusal of feeding; third, physical signs, such as right iliac fossa tenderness on palpation, right lower quadrant tenderness on hopping, coughing/percussion tenderness right lower quadrant, and pyrexia; fourth, laboratory investigations, such as white blood cell count, differential count including neutrophilic count, C-reactive protein (CRP), and urinalysis; fifth, pelviabdominal ultrasound

examination; and sixth, histopathological examination of the removed appendix. Cases with any associated gynecological or renal problems or medical conditions such as familial mediterranean fever (FMF) and inflammatory bowel disease (IBDs) were excluded from the study. The patients were evaluated using three scoring systems, the first one is APAS as follows:

- (1) Anorexia (refusal of feeding) (no=0 and yes=1).
- (2) Nausea/vomiting (no=0 and yes=1).
- (3) Tenderness over right lower quadrant (no=0 and yes=2).
- (4) Cough/percussion tenderness over right lower quadrant (no=0 and yes=2).
- (5) Elevated temperature more than 38°C (no=0 and yes=1).
- (6) Total Leukocytic count:
 - (a) Less than 10 000/mm³ (0).
 - (b) 10 000–20 000/mm³ (1).
 - (c) More than 20 000/mm³ (2).
- (7) Polymorphonuclear neutrophils:
 - (a) Less than 7500/mm³ (0).
 - (b) 7500/mm³ or more (1).
- (8) CRP:
 - (a) Less than 10 g/l (0).
 - (b) 10–50 g/l (1).
 - (c) More than 50 g/l (2).
- (9) Ultrasound examination findings:
 - (a) Normal ultrasound (0).
 - (b) Periappendicular fluid collection or intraperitoneal free fluid (1).
 - (c) Aperistaltic, noncompressible dilated appendix greater than 6 mm in diameter (2).
 - (d) Appendicolith (2).
 - (e) Inflammatory phlegmon (3).
 - (f) Abscess formation/pelvic collection (3)

Patients were divided into four categories:

- (1) Group A: 0–3 points, outpatient follow-up.
- (2) Group B: 4–7 points, in-hospital active observation with possibility of further investigations and rescoring.
- (3) Group C: 8–12 points, laparoscopic appendectomy.
- (4) Group D: 13–15 points, laparoscopy with the possibility of conversion to open surgery according to the findings.

The second scoring system used for evaluation of the cases is PAS score with a total score of 10 points, as follows:

- (1) Anorexia (1).
- (2) Nausea/vomiting (1).
- (3) Migration of pain (1).

- (4) Right lower quadrant tenderness (2).
- (5) Pain with cough, percussion or hopping (2).
- (6) Elevated Temperature more than 38°C (1).
- (7) White blood cell count more than 10 000/mm³ (1).
- (8) Neutrophils plus band forms more than 7000/mm³ (1).

The third scoring system used for evaluation of the cases is Alvarado score with a total score of 10 points, as follows:

- (1) Anorexia (1).
- (2) Nausea/vomiting (1).
- (3) Migratory right iliac fossa pain (1).
- (4) Tenderness in right iliac fossa (2).
- (5) Rebound tenderness in right iliac fossa (1).
- (6) Elevated Temperature more than 38°C (1).
- (7) White blood cell count more than 10 000/mm³ (2).
- (8) Shift to the left of neutrophils (1).

Follow-up of the patients was done at outpatient clinic at one week, two weeks, and after 6 months.

Results

Age and sex (demographic data)

The studied patients have age ranged from 1.5 to 18 years old. The mean age was 8.700±4.212 years. Among the 130 patients of our study, there were 72 male patients (55.38% of the studied patients) and 58 female patients (44.62% of the studied patients).

Results of management of the patients

In our study, conservative out-patient follow-up was done for 18 (13.85%) cases, in-active hospital

observation with conservative treatment was done for 38 (29.23%), laparoscopy with appendectomy was done for 64 (49.23%), open appendectomy was done for eight (6.15%) as the patients’ parents refused laparoscopy, and laparoscopy converted to open appendectomy was done for two (1.54%) cases due to intraoperative findings as one case showed very friable tissues with severe adhesions and the other case showed friable necrotic base in flush with the cecum which indicated formal repair (Fig. 1).

