# A Practical Score for the Early Diagnosis of Acute Appendicitis

*We conducted a retrospective study of 305 patients hospitalized with abdominal pain suggestive of acute appendicitis. Signs, symptoms, and laboratory findings were analyzed for specificity, sensitivity, predictive value, and joint probability. The total joint probability, the sum of a true-positive and a true-negative result, was chosen as a diagnostic weight indicative of the accuracy of the test. Eight predictive factors were found to be useful in making the diagnosis of acute appendicitis. Their importance, according to their diagnostic weight, was determined as follows: localized tenderness in the right lower quadrant, leukocytosis, migration of pain, shift to the left, temperature elevation, nausea-vomiting, anorexia-acetone, and direct rebound pain. Based on this weight, we devised a practical diagnostic score that may help in interpreting the confusing picture of acute appendicitis. [Alvarado A: A practical score for the early diagnosis of acute appendicitis. Ann Emerg Med May 1986;15:557-564.]*

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## INTRODUCTION

Acute appendicitis is a common cause of abdominal pain in all ages. However, it is often a perplexing diagnostic problem during the early stages of the disease. In many cases, usually during the prodromal phase, its clinical manifestations may be vague and uncertain. Failure to make an early diagnosis is a primary reason for the persistent rate of morbidity and mortality.[1-3] Perforation rates range from 4%[4] to 45%,[5] and death rates range from 0.17%[6] to 7.5%.[7] Mortality in children less than 2 years old is surprisingly high (20%).[5]

The number of unnecessary laparotomies, particularly in women, may be as high as 45%.[1] The overall "negative" appendectomy rate ranges from 14%[2,8] to 75%.[9]

Our goal is to be able to reduce the negative appendectomy rate without increasing the risk of perforation. This might be accomplished by sharpening our diagnostic acumen, especially during the early stages of the disease, because most of the perforations occur outside the hospital.[2,3] A careful evaluation of each patient may reduce the number of "healthy" appendices removed.[4,6,8]

## MATERIALS AND METHODS

The records of 305 patients who were hospitalized from January 1975 to December 1976 at Nazareth Hospital in Philadelphia, Pennsylvania, with abdominal pain (epigastric, periumbilical, diffuse, or in the right lower quadrant) suggestive of acute appendicitis were reviewed. Data, including age, sex, duration of pain, symptoms, physical signs, and such laboratory findings as white blood count (WBC), differential count, urinalysis, and pathology report, were tabulated from existing clinical records.

## RESULTS

Of 305 patients hospitalized, 51 (17%) were kept for observation and treated nonoperatively. They were discharged from the hospital with the diagnosis of possible acute mesenteric adenitis (29 patients, 57%) or nonspecific gastroenteritis (22 patients, 43%).

Of the 305 patients, 254 (83%) had an appendectomy. Of these, 27 (11%) did not have acute appendicitis. The remaining 227 (89%) did have acute appendicitis at varying pathological stages (Table 1).

Of 27 patients without acute appendicitis, four had a normal appendix with no signs of abdominal pathology at operation. One of these subsequently showed signs of pneumonia on radiograph. Of the remaining patients, 17 had such other abdominal conditions as acute mesenteric adenitis (12), ruptured ovarian cyst (three), acute pancreatitis (one), and gastroenteritis (one). The remaining six had acute periappendicitis with no other abdominal pathology (four), subacute mesenteric adenitis (one), and appendiceal fibrosis (one). There were no deaths.

There is a seasonal variation of acute appendicitis, with more cases during winter and summer months ($P < .001$) (Figure 1). There is no clear explanation for this, although it may be related to enteral viral infections.

Pathological stage of the disease was directly related to duration of pain before admission to the hospital (Table 2). The mean duration of pain for all stages of acute appendicitis was 1.5 days, with a range of one to 15 days.

Mean patient age was 25.3 years ($s = 15.9$), with a range of 4 to 80 years in the group of 227 patients with acute appendicitis (Table 3). Of these patients, 131 (58%) were male patients and 96 (42%) were female patients.

