Research Article

Effectiveness of the PAS for Diagnosing the Severity of Acute Appendicitis in Children: A Cohort Study

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Background: The Pediatric Appendicitis Score (PAS) is a highly utilized diagnostic tool for acute appendicitis in pediatric patients. The severity of appendicitis subclassified as simple appendicitis (congested or suppurated) vs complicated appendicitis (gangrenous or perforated). A duration of symptoms >1 day, CRP > 4 mg/dl and SBP ≥ 8 were predictors of complicated appendicitis[1]. Therefore, we propose as a possibility in this study that PAS ≥ 8 could differentiate complicated appendicitis from simple appendicitis. We must emphasize to the reader that we do not intend to question that PAS was designed for the diagnosis of appendicitis in children, in this study we intended to evaluate to differentiate the severity of pediatric appendicitis.

Methods: The cohort-type study, the population evaluated, 86 children aged 4 to 14 years with preoperative diagnosis of appendicitis, grouped into 2 groups: complicated appendicitis (43) and simple appendicitis (43) exposed to PAS≥8 or PAS<8.

Results: The effectiveness of PAS≥8 in diagnosing the severity of appendicitis showed an AUC of 59.3% and increases the probability of severity by 2.246 times (CI:95% 0.917-5.50 p=0.077) in the predictive model. There were statistically significant differences in cough sensitivity/jump/percussion, pain migration, anorexia, leukocytosis and neutrophilia, between PAS≥8 or PAS<8.

Conclusion: PAS≥8 alone is not sufficient to diagnose the severity of acute appendicitis with 59.3% predictive diagnostic accuracy and increases 2.246 times the probability of presenting with the severity of appendicitis in the logistic predictive model.

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Introduction

Acute appendicitis is a common cause of acute abdomen in emergencies. Its progression can become complicated if not diagnosed early or if its severity is not anticipated. Globally, the incidence of acute appendicitis is 100 new cases per 100 000 people per year[2]. In the U.S. 70 000 pediatric appendectomies are performed annually additionally, in the age group of 5 to 11 years, the incidence reaches 36%, with an average of 1.38 cases per 1,000 children[3][4].

For the diagnosis of appendicitis, clinical findings and auxiliary examinations are required. In children, it is not easy to determine the severity of the condition. This could be improved by using techniques such as the Pediatric Appendicitis Score (PAS) in emergency care.

Recently, the World Society of Emergency Surgery in their Jerusalem Guidelines reached a consensus that the PAS is a useful and sensitive tool to exclude acute appendicitis and recommended not making the diagnosis based solely on clinical in those with suspected pediatric appendicitis[5].

The PAS developed by Madan Samuel is still relevant and applicable today. It consists of 8 parameters, with the main ones being (**T**enderness in the right lower quadrant and cough/hop/percussion **T**enderness) and the other secondary parameters (**M**igration of pain, **A**norexia, **N**ausea/vomiting, **E**levated temperature, **L**eukocytosis, and **N**eutrophilia) **TT/MANELN**, being useful for predicting the risk of pediatric appendicitis[6].

The effectiveness of the PAS for diagnosing the severity of appendicitis is defined as a mechanism to achieve predictive diagnostic accuracy of the PAS≥8 for severity and predictive possibility through the binomial logistic regression model, for the number of correct cases over a period of 1 year and 9 months.

In a study of 72 patients in a hospital in Japan, it suggests that the PAS would have a correlation with the severity of appendicitis because they found with greater complications and prolonged hospital stay than those with PAS<8[7].

The study aims to evaluate the effectiveness of the PAS≥8 in diagnosing the severity of acute appendicitis in children and as secondary objectives the PAS characteristics with respect to other variables.

Methods

Study type

The type of study of the present research, according to Altman Douglas[8], is: Observational, Retrospective, Longitudinal. The design is of the cohort type, to evaluate the effectiveness of the PAS in diagnosing the severity of appendicitis.