Management plan was done according to APAS score of the patients. The range of the scores of nonoperated patients was 1–7, with mean 4.000±1.726, whereas the range of the scores of operated patients was 8–15, with a mean of 11.138±2.192. Among these results of the management, the operated patients were 80 (61.54%), and the nonoperated patients with conservative medical therapy were 50 (38.46%) (Table 1).

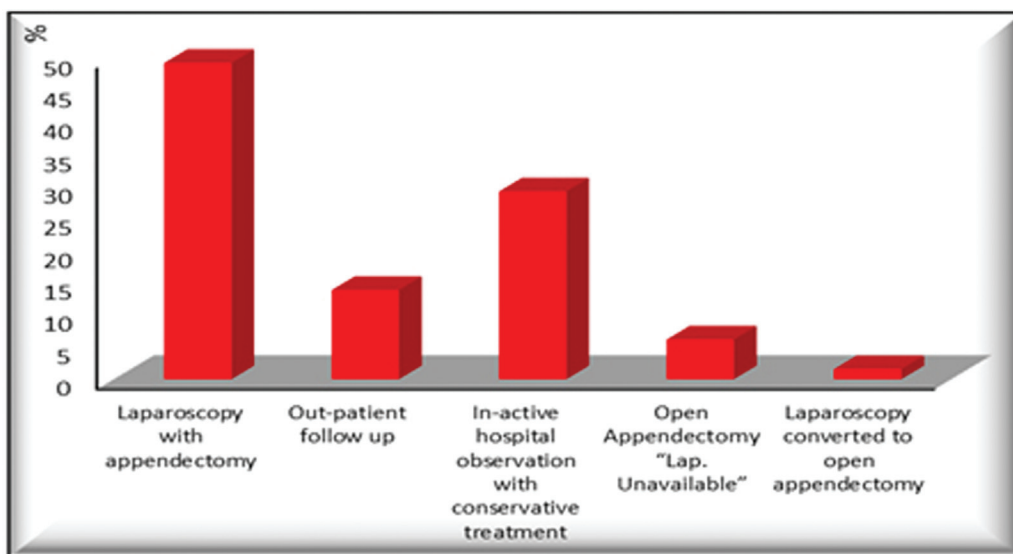
Duration of the symptoms

Regarding the management and the duration of symptoms of the nonoperated patients, it ranged from 2h to 5 days, with mean 0.629±0.758, whereas it was 1–11 days among the operated patients, with a mean of 3.688±2.526. There was a significant difference between both groups, with the operated patients having longer duration of symptoms (Fig. 2).

Results of the management findings

Regarding the findings following the management plan, 50 (38.46%) patients showed good outcome with conservative treatment.

Figure 1



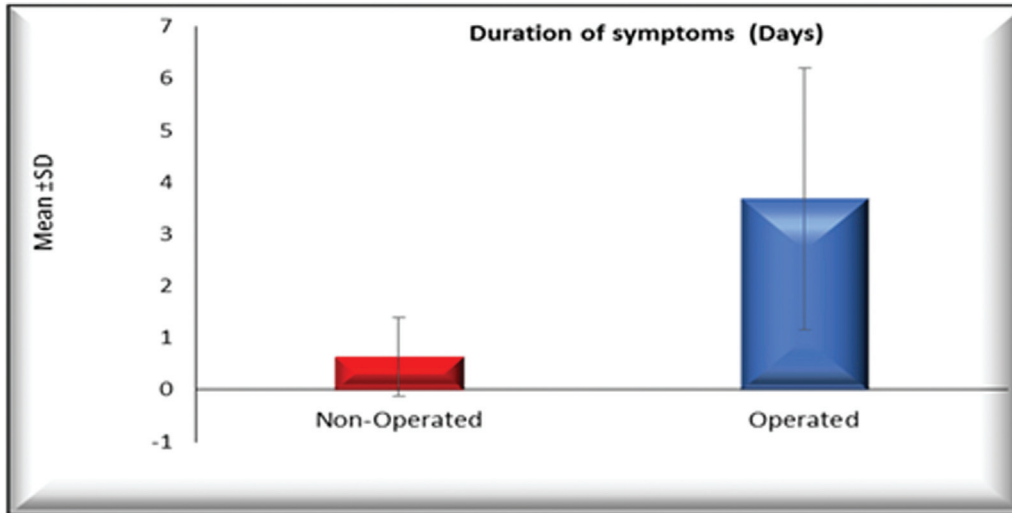
Histogram showing the percentage of patients subjected to each management plan.