## Evaluation of Findings

Of the initial 305 records, 28 were excluded from statistical evaluation because of incomplete clinical information. The study included 277 patients (227 with acute appendicitis, 50 without acute appendicitis).

To summarize the results, a statistical 2 × 2 table was made for each

**TABLE 1.** *Pathological stages of acute appendicitis*

| Stage | No. | (%) |
|---|---|---|
| Simple | 108 | 47 |
| Suppurative | 67 | 30 |
| Gangrenous | 15 | 7 |
| Perforated | 34 | 15 |
| Abscessed | 3 | 1 |
| Total | 227 | 100 |

**TABLE 2.** *Duration of pain in acute appendicitis*

| Stage | No. | Range (days) | Mean (days) |
|---|---|---|---|
| Simple | 108 | 1-5 | 1.2 |
| Suppurative | 67 | 1-4 | 1.2 |
| Gangrenous | 15 | 1-3 | 1.5 |
| Perforated | 34 | 1-5 | 2.7 |
| Abscessed | 3 | 5-15 | 9.3 |
| All cases | 227 | 1-15 | 1.5 |

$F > F.99$; $P > .001$.

**TABLE 3.** *Age in acute appendicitis*

| Stage | No. | Range (y) | Mean (y) |
|---|---|---|---|
| Simple | 108 | 4-80 | 23.5 |
| Suppurative | 67 | 6-63 | 22.3 |
| Gangrenous | 15 | 7-65 | 36.3 |
| Perforated | 34 | 9-68 | 29.0 |
| Abscessed | 3 | 49-60 | 53.0 |
| All cases | 227 | 4-80 | 25.2 |

**TABLE 4.** *Evaluation of clinical and laboratory findings in acute appendicitis*

| Diagnostic Indicants | Sensitivity P(T+ \| D+)* | Specificity P(T− \| D−) | Predictive Value P(D+ \| T+) | Predictive Value P(D− \| T−) | Joint Probability P(T+&D+) | Joint Probability P(T−&D−) | Diagnostic Weight |
|---|---|---|---|---|---|---|---|
| Migration | .69 | .84 | .95 | .37 | .57 | .15 | .72 |
| Anorexia-acetone | .61 | .72 | .91 | .29 | .50 | .13 | .63 |
| Nausea-vomiting | .74 | .36 | .84 | .23 | .60 | .06 | .66 |
| Tenderness | 1.00 | .12 | .83 | 1.00 | .82 | .02 | .84 |
| Rebound pain | .55 | .78 | .92 | .27 | .45 | .14 | .59 |
| Elevation | .73 | .50 | .87 | .29 | .60 | .09 | .69 |
| Leukocytosis | .93 | .38 | .87 | .53 | .76 | .07 | .83 |
| Shift | .71 | .68 | .91 | .34 | .58 | .12 | .70 |
| Rectal tenderness | .53 | .41 | .69 | .26 | .38 | .11 | .49 |

*P, probability; T, test, sign, or symptom; D, disease.

TABLE 5. *Evaluation of clinical and laboratory findings in nonacute appendicitis*

| Diagnostic Indicants | Sensitivity P(T+ \| D+)* | Specificity P(T− \| D−) | Predictive Value P(D+ \| T+) | Predictive Value P(D− \| T−) | Joint Probability P(T+&D+) | Joint Probability P(T−&D−) | Diagnostic Weight |
|---|---|---|---|---|---|---|---|
| **Migration** | .16 | .31 | .05 | .62 | .03 | .25 | .28 |
| **Anorexia-acetone** | .28 | .39 | .09 | .70 | .05 | .32 | .37 |
| **Nausea-vomiting** | .64 | .26 | .16 | .77 | .11 | .21 | .32 |
| **Tenderness** | .88 | 0 | .16 | 0 | .16 | 0 | .16 |
| **Rebound pain** | .22 | .45 | .08 | .72 | .04 | .37 | .41 |
| **Elevation** | .50 | .27 | .13 | .71 | .09 | .22 | .31 |
| **Leukocytosis** | .62 | .07 | .13 | .47 | .11 | .06 | .17 |
| **Shift** | .32 | .29 | .09 | .66 | .06 | .24 | .30 |
| **Rectal tenderness** | .59 | .47 | .31 | .74 | .17 | .34 | .51 |

*P, probability; T, test, sign, or symptom; D, disease.