Participants

The population consists of all patients aged 4 to 14 who are admitted with a diagnosis of acute appendicitis to the emergency department, undergo open appendectomy with intraoperative findings of simple or complicated appendicitis, and are hospitalized in the Pediatric Service from the Carlos Monge Medrano Hospital during 2020 to 2022, which meet selection criteria.

The 86 patients who met the criteria detailed in the inclusion flow, for more details see (results section). He grouped into two groups: First group, of 43 children with Simple Appendicitis (the surgical findings of: Congestive Appendicitis and Suppurative Appendicitis were considered). A second group, consisting of 43 children with Complicated Appendicitis (the surgical findings of Necrotizing Appendicitis and Perforated Appendicitis were considered). Both groups were exposed to PAS≥8 or PAS<8.

Variables

The severity of appendicitis in the present research is referred to as the differentiation between complicated appendicitis and simple appendicitis based on the intraoperative findings discovered by the surgeon during the open appendectomy.

Simple Appendicitis

It is an early phase appendicitis that includes congestive (catarrhal) appendicitis and suppurative (phlegmonous) appendicitis in the intraoperative findings. This type of appendicitis has not yet reached the stage of complications.

Complicated Appendicitis

It is a perforated appendicitis as a common component in addition to gangrene, pus, purulent peritonitis, presence of a fecalith or abscess[5]. Complicated appendicitis includes: necrotizing (gangrenous) appendicitis, due to the micro perforations observed, and perforated appendicitis found in intraoperative findings, in some cases with: localized peritonitis, generalized peritonitis, and abscesses.

PAS

PAS parameters

Main parameters (**T**enderness in right iliac fossa when coughing/jumping/percussing, manifests during the patient's physical examination; **T**enderness in the right lower quadrant is a symptom that the patient exhibits at the level of the right iliac fossa, most representative in the late stages of appendicitis) and secondary parameters (**M**igration of pain is when abdominal pain changes position from being periumbilical or diffuse to localizing in the right lower quadrant, **A**norexia, it is the decrease in appetite, an early manifestation may or may not be present, **N**ausea/vomiting, it is when the patient expresses a nauseous feeling alone or it may be followed by vomiting, **E**levation of temperature, for this research we consider T≥37.5 Grades Celsius(°C), it is a thermal rise sensation quantified at the axillary level, **L**eukocytosis is the value above >10,000/μL of leukocytes, a range that exceeds normal, **N**eutrophilia is considered an absolute neutrophil count value >7.5 000/μ.).

PAS≥8

The PAS≥8 and PAS<8 were evaluated upon admission to the emergency room and follow-up was conducted because all were exposed to various PAS scores. Additionally, regarding its severity, the severity variable in emergency simple appendicitis vs complicated appendicitis was also evaluated, and after the surgical finding, simple appendicitis vs complicated appendicitis was also verified.

Procedures

The following database was used: hospitalization registry and statistical database with ICD 10 acute appendicitis K35.9, then a single database was created to help register the surgical report located in

the surgical center, records and pediatric hospitalization registry notebook. The final database did not include the names of the patients or their national identification numbers.

The period of recruitment and data collection was during November 11, 2022 to December 27, 2022, the exposure and follow-up of the variables, including PAS≥8, was analyzed during 2020 to 2022.

Data analysis

The statistical software Excel was used to analyze the database without selection criteria and another with selection criteria, and then it was processed in the statistical software Jamovi 2.3.28[9].

Descriptive statistics were used for: frequencies, means, SD, medians, minimums, and maximums for the analysis of the variables. Additionally, binomial logistic regression was used for predictive diagnostic accuracy of severity (through diagnostic accuracy of the ROC curve (AUC)) and predictive possibility (OR) in the predictive model for the PAS with a 95% CI.

