Pediatric Appendicitis Score

By Madan Samuel
London, England

Background/Purpose: Morbidity in children treated with appendicitis results either from late diagnosis or negative appendectomy. A Prospective analysis of efficacy of Pediatric Appendicitis Score for early diagnosis of appendicitis in children was conducted.

Methods: In the last 5 years, 1,170 children aged 4 to 15 years with abdominal pain suggestive of acute appendicitis were evaluated prospectively. Group 1 (734) were patients with appendicitis and group 2 (436) nonappendicitis. Multiple linear logistic regression analysis of all clinical and investigative parameters was performed for a model comprising 8 variables to form a diagnostic score.

Results: Logistic regression analysis yielded a model comprising 8 variables, all statistically significant, $P < .001$. These variables in order of their diagnostic index were (1) cough/percussion/hopping tenderness in the right lower quadrant of the abdomen (0.96), (2) anorexia (0.88), (3) pyrexia (0.87), (4) nausea/emesis (0.86), (5) tenderness over the right iliac fossa (0.84), (6) leukocytosis (0.81), (7) polymorphonuclear neutrophilia (0.80) and (8) migration of pain (0.80). Each of these variables was assigned a score of 1, except for physical signs (1 and 5), which were scored 2 to obtain a total of 10. The Pediatric Appendicitis Score had a sensitivity of 1, specificity of 0.92, positive predictive value of 0.96, and negative predictive value of 0.99.

Conclusion: Pediatric appendicitis score is a simple, relatively accurate diagnostic tool for accessing an acute abdomen and diagnosing appendicitis in children.
J Pediatr Surg 37:877-881. Copyright 2002, Elsevier Science (USA). All rights reserved.

INDEX WORDS: Appendicitis, nonappendicitis, scoring system.

DEFINITIVE DIAGNOSIS of appendicitis is made in only 50% to 70% of children at the time of initial assessment.[1] Overall morbidity related to delayed diagnosis and treatment of appendicitis are an increased perforation rate (18% to 20%), wound infection (0 to 11%), pelvic abscess (1.5% to 5%), prolonged hospital stay, delayed return to normal activities, and risk of late adhesive bowel obstruction.[2-5] However, unnecessary surgery should be avoided. Proportion of appendices that are normal on histologic studies identifies this problem with a negative appendectomy rate of 10% to 30%.[5-7] Various clinical and computer-assisted scoring systems are available, but their clinical benefit is varied. Improvement in clinical performance with their use has increased diagnostic accuracy from 58% to 71% with a drop in perforation rate from 27% to 12.5%.[7-10] However, negative appendectomy rate despite active in-hospital observation is high (11.5%).[5] The purpose of this prospective study was to propose a diagnostic score (Pediatric Appendicitis Score [PAS]) unique to children aged 4 to 15 years to sharpen diagnostic acumen in accurate early diagnosis of appendicitis and to reduce the incidence of negative appendectomy.

MATERIALS AND METHODS

In the last 5 years, 1,170 children aged 4 to 15 years with abdominal pain suggestive of acute appendicitis at Southampton General Hospital, Southampton and St George's Hospital, London were analyzed prospectively. A uniform prospective data form was completed, which included. (1) demographic data (age and sex); (2) duration of symptoms: (a) anorexia, (b) nausea/vomiting, and (c) migration of pain from umbilical area to right lower quadrant; (3) physical signs: (a) right iliac fossa tenderness on palpation, (b) right lower quadrant tenderness on hopping, (c) coughing/percussion tenderness right lower quadrant, and (d) pyrexia; (4) laboratory investigations: (a) white blood cell count, (b) differential count, and (c) urinalysis; (5) histopathology of appendix. Patients who had appendicular mass with periappendiceal abscesses diagnosed were excluded from the study. Patients were classified into 2 groups: group 1 (734) with appendicitis and group 2 (436) nonappendicitis.

Symptoms, signs, and laboratory findings were evaluated for specificity, sensitivity, predictive value, and joint probability. The total joint probability, which is the sum of a true-positive and a true-negative result, was chosen as the diagnostic index indicative of accuracy of the test. Joint probabilities were calculated by dividing total number of patients by number of true-positive or true-negative test results. Diagnostic index/weight for each clinical feature and investigation was calculated. Multiple linear logistic regression analysis of all parameters was performed for a model comprising 8 variables to form a diagnostic score. One-way analysis of variance, χ^2 with P less than .05 considered statistically significant was used for parametric and nonparametric data. Pearson correlation coefficient was evaluated, and results are presented as mean $\pm$ SD.