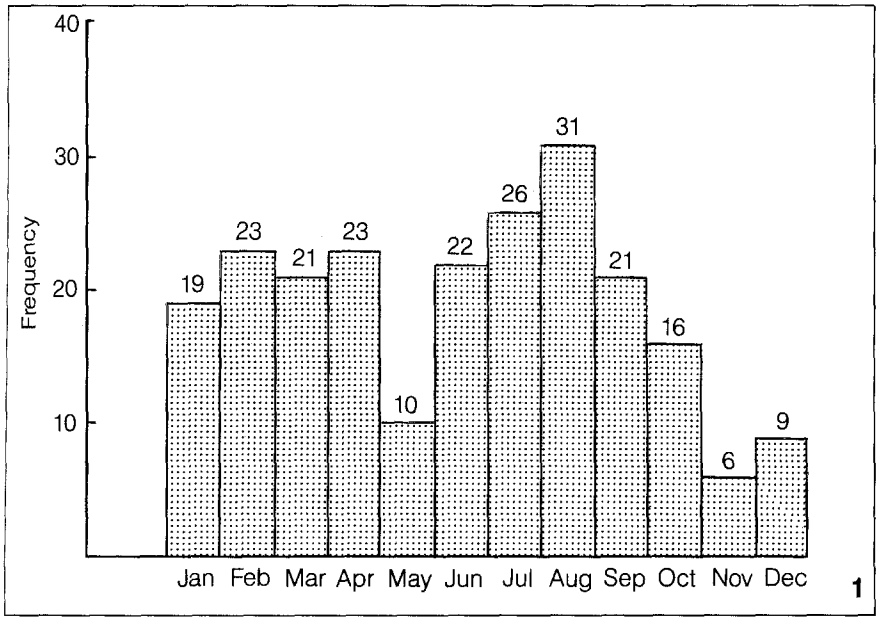



**FIGURE 1.** *Frequency distribution of acute appendicitis during the year. N=227; $X^2$= 31.77; P < .001.*

diagnostic indicant, and from these tables an estimate of probabilities, sensitivity, specificity, and predictive values was calculated.[10]

The "ideal test" should be 100% sensitive and 100% specific, and should have a predictive value of 100%. Also, there should be no false-positive or false-negative results, so that the total joint probability should add up to 100%. A diagnostic weight of such a test should be 1.0. This is obtained by adding the joint probability of a negative test to the joint probability of a positive test.

The joint probabilities were calculated directly by dividing the total number of patients by the number of true-positive or true-negative tests. Using this method, a diagnostic weight for each clinical and laboratory finding was assigned (Tables 4, 5, and 6 and Figures 2 and 3). This should indicate the diagnostic accuracy of each test because it considers only the true-positive and true-negative results.

## Analysis of Diagnostic Indicants

*Migration of pain.* Pain usually starts in the epigastrium or periumbilical area and in a few hours migrates to the right lower quadrant. This symptom had a good predictive value (0.95) and a good specificity (0.84). Its sensitivity, however, was only fair (0.69) (Table 4).

*Anorexia-acetone.* One of the specific symptoms of acute appendicitis is anorexia,[1,8,11] which may be associated with acetone in the urine. We can use this as an indirect sign of anorexia. Thus anorexia or acetone in the urine (or both) has a fair sensitivity (0.61) but a good positive predictive value (0.91). Its specificity, however, is only fair (0.72).

*Nausea-vomiting.* The symptom complex of nausea and vomiting[1,5,11] has a good sensitivity (0.74) but a poor specificity (0.36), and its predictive value is good (0.84).