Assisted by ROC curves for sensitivity, specificity, area under the ROC curve, PPV, NPV, and OR measures. The highest Youden index was used to determine the cutoff value of the score on the PAS using the Friesen Plugin, PPDA (ROC Test) for Jamovi.

We used Jamovi for Shapiro Wilk, Whitney U-test and frequencies (contingency table) was used for quantitative variables for independent samples for the present study, statistical significance is $p<0.05$.

Ethics

This study was reviewed and approved by the Institutional Ethics Review Board of the Hospital Carlos Monge Medrano (Exp. N° 294-2022-j-UADI-HCMM-RED-S-SR/J), Juliaca, Puno, Peru.

It was a secondary data study and there was no contact with the patient, therefore patient consent was not requested. The patient's anonymity and the confidentiality of data such as identity or any other information that could compromise the patient were maintained.

Results

Between January 2020 and September 2022, 86 children were studied at HCMM using a cohort design. Eligibility criteria were applied, with stages of evaluation, inclusion, and exclusion, as well as losses during follow-up, until the process was completed as detailed in“ Figure 1”.

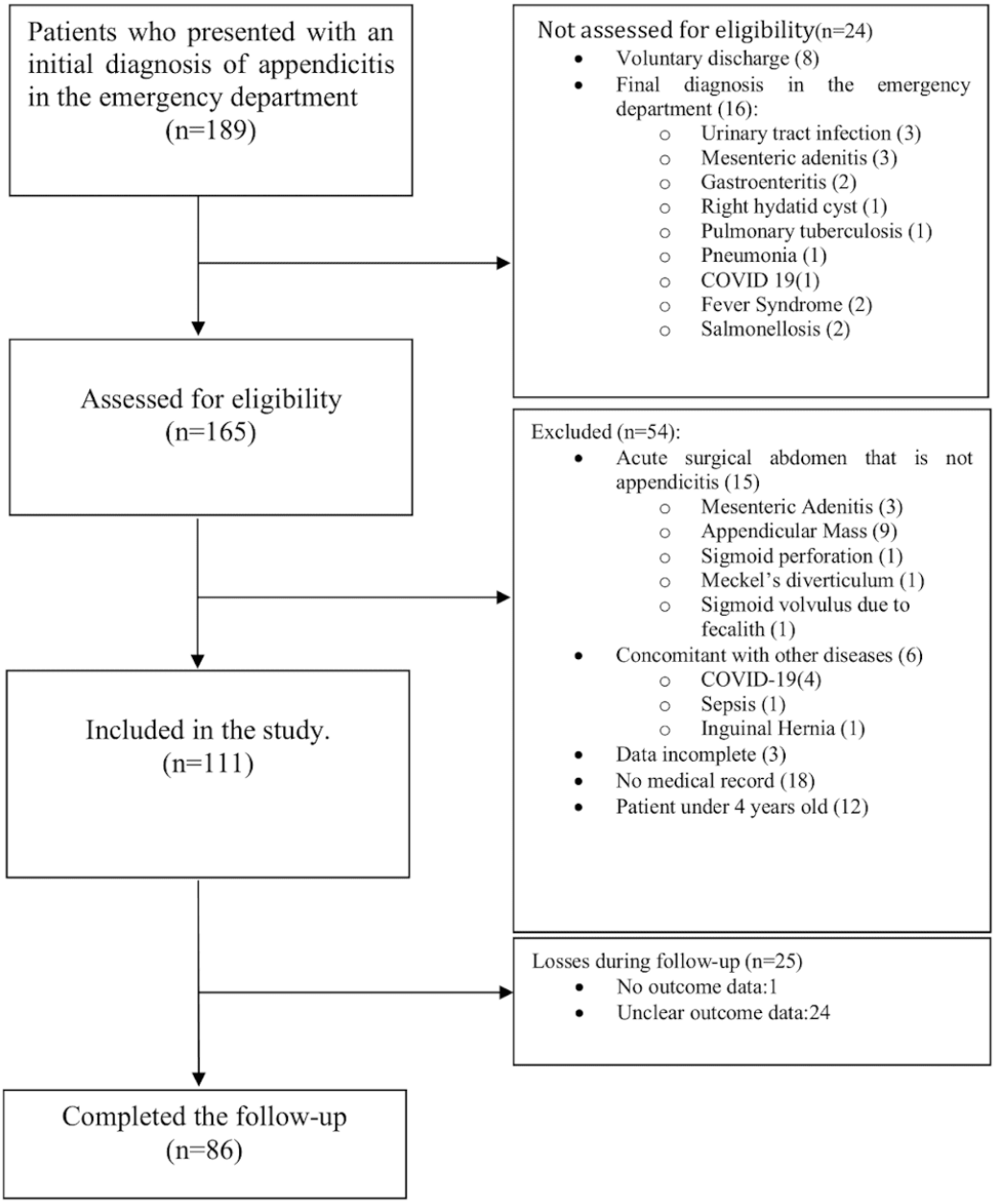

Figure 1. Flow diagram (study selection).

The losses during the follow-up were due to: 1 did not have a report of findings and the remaining 24 had two to three findings of appendicitis (Example: Necrotizing appendicitis + perforated appendicitis or suppurative appendicitis + necrotizing appendicitis + perforated appendicitis/appendiceal abscess).

Characteristics of the participants