Table 1. Comparative Evaluation of Clinical Features in Appendicitis and Nonappendicitis Patients

| | Appendicitis (group 1) / Nonappendicitis (group 2) | | | |
Diagnostic Indicants	Sensitivity	Specificity	Predictive Value	Negative Predictive Value
Symptoms				
Migration of pain	0.98/0.42	0.66/0.02	0.70/0.3	0.97/0.03
Anorexia	0.93/0.19	0.82/0.07	0.88/0.12	0.89/0.11
Nausea/emesis	0.85/0.13	0.87/0.15	0.94/0.07	0.73/0.27
Signs				
Tenderness in right lower quadrant	0.80/0	1.00/0.2	1.00/0	0.57/0.43
Cough/percussion tenderness	0.93/0	1.00/0.07	1.00/0	0.88/0.12
Hopping tenderness	0.93/0	1.00/0.07	1.00/0	0.88/0.12
Pyrexia	0.89/0.15	0.85/0.11	0.92/0.08	0.82/0.18
Investigations				
Leukocytosis	0.85/0.26	0.74/0.15	0.84/0.16	0.74/0.26
Polymorphonuclear neutrophilia	0.81/0.29	0.72/0.13	0.91/0.17	0.71/0.32

RESULTS

Age and Sex

Mean age of patients with appendicitis was 9.9 ± 3.3 versus 11 ± 2.7 years in those without appendicitis ($P > .05$). Sex ratio (male to female) of children with appendicitis was (471:263) 1.7:1 versus 1.8:1 (281:155) without appendicitis ($P > .05$). There was a good correlation between the 2 groups regarding age and sex ($r = 0.84$).

Pathology

Group 1. Sixty-three percent (734 of 1,170) had appendicitis confirmed by histology. Pathologic stages of acute appendicitis were inflamed, 35% (acute inflammatory infiltrate is confined mainly to the mucosa); suppurative, 36% (mucosal necrosis with transmural extension of the inflammation); perforated, 20% (mucosal necrosis with transmural extension of the inflammation and peritonitis); and gangrenous, 9%.

Group 2. In 37% (436 of 1,170) without appendicitis, negative appendectomy was performed in 3% (36 of 1,170). Primary pathology in these 36 children was acute pancreatitis (n = 1), pneumonia (n = 2), inflamed and ruptured Meckel's diverticulum (n = 4), ruptured ovarian cyst (n = 5), normal appendices with no identifiable pathology (n = 7), acute mesenteric lymphadenitis (n = 8), and enterobium vermicularis infestation (n = 9). In the other 34% (400 of 1,170) treated conservatively, 62% (249/400) had nonspecific or idiopathic abdominal pain, 21% (85 of 400) constipation, 12% (47 of 400) gastroenteritis, and 5% (19 of 400) mesenteric adenitis with upper respiratory tract infection.

Duration of symptoms. Mean duration of symptoms in all cases of appendicitis (734) was 2.3 ± 1.1 versus 2.2 ± 0.8 days without appendicitis (436; P .03). Mean duration of symptoms in inflamed appendix was 2.5 ± 1.2, in suppurative 2 ± 0.9, in gangrenous 2 ± 0.9, and in peritonitis 3 ± 0.9 days.

Analysis of diagnostic indicants. Table 1 summarizes sensitivity, specificity, positive predictive value and negative predictive value of each of the clinical features in both groups. Table 2 shows the comparison of the diagnostic weight for each of the clinical features (diagnostic indicants) between the 2 groups. Mean white blood cell count in 734 cases of appendicitis was 15.5 ± 5 versus 8.6 ± 3 (10^9/L) in 436 cases of nonappendicitis ($P < .001$). Mean white blood cell count was 13.5 ± 4 in inflamed, 10.8 ± 3.4 in suppurative, 20.8 ± 2.4 in gangrenous, and 20.5 ± 2 (10^9/L) in perforated appendicitis. A significant shift to the left in white blood cell count was seen in gangrenous and perforated appendicitis ($P < .001$) in comparison with inflamed and nonappendicitis children. Urinalysis should be performed routinely in all children with abdominal pain, but it was not statistically significant between the 2 groups to be con-

Table 2. Comparison of the Diagnostic Weight of the Diagnostic Indicants Between Group 1 and Group 2

Diagnostic Indicants	Appendicitis (group 1) Diagnostic Weight	Nonappendicitis (group 2) Diagnostic Weight	P Value*	PAS (10)
Cough/percussion tenderness	0.96	0.37	<.001	2
Hopping tenderness	0.96	0.37	<.001	
Anorexia	0.88	0.12	<.001	1
Pyrexia	0.87	0.12	<.001	1
Nausea/Emesis	0.86	0.14	<.001	1
Tenderness in right lower quadrant	0.84	0.37	<.001	2
Leukocytosis†	0.81	0.2	<.001	1
Polymorphonuclear neutrophilia	0.80	0.22	<.001	1
Migration of pain	0.80	0.2	<.001	1

*$P < .05$ statistically significant.