*Tenderness.* The most common sign of acute appendicitis is tenderness in the right lower quadrant, especially at the McBurney's point.[1,5] Tenderness has an excellent sensitivity (1.00) and excellent predictive value (1.00), but a poor specificity (0.12). Its positive joint probability is good (0.82) but its specificity is poor (0.12) (Table 4).

*Rebound pain.* Although this sign is sometimes difficult to elicit, direct rebound pain is one of the specific signs of acute appendicitis (0.78 specificity). Rebound pain has a good predictive value (0.92) but a poor sensitivity (0.55).

*Elevation of temperature.* Initial slight temperature elevation, defined as oral temperature ≥ 37.3 C, is a common finding in acute appendicitis.[1,5] It has a fairly good sensitivity (0.73) but a poor specificity (0.50). Slight fever, however, has a good predictive value (0.87).

*Leukocytosis.* A white blood count above 10,000 is a valuable finding in

TABLE 6. *Evaluation of clinical and laboratory findings in acute mesenteric adenitis*

| Diagnostic Indicants | Sensitivity P(T+ \| D+)* | Specificity P(T− \| D−) | Predictive Value P(D+ \| T+) | Predictive Value P(D− \| T−) | Joint Probability P(T+&D+) | Joint Probability P(T−&D−) | Diagnostic Weight |
|---|---|---|---|---|---|---|---|
| **Migration** | .15 | .94 | .29 | .77 | .02 | .78 | .80 |
| **Anorexia-acetone** | .29 | .39 | .08 | .76 | .04 | .34 | .38 |
| **Nausea-vomiting** | .56 | .15 | .10 | .67 | .08 | .13 | .21 |
| **Tenderness** | .88 | 0 | .13 | 0 | .13 | 0 | .13 |
| **Rebound pain** | .15 | .45 | .04 | .75 | .02 | .38 | .40 |
| **Elevation** | .39 | .25 | .08 | .70 | .06 | .21 | .27 |
| **Leukocytosis** | .56 | .11 | .10 | .60 | .08 | .10 | .18 |
| **Shift** | .29 | .29 | .07 | .70 | .04 | .25 | .29 |

*P, probability; T, test, sign, or symptom; D, disease.