The mean age of patients was 9.6 ±3 years, Male 53.5% and similar distribution of rural and urban(p=0.982) in patients with PAS ≥8 and PAS <8. There were statistically significant differences in the cough/hop/percussion Tenderness (100% vs 78.1% p<0.001), migration of pain (77.8% vs 31.3% p<0.001), anorexia (42.6% vs 12.5% p=0.004), leukocytosis (96.3% vs 62.5% p<0.001) and neutrophilia (100% vs 65.6% p<0.001) between PAS≥8 vs PAS<8. Tenderness right lower Quadrant (RLQ) found in almost all patients (98.8% p=0.191) in the mnemotechnic **TT/MANELN** and Appendicitis Complicated were more common in PAS ≥8 compared a PAS <8(57.4% vs 37.5% p=0.074) "Table 1-2".

Parameters		**Score**
Main Parameters	**T**enderness in right lower quadrant	2
	Cough/Hop/Percussion **T**enderness	2
Secondary Parameters	**M**igration of pain	1
	Anorexia	1
	Nausea/vomiting	1
	Elevated temperature	1
	Leukocytosis	1
	Neutrophilia	1

Table 1. PAS (TT/MANELN Mnemotechnic)

Based in: Samuel M. Pediatric appendicitis score[6]

	PAS		Total %(n)	p
	PAS≥8 %(n)	PAS <8 % (n)		
Age(years)*			9.6±3	
Sex				
Male	60.9(28)	39.1(18)	53.5(46)	0.693
Female	65.0(26)	35.0(32)	46.5(40)	
Origin				
Rural	68.5(37)	68.8(22)	31.4(27)	0.982
Urban	31.5(17)	31.3(10)	68.6(59)	
Characteristics of Parameters PAS				
Tenderness in RLQ				
Yes	100(54)	96.9(31)	98.8(85)	0.191
No	0.0(0)	3.1(1)	1.2(1)	
Cough/hop/percussion Tenderness				
Yes	100(54)	78.1(25)	91.9(79)	<0.001
No	0.0(0)	21.9(32)	1.2(7)	
Migration of pain				
Yes	77.8(42)	31.3(10)	60.5(52)	<0.001
No	22.2(12)	68.8(22)	39.5(34)	
Anorexia				
Yes	42.6(23)	12.5(4)	31.4(27)	0.004
No	57.4(31)	87.5(28)	68.6(59)	
Nauseas/vomiting				
Yes	96.3(52)	87.5(28)	93.0(80)	0.122
No	3.7(2)	12.5(4)	7.0(6)	