Table 1 Management based on APAS score

APAS	Management		<i>t</i>	<i>P</i> value
	Nonoperated [50 (38.46%)]	Operated [80 (61.54%)]		
Range	1–7	8–15	-18.059	<0.001*
Mean±SD	4.000±1.726	11.138±2.192		

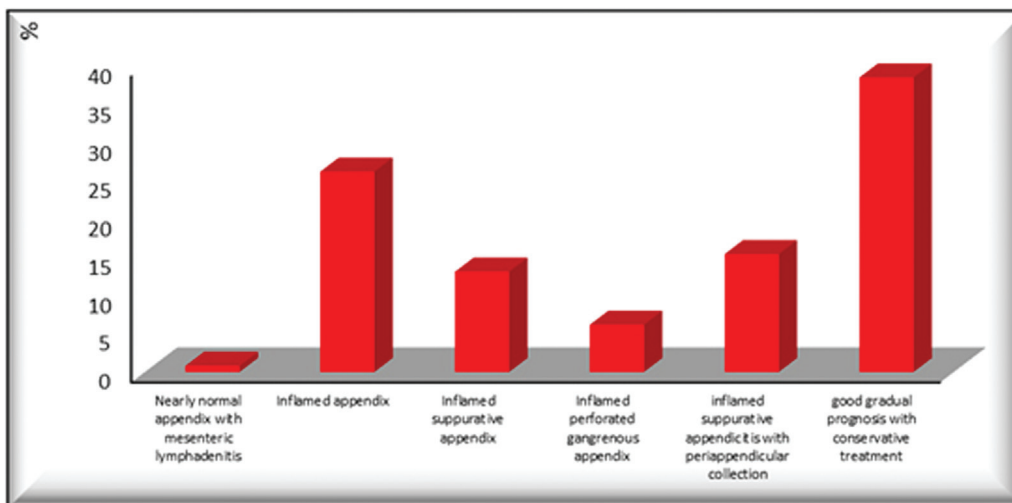
APAS, Acute Pediatric Appendicitis Score.

Figure 2



Histogram showing relation of duration of symptoms with the management.

Figure 3



The percentage of the patients showing different management findings.

The operated patients regarding the intraoperative findings showed inflamed appendix in 34 (26.15%), inflamed suppurative appendix in 17 (13.08%), inflamed perforated gangrenous appendix in eight (6.15%), inflamed suppurative appendicitis with periappendicular collection in 20 (15.38%), and only one operated patient (0.77%) showed nearly normal appendix with mesenteric lymphadenitis (Fig. 3).

Regarding the operated cases, there were six patients admitted with low scores, and rescoring after 24h showed higher scores, and they were operated, showing four cases with inflamed appendix and two cases with inflamed suppurative appendix.

Among the studied patients, after finishing the management of the cases based on the management

plan suggested by APAS score, 51 (39.23%) patients were cases of the observation group, whereas 79 (60.77%) patients were cases with proven appendicitis as a result of management findings.