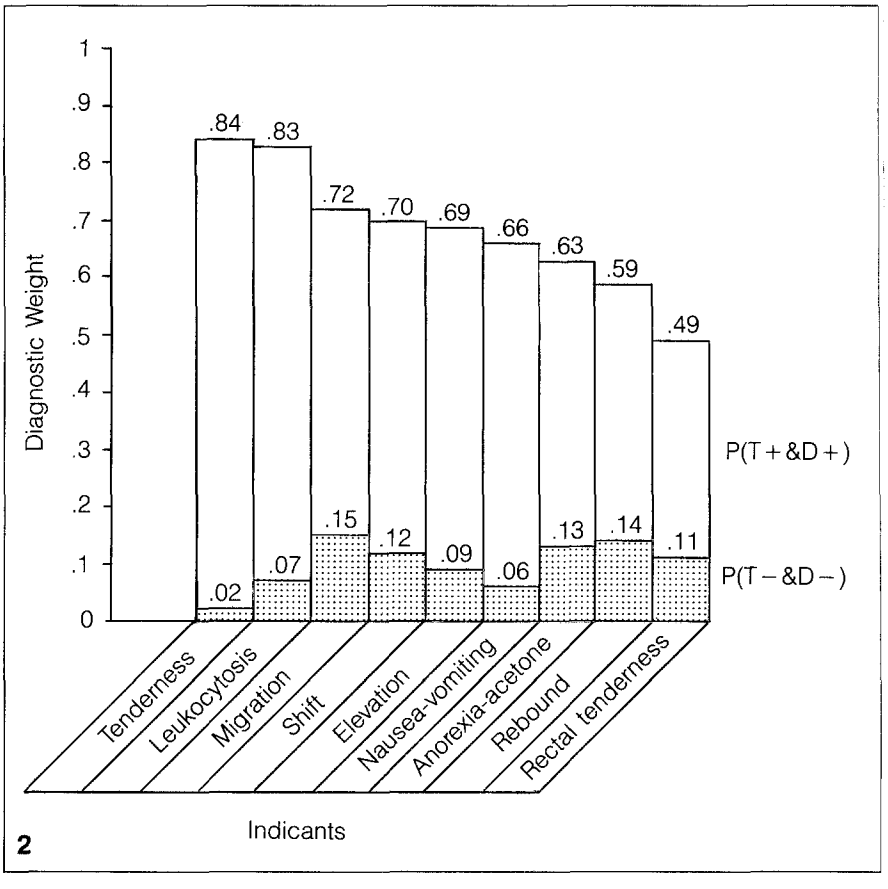



FIGURE 2. *Indicants and their diagnostic weights in acute appendicitis.*

acute appendicitis.[1,5,7,8] Leukocytosis has a good sensitivity (0.93) and a good predictive value (0.87); however, its specificity is low (0.38).

*Shift to the left.* A differential white count with shift to the left (eg, neutrophils of more than 75%) is also a useful indicant in acute appendicitis.[1,7] It has a good predictive value (0.91) but a fair sensitivity (0.71).

*Urinalysis.* Routine urinalysis should be done to rule out a urinary tract infection. Slight elevation of white cells in the urine could be due to the inflammatory process of acute appendicitis near the ureter or bladder.[12] Very frequently, patients with acute appendicitis show a few red blood cells in the urine; however, this is nonspecific.[1]

*Rectal examination.* Of 95 patients who had documented rectal examination in this series (Table 4), 52 had right-side rectal tenderness (0.55 estimate of the test outcome). Of 68 patients with confirmed acute appendicitis, 36 had rectal tenderness (0.53 sensitivity), and of 52 patients with positive rectal examination, 36 proved to have acute appendicitis (0.69 predictive value). In this subgroup of 95 patients with suspected acute appendicitis, 36 had acute appendicitis (0.38 positive joint probability). The total diagnostic weight of rectal tenderness was 0.49, which is too low to be considered a reliable sign.[1,5,7,8] Rectal examination, however, could be helpful when a pelvic abscess is suspected.

*Pelvic examination.* A pelvic examinationis useful to confirm gynecological disorders.

## Other Abdominal Pathology

Of 305 patients studied, 41 were discharged with the diagnosis of possible or confirmed acute mesenteric adenitis. Of these, 29 were observed and treated nonoperatively. The remaining 12 had laparotomies that showed normal appendices but clear signs of acute mesenteric adenitis.

The age range in acute mesenteric adenitis was 5 to 26 years with a mean of 11.5 years (s = 4.8), which is lower than in acute appendicitis (25.3 years) ($P < .001$) (Table 3).

The male:female ratio was 14:27 (34% male), which is the opposite of the ratio of appendicitis (58% male) ($P < .005$).