	PAS		Total %(n)	p
	PAS≥8 %(n)	PAS <8 % (n)		
Elevation temperature				
Yes	46.3(25)	28.1(9)	39.5(34)	0.096
No	53.4(29)	71.9(23)	60.5(52)	
Leukocytosis				
Yes	96.3(52)	62.5(20)	83.7(72)	<0.001
No	3.7(2)	37.5(12)	16.3(14)	
Neutrophilia				
Yes	100(54)	65.6(21)	87.2(75)	<0.001
No	0.0(0)	34.4(11)	12.8(11)	
Severity of Appendicitis				
Complicated	57.4(31)	37.5(12)	50.0(43)	0.074
Simple	42.6(23)	62.5(20)	50.0(43	

Table 2. Characteristics of the patients in the study(N=86)

Note: *N: Total number of participants analyzed; *: Mean±Standar deviation; % (n): Percentage (total found); RLQ: Right lower quadrant.*

Analysis for the main objective

The effectiveness of the PAS≥8 showed a diagnostic accuracy of 59.3% to predict the severity of appendicitis in the binomial logistic regression model, a cutoff value of 0.5. For the PAS≥8 as a predictor for diagnosing the severity of acute appendicitis, an ROC curve was designed in which the sensitivity was found to be 72.1%, the specificity was 46.5%, and the area under the curve was 0.593 for the model "Figure 2".

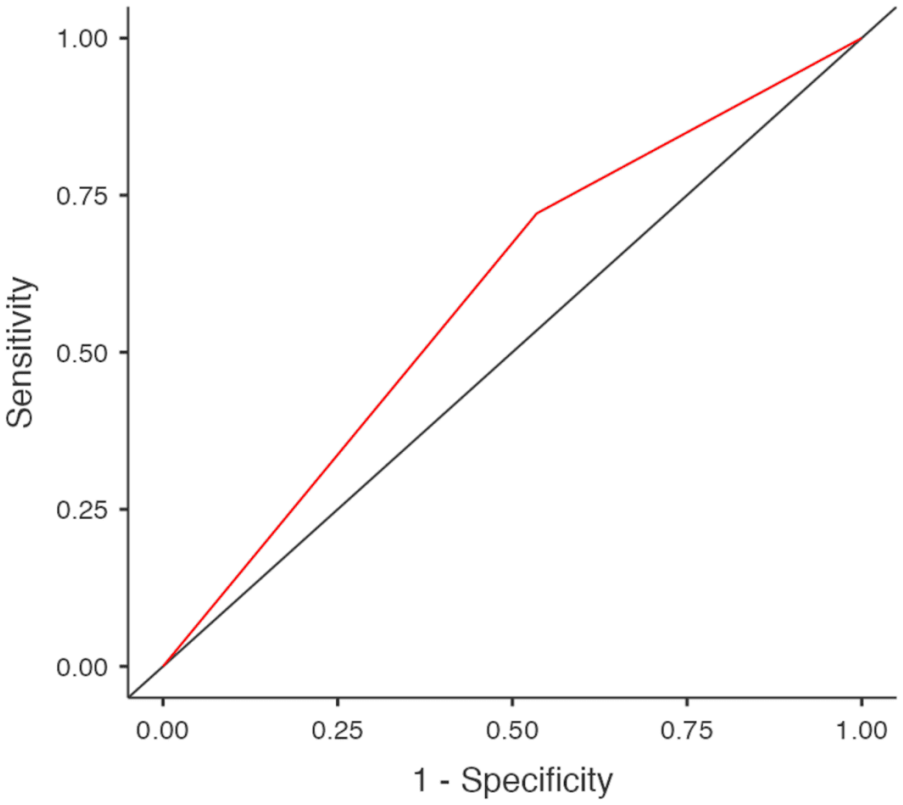

Figure 2. ROC. Curve receiver operating characteristic curves with the corresponding area under the curve (AUC) for PAS scoring system in predicting severity acute appendicitis.