Sensitivity and specificity of each item of APAS score

Regarding multivariate analysis of the data collected on more than one variable such as anorexia, nausea and vomiting, fever, and other APAS items in correlation to each other and the management findings, we found a significant correlation between the management findings and these four APAS items (anorexia, right lower quadrant tenderness, cough/percussion tenderness, and positive ultrasound findings), as they showed the highest significant values statistically and were very predictive regarding the management of the cases with the ultrasound examination showing the most accuracy value between all the items (95.38%) (Tables 2 and 3).

Results of histopathological examination

Regarding the histopathological examination of the removed appendix in the operated cases, only one case showed normal appendix (1.25%), 35 (43.75%) showed

acute appendicitis, 25 (31.25%) showed acute suppurative appendicitis, nine (11.25%) cases showed acute suppurative appendicitis with pyogenic fluid aspirated showing pus cells on examination suggesting associated periappendicular abscess, and 10 (12.5%) cases showed acute gangrenous appendicitis (Fig. 4).

Validation of APAS score

The results of comparison between the accuracy, sensitivity, and specificity of APAS, PAS, and Alvarado scores confirmed that some cases had appendicitis and yet they obtained low scores using both PAS and Alvarado scores, whereas they obtained reasonable scores using our newly developed APAS score. So, the accuracy of APAS score to differentiate between both proven appendicitis and observation groups was 99.2%, the accuracy of PAS score to differentiate between both groups was 95.3%, and the accuracy of Alvarado score was 91.3% (Table 4). The receiver operating characteristic curves were used to illustrate these results (Figs 5–8). These results support the validation of APAS scoring system as an ideal test for the diagnosis of acute appendicitis in the pediatric age group.

Table 2 Sensitivity and specificity of each item of APAS score in relation to the operated and nonoperated groups

	Management [n (%)]			χ^2	P value	Sensitivity	Specificity	PPV	NPV	Accuracy
	Nonoperated	Operated	Total							
Anorexia										
No	18 (36.00)	8 (10.00)	26 (20.00)	13.000	<0.001*	90.00	36.00	69.23	69.23	69.23
Yes	32 (64.00)	72 (90.00)	104 (80.00)							
Nausea and vomiting										
No	21 (42.00)	32 (40.00)	53 (40.77)	0.051	0.821	60.00	42.00	62.34	39.62	53.08
Yes	29 (58.00)	48 (60.00)	77 (59.23)							
RLQ tenderness										
No	16 (32.00)	8 (10.00)	24 (18.46)	9.893	0.002*	90.00	32.00	67.92	66.67	67.69
Yes	34 (68.00)	72 (90.00)	106 (81.54)							
Cough/percussion tenderness										
No	44 (88.00)	10 (12.50)	54 (41.54)	72.225	<0.001*	87.50	88.00	92.11	81.48	87.69
Yes	6 (12.00)	70 (87.50)	76 (58.46)							
Fever '>38°C'										
No	28 (56.00)	32 (40.00)	60 (46.15)	3.170	0.075	60.00	56.00	68.57	46.67	58.46
Yes	22 (44.00)	48 (60.00)	70 (53.85)							
Elevated TLC										
No	19 (38.00)	19 (23.75)	38 (29.23)	3.020	0.082	76.25	38.00	66.30	50.00	61.54
Yes	31 (62.00)	61 (76.25)	92 (70.77)							
Elevated CRP										
No	26 (52.00)	30 (37.50)	56 (43.08)	2.638	0.104	62.50	52.00	67.57	46.43	58.46
Yes	24 (48.00)	50 (62.50)	74 (56.92)							
Elevated neutrophilic count										
No	27 (54.00)	33 (41.25)	60 (46.15)	2.013	0.156	58.75	54.00	67.14	45.00	56.92
Yes	23 (46.00)	47 (58.75)	70 (53.85)							
Ultrasound findings										
No	47 (94.00)	3 (3.75)	50 (38.46)	105.88	<0.001*	96.25	94.00	96.25	94.00	95.38
Yes	3 (6.00)	77 (96.25)	80 (61.54)							