†Leukocytosis with a white blood count of $\geq$ 10,000(10^9/L).
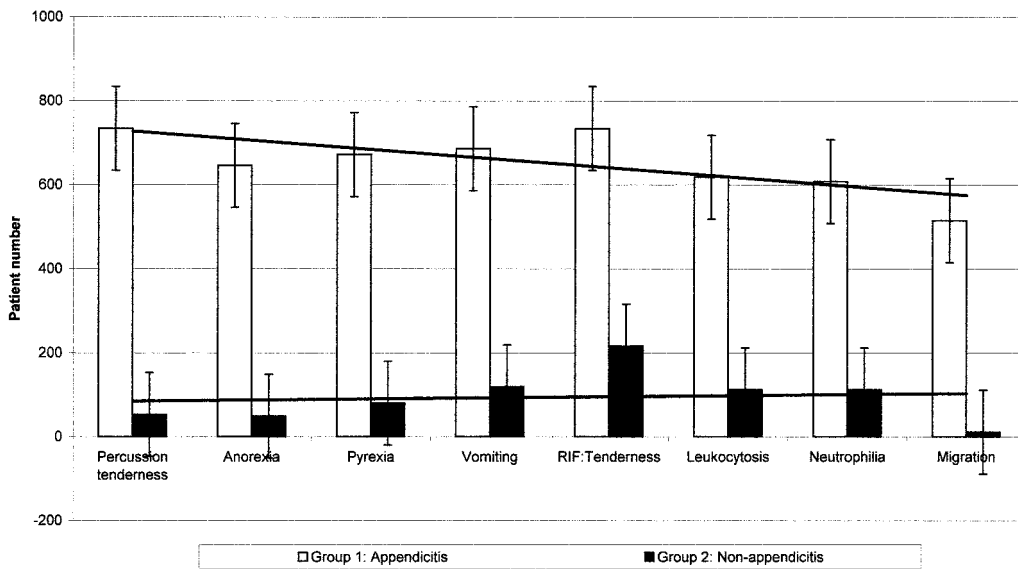
Fig 1. Distribution of diagnostic variables between group 1 (appendicitis) and group 2 (nonappendicitis).

sidered a diagnostic variable ($P > .05$). Common urinalysis findings showed presence of few red blood cells and ketones, which was nonspecific.

PAS

Stepwise multiple linear logistic regression analysis of the above variables yielded a model comprising of 8 variables, all highly statistically significant ($P < .001$) (Table 2; Fig 1). These variables in order of their diagnostic index were (1) cough/percussion/hopping tenderness in the right lower quadrant of the abdomen (0.96), (2) anorexia (0.88), (3) pyrexia (0.87), (4) nausea/emesis (0.86), (5) tenderness over the right iliac fossa (0.84), (6) leukocytosis (0.81), (7) polymorphonuclear neutrophilia (0.80), and (8) migration of pain (0.80).

Each of these variables was assigned a score of 1, except for physical signs (1 and 5), which were scored 2 to obtain a total of 10. Cough/percussion tenderness or hopping tenderness in the right lower quadrant of the abdomen had a good correlation coefficient and hence were considered as a single diagnostic variable ($r = 0.9$). These signs had an excellent specificity (1.00), predictive value (1.00), and a diagnostic index of 0.96. Hence, they were assigned a score of 2 as a diagnostic tool in the PAS (Table 2). Tenderness confined to the right lower quadrant, especially at the McBurney's point had an excellent specificity (1.00) and positive predictive value (1.00) but a poor negative predictive value (0.57). However, being a sign with a diagnostic index of 0.84, it was assigned a score of 2 in the PAS (Table 2). A cut-off point of 5 as shown in Fig 2 will provide no potential perforations or missed appendicitis but an unnecessary operation rate of 19 of 1,170. At a cut-off point of 6, there will be 9 of

1,170 potential missed appendicitis and 13 of 1,170 unnecessary operations (Fig 2). Hence, a score of ≤ 5 is not compatible with the diagnosis of appendicitis, whereas a score of ≥ 6 is compatible with the diagnosis of appendicitis (P .001; Fig 2, Table 3). Scores of 7 to 10 indicate high probability of appendicitis (P .001; Fig 2, Table 3).