Obtaining a PAS≥8 score increases the likelihood of presenting with severe appendicitis by 2.246 times compared to those with a PAS<8 score (CI: 95% 0.917 to 5.50 p=0.077), a statistically non-significant result, to see "Table 3".

						95% Confidence Interval	
Predictor	**Estimate**	**SE**	**Z**	**p**	**OR**	**Lower**	**Upper**
Intercept	-0.511	0.365	-1.40	0.162	0.600	0.293	1.23
PAS≥8:							
Si – No	0.809	0.457	1.77	0.077	2.246	0.917	5.50

Table 3. Model Coefficients -Severity of Acute Appendicitis (N=86)

Note. Estimates represent the log odds of "Severity= Complicated Appendicitis " vs. "Severity= Simple Appendicitis "; N: Total number of participants analyzed; OR: ***Odds ratio***

The logistic regression model is employed in clinical studies with the following formula[10]:

$$\operatorname{Logit}(p_x) = \operatorname{logit}(p_x) = \log\left(\frac{p_x}{1-p_x}\right) = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k$$

The formula, to assess the effectiveness of the probability of predicting the effectiveness of the PAS≥8 for diagnosing the severity of appendicitis is:

$$\text{Probability of predicting severity} = -0.511 + 0.809 \times \text{PAS} \geq 8 \; \mathbf{R^2_{McF}} = 0.0269$$

Additional approaches to the treatment of appendicitis include:

Garcia-Amado C. et al.[11]:

$$\begin{gathered}\text{Probability predicting} = \mathrm{t} = -(-9.99 + 0.030\mathrm{xage(years)} \\ + 0.016\mathrm{xduration\ of\ symptoms\ (h)} + 0.084\mathrm{xpercentage\ of\ neutrophils\ (\%)} \\ + 0,008\mathrm{xCRP(mg/L)})\end{gathered}$$

Feng W. et al.[12]:

$$\begin{gathered}\text{Probability predicting} = \mathrm{u} = -(2.997 - 1.559\mathrm{xage(years)} \\ + 0.090\mathrm{x\ white\ blood\ cell\ count\ (WBC)}(10^9/\mathrm{L}) \\ + 0.010\mathrm{xDuration\ of\ symptoms(hours)})\end{gathered}$$

Eddama M. et al.[13]:

$$\begin{gathered}\text{Probability predicting} = \mathrm{v} = -(-8.814 + 0.364\mathrm{xlog\ 2\ CRP} + 1.768\mathrm{xlog\ 2\ WWC} \\ + 0.025\mathrm{xage} + 0.647\mathrm{x(0\ if\ Female/\ 1\ if\ Male)}\end{gathered}$$

Chambers A.C. et al[14]

$$\text{Probability predicting} = \text{w} = -(-2.77 + 0.005\text{xCRP} + 0.061\text{xBilirubin} + 0.211\text{xWCC})$$

Analysis for secondary objectives

In our study, no cases of PAS<5 and we were observed Positive and negative predictive values for each score "Table 4". In the evaluated patients, there were statistically significant: leukocytosis (16.98x10^3/µL ±4.81 vs 13.29x10^3/µL ±5.69 p<0.001), neutrophilia (14.70 x10^3/µL ±4.68 vs 11.06 x10^3/µL ±4.68 p<0.001), PAS score (8.59±0.59 vs 6.38±0.71 p<0.001), between PAS≥8 vs PAS<8 "Table 5".

PAS	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Youden's índex	AUC	Metric Score
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	100%	0%	50%	0%	0.00	0.58	1.00
6	90.7%	0%	47.56%	0%	-0.09	0.58	0.90
7	86.05%	23.26%	52.86%	62.5%	0.09	0.58	1.09
8	72.09%	46.51%	57.41%	62.5%	0.19	0.58	1.18
9	37.21%	69.77%	55.17%	52.63%	0.07	0.58	1.07
10	6.98%	100%	100%	51.81%	0.07	0.58	1.07

Table 4. Positive and negative predictive values for each score

Note: PAS: Pediatric Appendicitis Score, PPV: Positive Predictive Value, NPV: Negative Predictive Value; AUC: Receiver Operating Characteristic.