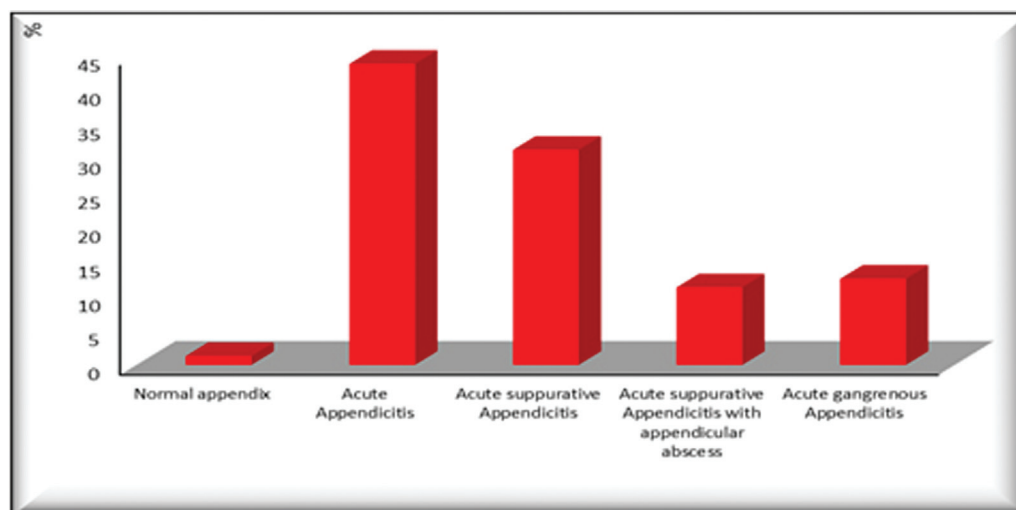
APAS, Acute Pediatric Appendicitis Score; CRP, C-reactive protein; NPV, negative predictive value; PPV, positive predictive value; RLQ, right lower quadrant; TLC, total leukocytic count.

Table 3 Odds ratio and 95% confidence interval of each item of APAS score in relation to the operated and nonoperated groups

	Management [n (%)]		Total [N (%)]	χ^2	P value	Odds ratio	95% CI	P value
	Nonoperated	Operated						
Anorexia								
No	18 (36.00)	8 (10.00)	26 (20.00)	13.000	<0.001*	5.062	1.995–12.845	0.001*
Yes	32 (64.00)	72 (90.00)	104 (80.00)					
Nausea and vomiting								
No	21 (42.00)	32 (40.00)	53 (40.77)	0.051	0.821	1.086	0.530–2.227	0.821
Yes	29 (58.00)	48 (60.00)	77 (59.23)					
RLQ tenderness								
No	16 (32.00)	8 (10.00)	24 (18.46)	9.893	0.002*	4.235	1.652–10.860	0.003*
Yes	34 (68.00)	72 (90.00)	106 (81.54)					
Cough/percussion tenderness								
No	44 (88.00)	10 (12.50)	54 (41.54)	72.225	<0.001*	51.329	17.430–151.158	<0.001*
Yes	6 (12.00)	70 (87.50)	76 (58.46)					
Fever '>38°C'								
No	28 (56.00)	32 (40.00)	60 (46.15)	3.170	0.075	1.909	0.933–3.904	0.076
Yes	22 (44.00)	48 (60.00)	70 (53.85)					
TLC								
No	19 (38.00)	19 (23.75)	38 (29.23)	3.020	0.082	1.968	0.912–4.245	0.085
Yes	31 (62.00)	61 (76.25)	92 (70.77)					
CRP								
No	26 (52.00)	30 (37.50)	56 (43.08)	2.638	0.104	1.805	0.882–3.694	0.106
Yes	24 (48.00)	50 (62.50)	74 (56.92)					
Neutrophils								
No	27 (54.00)	33 (41.25)	60 (46.15)	2.013	0.156	1.672	0.820–3.408	0.157
Yes	23 (46.00)	47 (58.75)	70 (53.85)					
Ultrasound findings								
No	47 (94.00)	3 (3.75)	50 (38.46)	105.886	<0.001*	402.104	77.929–2074.793	<0.001*
Yes	3 (6.00)	77 (96.25)	80 (61.54)					

APAS, Acute Pediatric Appendicitis Score; CI, confidence interval; CRP, C-reactive protein; RLQ, right lower quadrant; TLC, total leukocytic count.