Validation of PAS as a Diagnostic Tool

PAS in the 1,170 children analyzed had a sensitivity of 1, specificity of 0.92, positive predictive value of 0.96, and negative predictive value of 0.99 (Fig 2, Table 3).

DISCUSSION

PAS specifically addresses symptomatology and physical signs unique to children. Physical signs, such as cough, percussion tenderness, and hopping tenderness in the right iliac fossa had significant correlation and, hence, were assigned as a single variable with a score of 2. Tenderness in the right iliac fossa especially over the McBurney's point in combination with the above physical sign had a good diagnostic index with a high probability of predicting true prevalence of appendicitis ($P < .001$) and therefore was assigned a score of 2. Rebound tenderness is a particularly painful clinical feature to elicit and results in undue pain, loss of confidence and trust, and ultimately leads to loss of cooperation. Hence, this physical sign should not be elicited in children. Pyrexia, leukocytosis, and polymorphonuclear neutrophilia were valuable variables in diagnosing appendicitis, especially in cases of inflamed and suppurative appendicitis. Our study correlates with that shown by Thompson and Underwood[11] wherein total white blood cell count
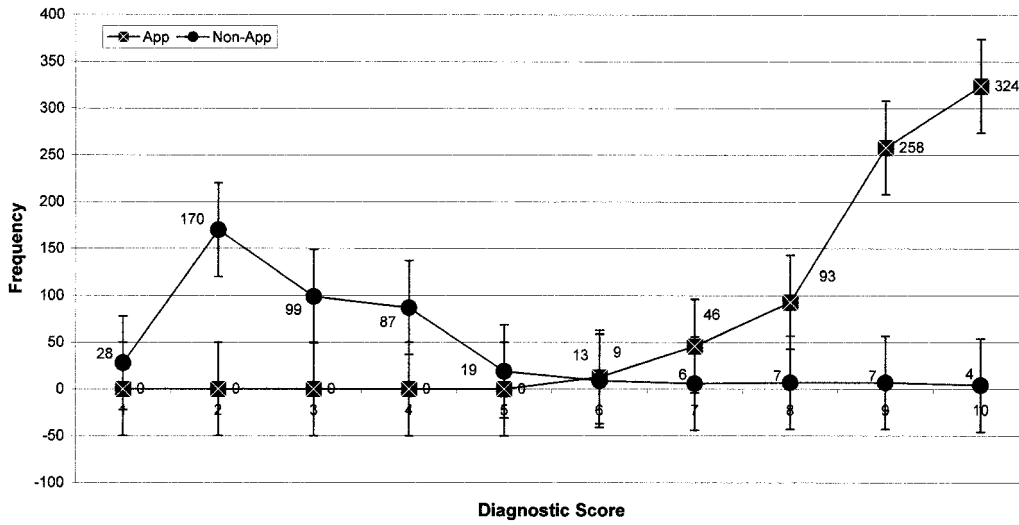
Fig 2. Comparison of frequency distribution according to diagnostic score in group 1 (App, appendicitis) and group 2 (Non-app, nonappendicitis).

had a good sensitivity (>80%) and specificity (>90%) and was relatively accurate in the diagnosis of appendicitis in conjunction with other symptoms and signs.

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 8 variables in PAS do overlap with other diseases as seen in this cohort; hence, PAS does not give 100% certainty. There is no symptom, sign, or laboratory test that is 100% reliable in the diagnosis of appendicitis. Recently, Douglas et al[7] have shown that graded compression ultrasonography has an accuracy of 93% equivalent to contrast computed tomography but failed to show better outcome than clinical diagnosis.[7,12] They also showed it does not prevent adverse outcome or reduce the length of hospital stay.[7] Hence, a simple recurrent clinical examination using PAS as a guide may be more helpful than a single investigation.