Pain duration in acute mesenteric adenitis prior to admission was from

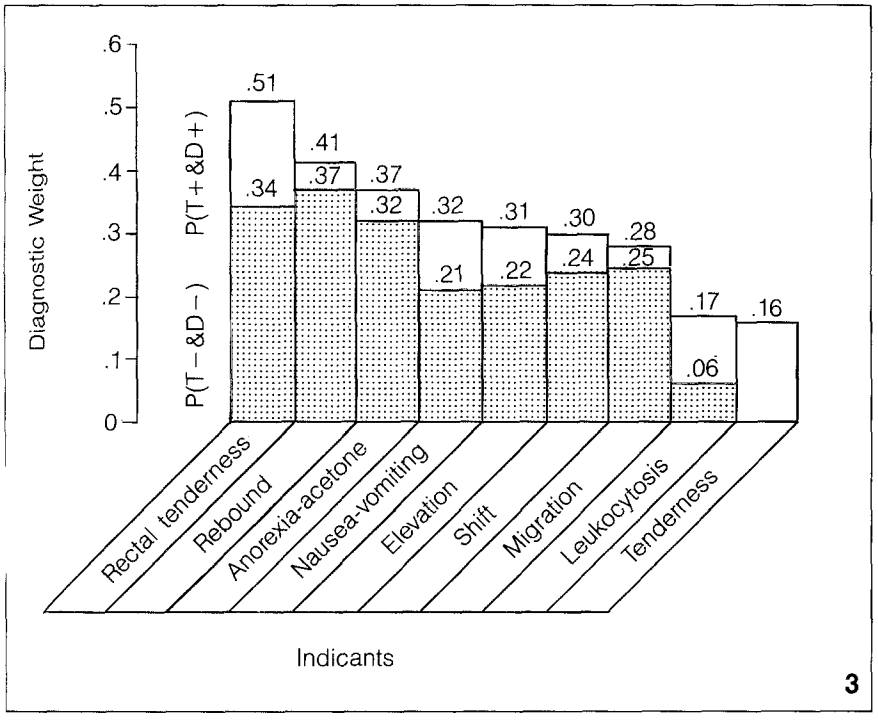



**FIGURE 3.** *Indicants and their diagnostic weights in nonappendicitis.*

**TABLE 7.** *Mnemonic for the diagnostic score of acute appendicitis: MANTRELS*

| | | Value |
|---|---|---|
| **Symptoms** | **M**igration | 1 |
| | **A**norexia-acetone | 1 |
| | **N**ausea-vomiting | 1 |
| **Signs** | **T**enderness in right lower quadrant | 2 |
| | **R**ebound pain | 1 |
| | **E**levation of temperature | 1 |
| **Laboratory** | **L**eukocytosis | 2 |
| | **S**hift to the left | 1 |
| Total score | | 10 |

**TABLE 8.** *Mean score and sample standard deviation for different stages of acute appendicitis*

| Stage | N | $\bar{x}$ | s |
|---|---|---|---|
| Simple | 108 | 7.40 | 1.49 |
| Suppurative | 67 | 7.92 | 1.66 |
| Gangrenous | 15 | 7.73 | 0.96 |
| Perforated | 37 | 8.21 | 1.45 |

one to 12 days, with a mean of 2.6 days; this was longer than pain duration in acute appendicitis (1.5 days) ($P < .001$) (Table 6).

Clinical and laboratory findings were much less sensitive than in acute appendicitis.

The most sensitive signs in acute mesenteric adenitis were tenderness in the right lower quadrant (0.88) and leukocytosis (0.56) but the specificity of these two signs was too low (0 and 0.11, respectively). In addition, the diagnostic weight of tenderness and leukocytosis was low (0.13 and 0.18, respectively). Migration of pain, however, had a high diagnostic weight (0.80), due primarily to its high negative joint probability (0.78).

In our series, three patients had ruptured ovarian cysts that required laparotomy. Age range was from 13 to 31 years and pain duration was from one to 6 days, with a mean of 2.6 days.

The most noticeable sign was rebound tenderness, with a sensitivity of 0.66 and a predictive value of 0.15. All the remaining signs and symptoms showed very low diagnostic weights.

## DISCUSSION

Three symptoms (migration, anorexia, and nausea-vomiting), three physical signs (tenderness, rebound pain, and elevation of temperature), and two laboratory findings (leukocytosis and shift to the left) appear to be useful in the diagnosis of acute appendicitis. If we assign a small number to the diagnostic weight of each indicant (Table 4), we obtain a workable score that can be used in practice (Table 7).

If we assign a value of 2 to the more important elements (tenderness, leukocytosis) and a value of 1 to the remaining elements, we reach a total, perfect score of 10. A score of 5 or 6 is compatible with the diagnosis of acute appendicitis. A score of 7 or 8 indicates a probable appendicitis, and a score of 9 or 10 indicates a very probable appendicitis.