Figure 4



Histogram showing findings of histopathological examination.

Discussion

Many clinical scoring systems have been developed to help in improvement of diagnosis of acute appendicitis [14]. These scoring systems have been advocated to

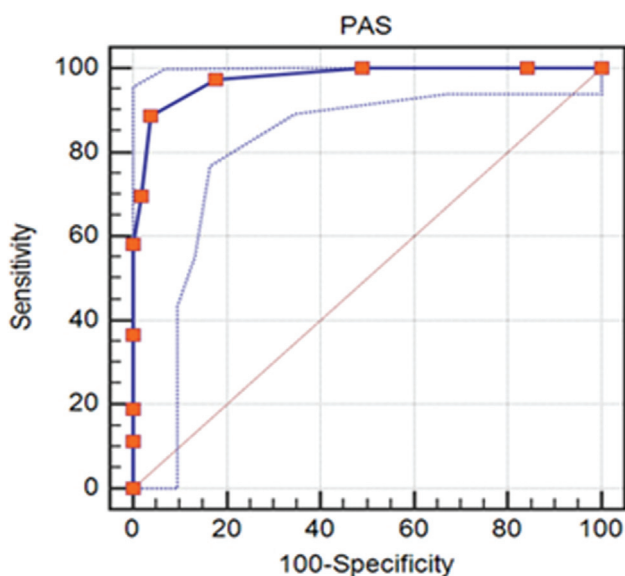
minimize the number of negative appendectomies. In daily clinical practice, the use of a practical scoring system has been found to be associated with reduced rate of negative appendectomies [15].

Table 4 Accuracy of APAS, PAS, and Alvarado scores regarding proven appendicitis and observation groups

ROC curve between proven appendicitis and observation groups (%)						
	Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
APAS	>7	100.0	98.04	98.7	100.0	99.2
PAS	>4	88.61	96.08	97.2	84.5	95.3
Alvarado score	>4	86.08	90.20	93.2	80.7	91.3

taAPAS, Acute Pediatric Appendicitis Score; NPV, negative predictive value; PAS, Pediatric Appendicitis Score; PPV, positive predictive value; ROC, receiver operating characteristic curve.

Figure 5



Receiver operating characteristic curve of Pediatric Appendicitis Score between proven appendicitis and observation groups.

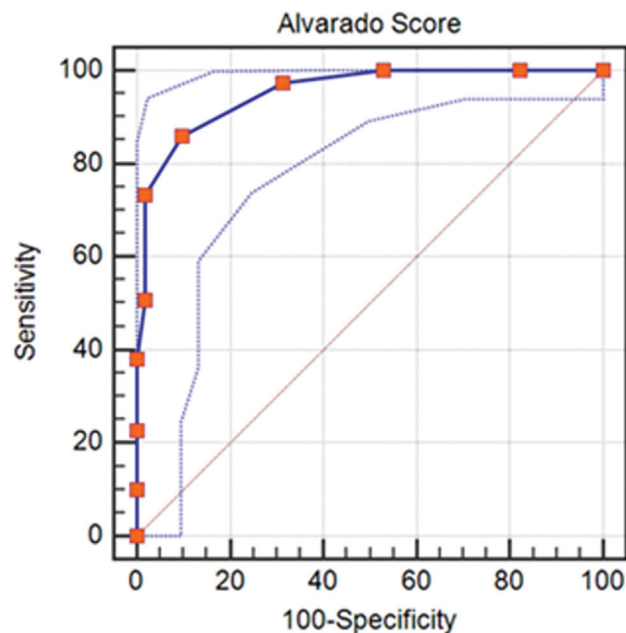
In our study, we evaluated a new clinical scoring system for diagnosis of acute pediatric appendicitis which differs from the other previous scores and suggests a management plan for dealing with different case scenarios.