PAS allows a clinician to approach a child with abdominal pain rationally using common symptoms, signs, and full blood count result to arrive at a decision whether to operate or observe. In patients with uncertain diagnosis of acute abdominal pain, a policy of active observation in the hospital usually is practiced. PAS can be used as a simple guide for repeated structured clinical examination to decide if the patient needs observation or surgery. PAS should be correlated with the clinical impression of the examiner because there always is an intangible ingredient in the diagnosis of acute appendicitis. If there are questions relating to the diagnosis, the patient should be re-evaluated after 4 hours after adequate intravenous fluid resuscitation, and, if the score remains the same or increases, the patient may need laparotomy. PAS is flexible to allow a ± 1 bias on an individual basis, and a score of ≥6 shows a high probability of appendicitis. PAS can be used in regular critical clinical audit of appendectomies so as to reduce the negative appendectomy rate to less than 5%, as shown in this study and can be used as an ongoing stimulus to good clinical practice.

Pediatric appendicitis score is a simple, relatively accurate diagnostic tool, which is applicable in all clinical situations and has been proposed as a guide to assist in deciding whether to operate or observe a child with abdominal pain. The scoring system can be used for repeated structured reevaluation during active observation.

Table 3. Mean Score and Standard Deviation for Different Stages of Appendicitis and Nonappendicitis

Categories	Age	Mean Score ± SD
Appendicitis		
Inflamed (256)	9.7 ± 2.9	8.9 ± 0.5
Suppurative (265)	10.8 ± 3.4	8.9 ± 0.5
Gangrenous (68)	6.7 ± 2.7	9.6 ± 0.1
Perforated (145)	10.5 ± 3.2	9.5 ± 0.1
Group 1: all cases of appendicitis		
(734)	9.9 ± 3.3	9.1 ± 0.1
Group 2: nonappendicitis (436)	11 ± 2.7	3.1 ± 1.1
Age: group 1 versus group 2:		
P > .05		
Mean score: group 1 versus group 2:		
P .001		

ADDENDUM

To further validate the PAS, 66 children aged 8.9 ± 2.4 years were assessed prospectively since the completion of the above study. Thirty-nine patients aged 7.9 ± 1.8 years with a PAS of ≥8 had appendicitis diagnosed. Thirty-five had appendicitis confirmed by histology, 2 had an inflamed Meckel's diverticulum with normal appendixes, and 2 had normal appendixes with enterobium vermicularis infestation. Of the 27 children aged 10.3 ± 2.5 years with a PAS of ≤5 treated conservatively, the diagnosis was nonspecific abdominal pain (n = 22), constipation (n = 2), gastroenteritis (n = 2), and urinary tract infection (n = 1). The PAS had a sensitivity of 1, specificity of 0.87, positive predictive value of 0.90, and negative predictive value of 1.

REFERENCES

1. Balthazar EJ: Appendicitis: Prospective evaluation with high resolution CT. Radiology 180:21-24, 1991

2. Curran TJ, Muenchow SK: The treatment of complicated appendicitis in children using peritoneal drainage: Results from a public hospital. J Pediatr Surg 28:204-208, 1993

3. McAnena OJ, Austin O, O'Connell PR, et al: Laparoscopic versus open appendicectomy: A prospective evaluation. Br J Surg 79:818-820, 1992

4. McLean AD, Stonebridge PA, Bradbury AW, et al: Time of presentation, time of operation and unnecessary appendicectomy. Br Med J 306:307, 1993

5. Surana R, O'Donnell B, Puri P: Appendicitis diagnosed following active observation does not increase morbidity in children. Pediatr Surg Int 10:76-78, 1995

6. Pearl RH, Hale DA, Molloy M, et al: Pediatric appendectomy. J Pediatr Surg 30:173-181, 1995

7. Douglas CD, Macpherson NE, Davidson PM, et al: Randomised controlled trial of ultrasonography in diagnosis of acute appendicitis, incorporating the Alvarado score. Br Med J 321:919-922, 2000

8. Bergeron E, Richer B, Gharib R, et al: Appendicitis is a place for clinical judgement. Am J Surg 177:460-462, 1999

9. Adams ID, Chan M, Clifford PC, et al: Computer aided diagnosis of acute abdominal pain: A multi-centre study. Br Med J 293:800-804, 1986

10. Alvarado A: A practical score for the early diagnosis of acute appendicitis. Ann Emerg Med 15:557-564, 1986

11. Thompson M, Underwood M: Role of sequential leukocyte counts and C-reactive protein measurements in acute appendicitis. Br J Surg 79:822-824, 1992

12. Rao PM, Boland GWL: Imaging of acute right lower abdominal quadrant pain. Clin Radiol 53:639-649, 1998