This system does not give a 100% certainty because there is the chance of overlapping of symptoms with other diseases. There is no sign, symptom, or laboratory test that is 100% reliable in the diagnosis of acute appendicitis (Figure 2). This test should have a diagnostic weight of 1.0; however, we can use the diagnostic score as a guide to decide if the patient needs observation or surgery. A patient with a score of 5 or 6 may be observed; a patient with a score of 7 or

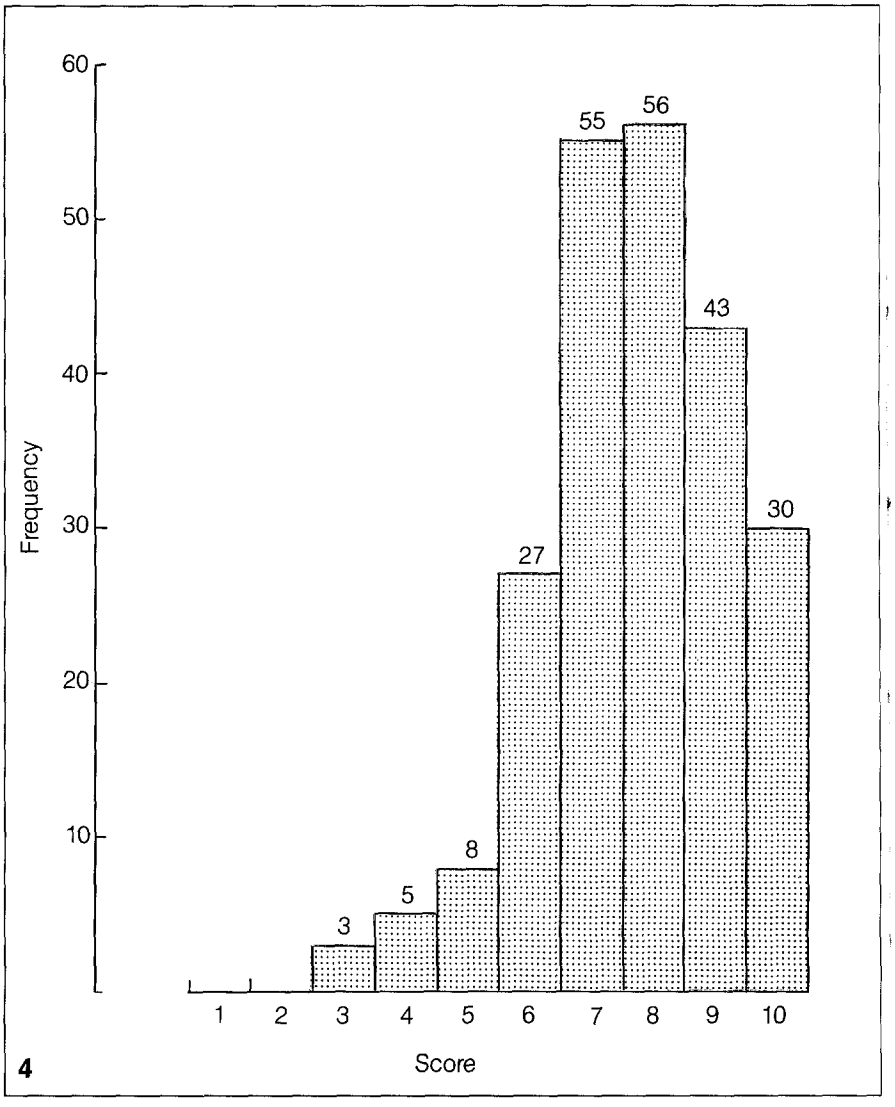



**FIGURE 4.** *Frequency distribution according to the diagnostic score in all cases of acute appendicitis. N=227; $\bar{x}$ =7.71; s= ±1.53.*