Moreover, according to our knowledge in the literature, there were not enough studies comparing different clinical scores regarding the diagnosis of acute appendicitis in the pediatric age group.

Regarding laboratory and radiological investigations, in APAS score, leukocytosis was found in 70.77%, neutrophilia in 53.85%, elevated CRP levels in 56.92%, and positive ultrasound findings were found in 61.54%, and in the statistical analysis of the results, leukocytosis had *P* value of 0.082, neutrophilia had *P* value of 0.156, elevated CRP levels had *P* value of 0.104, and positive ultrasound findings had *P* value less than 0.001, being the most significant item between the investigations.

This result was matched with Samuel's study, using PAS score, where leukocytosis was found in 73.24% and neutrophilia in 56.14%, and in the statistical

Figure 6



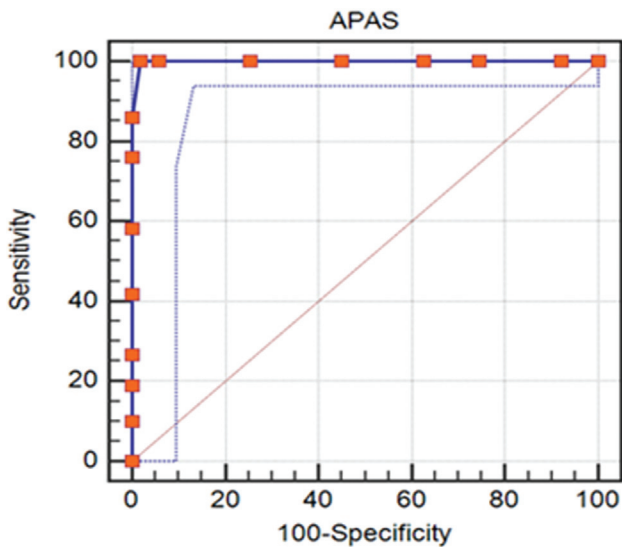
Receiver operating characteristic curve of Alvarado between proven appendicitis and observation groups.

analysis of the results, leukocytosis had *P* value of less than 0.001 and neutrophilia had *P* value of less than 0.001. Samuel did not incorporate neither CRP levels nor ultrasound examination in his PAS score.

Khan and colleagues had conducted a study to determine the accuracy of ultrasound in diagnosis of acute appendicitis in children keeping histopathology as the gold standard [16]. Of the 223 pediatric appendectomies performed in this study, a total of 192 (86%) were diagnosed by ultrasound. The histopathology of eight (3.6%) was normal. The negative appendectomy rate was 3.6%. Ultrasound was the sole imaging modality in all patients. So, the conclusion of their study is that ultrasound is useful and accurate method, which results in a significant decrease in negative appendectomies. This has important implications in the reduction of childhood radiation exposure.

Douglas *et al.* [17] also have shown that ultrasonography has an accuracy of 93% equivalent

Figure 7



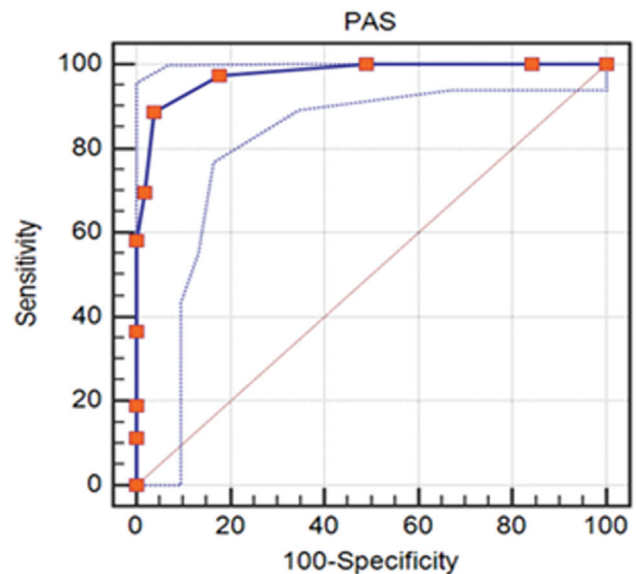
Receiver operating characteristic curve of Acute Pediatric Appendicitis Score between proven appendicitis and observation groups.