	PAS≥8	N	Mean	SD	p Mann Wiltney	p Shapiro-Wilk
Hospital Stay	Si	54	6.17	2.081	0.116	< 0.001
	No	32	5.81	2.912		< 0.001
Leukocytosis x10^3/µL	Si	54	16.98	4.962	< 0.001	0.066
	No	32	13.29	5.693		0.003
Neutrophilia x10^3/µL	Si	54	14.70	4.678	< 0.001	0.038
	No	32	11.06	5.562		0.011
Score PAS	Si	54	8.59	0.599	< 0.001	< 0.001
	No	32	6.38	0.707		< 0.001
Temperature elevation	Si	54	37.22	0.746	0.697	< 0.001
	No	32	37.19	0.898		0.015
Segmented neutropils	Si	54	84.80	6.363	0.008	< 0.001
	No	32	79.22	10.646		0.002
Band neutropils	Si	54	1.38	2.244	0.406	<0 001
	No	32	1.82	2.690		< 0.001

Table 5. Description of leukocytosis, neutrophilia, temperature elevation, segmented neutrophils, band neutrophils and score PAS and PAS≥8

SD: Standar deviation; Number of participants analyzed=86; N: Total.

We obtained higher percentages in the PAS≥8: duration of illness (24 to 48h 33.7% p=0.025), perforated appendicitis (31.4%p<0.001), Rockey Davis incision (33.7% p=0.004) and appendicitis with generalized peritonitis (19.8% p<0.001) all of the above when compared to the PAS<8 "Table 6".

Variables	PAS≥8	% (Total)	p
Duration of illness			0.025
<24h	Yes	5.8% (5)	
	No	5.8% (5)	
24 a 48h	Yes	33.7% (29)	
	No	19.8% (17)	
>48h	Yes	23.3% (20)	
	No	11.6% (10)	
Operative Finding of Appendicitis			<0.001
Congestive	Yes	3.5% (3)	
	No	3.5% (3)	
Suppurative	Yes	9.3% (8)	
	No	9.3%(8)	
Necrotizing	Yes	18.6% (16)	
	No	14.0% (12)	
Perforated	Yes	31.4% (27)	
	No	10.5% (9)	
Incision through the skin			0.004
Rockhy Davis	Yes	33.7% (29)	
	No	25.6% (22)	
IMIU	Yes	22.1% (18)	
	No	8.1% (7)	
IPMIUD	Yes	5.8% (5)	
	No	3.5% (3)	
IMSU	Yes	1.2% (1)	
	No	0.0% (0)	

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Variables	PAS≥8	% (Total)	p
Appendicitis with peritonitis			<0.001
Generalizaded	Yes	19.8% (17)	
	No	9.3% (8)	
Localized	Yes	11.6% (10)	
	No	3.5% (3)	
Without	Yes	31.4% (27)	
	No	24.4% (21)	

Table 6. Characteristics of the duration of duration of illness and operative findings compared with a PAS≥8 (N=86)

PAS=Pediatric Appendicitis Score; %=Percentage; IMIU=Median Infraumbilical Incision; IMPIUD=Right Infraumbilical Paramedian Incision; IMSU=Supraumbilical Median Incision; N: Total number of participants analyzed

Discussion

In the latest update of the Jerusalem Guidelines by the World Society for Emergency Surgery, the PAS is considered one of the most used clinical scoring systems in children[5]. Current scoring systems (PAS, Lintula, Alvarado, MPAS and Tzanakis) help us in the diagnosis of appendicitis and reduce negative appendectomy rates in children at present[15].