to contrast computed tomography but failed to show better outcome than clinical diagnosis.

Aydin [18] proved through his study that ultrasound or abdominal radiography in children with possible appendicitis should be integrated with PAS to determine the next steps in management. In the case of discordance between the clinical findings and radiology, prolonged observation or further imaging is recommended.

To our knowledge, no former diagnostic scores for appendicitis included the ultrasound examination among the items of the score, which was shown to be of a significant value in our study. In our study, according to APAS score, conservative out-patient follow-up was done for 18 (13.85%) cases, in-active hospital observation with conservative treatment was done for 38 (29.23%), laparoscopy with appendectomy was done for 64 (49.23%), open appendectomy was done for eight (6.15%) as either the patients' parents refused laparoscopy or laparoscopy was not available, and laparoscopy converted to open appendectomy was done for two (1.54%) cases owing to intraoperative findings as one case showed very friable tissues with severe adhesions and the other case showed friable necrotic base in flush with the caecum, which indicated formal repair. So, 51 (39.23%) patients were cases of the observation group, whereas 79 (60.77%) patients were cases with proven appendicitis. The rate of negative appendectomy was only 1.25%, the accuracy of APAS score was 99.2%, specificity was 98.04%, positive predictive value was 98.7%, sensitivity was 100%, and negative predictive value was 100%.

Figure 8



Receiver operating characteristic curve of Acute Pediatric Appendicitis Score, Pediatric Appendicitis Score, and Alvarado scores between proven appendicitis and observation groups.

Maala Bhatt [19] and coworkers had conducted a study to validate the PAS suggested by Samuel in 2002; the results of the enrolled children who met inclusion criteria ($n=246$) showed that 83 (34%) had pathology-proven appendicitis. Using the single cut-point suggested in the derivation study (PAS of 5) resulted in an unacceptably high number of false positives (37.6%). The score's performance improved when two cut-points were used. When children with a PAS of 4 or less were discharged home without further investigations, the sensitivity was 97.6% with negative predictive value of 97.7%. When a PAS of 8 or more determined the need for appendectomy, the score's specificity was 95.1% with a positive predictive value of 85.2%. Using this strategy, the negative appendectomy rate would have been 8.8%, and the missed appendicitis rate would have been 2.4%.

The conclusion of Bhatt's study was that the PAS is a useful tool in the evaluation of children with possible appendicitis. Scores of 4 or less help rule out appendicitis, whereas scores of 8 or more help to predict appendicitis. Patients with a PAS of 5–7 may need further radiologic evaluation, which was implicated in our study as ultrasound examination.

An ideal test should be 100% sensitive and specific, with a predictive value of 100%, with no false-positive or negative results, so that the total joint probability is 100%, with a diagnostic index/weight of the test being 1.0. However, the nine variables in APAS do overlap with other diseases; hence, APAS does not give 100%

certainty. There is no symptom, sign, or laboratory test that is 100% reliable in the diagnosis of appendicitis.

Conclusion

APAS score was a significant representative as one of the important diagnostic tools for diagnosis of acute appendicitis in the pediatric age group. The study also provides a solid comparison between APAS score, PAS score, and Alvarado score. APAS score is the first score in well-known literature to introduce ultrasound examination as a routine investigation among the suspected children with acute appendicitis, with an accuracy reaching up to 95.38%.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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