Our study was to evaluate the effectiveness for diagnosing the severity of acute appendicitis (complicated appendicitis and simple appendicitis) using the PAS≥8.The results of the cut-off value of the PAS score equal to 8 in the PAS to diagnose the severity of appendicitis agree with the study of Fugii et al[7].

PAS, in conjunction with symptom duration, may assist in predicting patients with a higher likelihood of developing a postoperative intraabdominal abscess[16].PAS≥8 only was not effective, for diagnosing complicated appendicitis.

In our study, no cases of PAS<5 were observed; we agree with another study that did not observe PAS<4[17].

A study in a hospital, analyzed in 161 children three predictors: the PAS≥8, CRP>4mg/dl and symptom duration>1day for complicated appendicitis, they designed a ROC curve for the three predictors obtaining: an area under the curve 0.91, sensitivity of 51%, specificity of 99%, PPV of 83% and NPV of 66%, different from our study that only analyzed one predictor which was the PAS≥8[1].Higher CRP levels and PAS were associated with increased histologic inflammation of the appendix[18].

Currently, scoring systems based on NLR(NLR: neutrophil-to-lymphocyte ratio), PLR(platelet-to-lymphocyte ratio), and LMR(lymphocyte-to-monocyte ratio) reference values vary according to age and gender[19]. New regression analyses could include the PAS to distinguish complicated appendicitis and simple appendicitis in children. As a scoring system called POPs, which combines inflammatory predictors, ultrasound findings[20]. The clinical prediction rules, which combine clinical and objective variables, had the highest discriminant capacity[21].

In addition, another study of 260 children evaluated the performance of the PAS and found an area under the curve of 0.992, sensitivity of 98.74%, specificity of 95.65%, PPV of 95.7%, and NPV of 96.65% for a PAS≥6[22]. In 104 children studied, sensitivity of 96.8%, specificity of 80%, PPV of 98.91%, NPV of 57.14% and area under the curve of 0.84[23]. Both studies contradict ours because they are for the diagnosis of appendicitis but not for the severity of acute appendicitis.

The most accurate predictors of appendicitis (both simple and perforated) were rebound tenderness, hop/cough tenderness, laboratory results, and ultrasound findings, as demonstrated in a study of multi-center cohorts[24]. Pediatric predictors could include neutrophilia, leukocytosis, pain upon cough/hop/percussion Tenderness, migration of pain, anorexia, as they are significant in the present investigation or the PAS≥8 to be evaluated alongside other predictive models. In another study PAS score ≥ 7 is associated with prolonged hospital stay[25].

A study of 1141 children showed that delaying appendectomy within 24h after the onset of appendicitis is safe and feasible[26]. The duration of illness between 24 and 48 hours is associated with a PAS≥8.

The present research, during periods when open surgery was the only option at the hospital, the limitation was that being a retrospective study, there was no control of variables such as surgical findings.

The results obtained serve to think in regression models could help developing countries that include clinical variables and variables of basic laboratory packages due to the deficit of human resources and help with the diagnosis of the severity of appendicitis in children.

Conclusion

The PAS≥8 alone is not sufficient to diagnose the severity of acute appendicitis, with a 59.3% predictive diagnostic accuracy and increasing the probability of presenting with the severity of appendicitis by 2.246 times. It could be combined PAS with other variables to create models that help differentiate complicated appendicitis and simple appendicitis in children.

Abbreviations

- PAS: Pediatric appendicitis score
- IY: Youden Index
- USA: United States
- CRP: C Reactive Protein
- ROC: Receiver Operating Characteristic
- AUC: Area under the curve
- PPV: Positive predictive value
- NPV: Negative predictive value
- PMN: Polymorphonuclear
- CI: confidence interval
- SD: standard deviation

Statements and Declarations

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Conflicts of Interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

To request access, for further research purposes, please to write to the corresponding author.

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