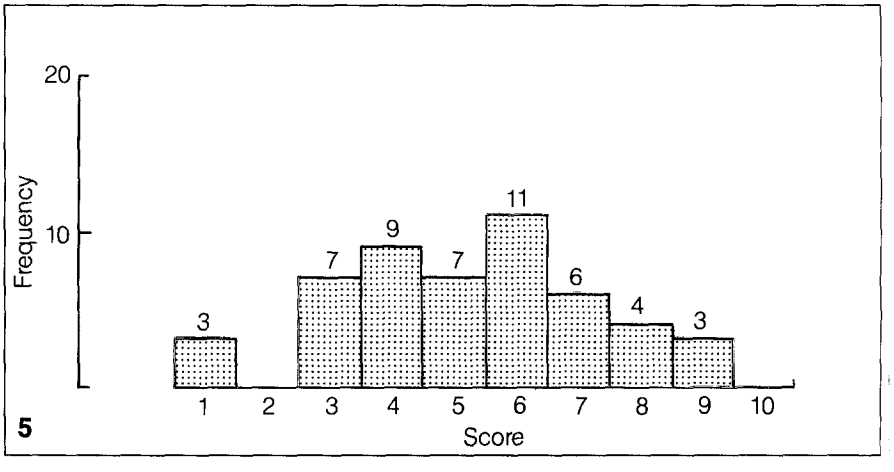



**FIGURE 5.** *Frequency distribution according to the diagnostic score in non-acute appendicitis. N=50; $\bar{x}$ =5.24; s= ±2.02.*

more requires surgery.

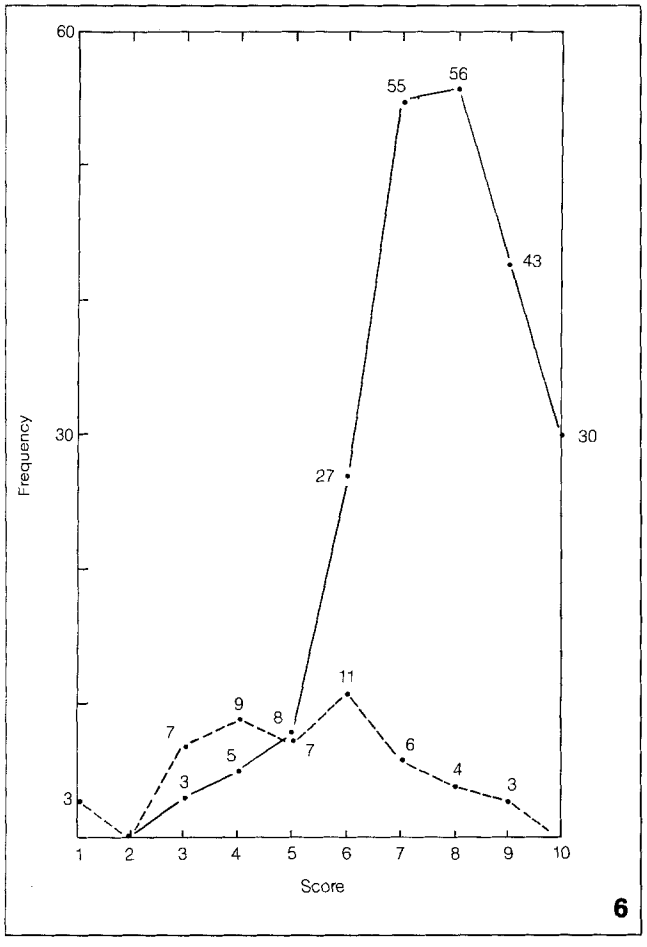
Certain symptoms and physical signs are not always easy to elucidate, especially in young children or mentally impaired patients. If there is any doubt about the presence of a determined sign or symptom, however, it is safer to recognize a sign or symptom as present even if its manifestation is not quite clear. Under these circumstances the diagnostic score should be correlated with the clinical impression of the examiner because there is always an intangible ingredient in the diagnosis of acute appendicitis. If there is any question about the diagnosis, more physical examinations and laboratory tests should be performed and the patient should be evaluated every four or six hours, preferably in the hospital.[5,6,8] If the score remains the same or increases after this reevaluation, the patient may need laparotomy.

The diagnosis of acute appendicitis is more difficult in women because of the presence of gynecological disorders. In these cases a pelvic examination is essential because it can reveal the missing information. A rectal examination does not appear to be a reliable element in the diagnosis of acute appendicitis because of its low diagnostic weight.[1,5,7,8]

## Statistical Aspects of the Score

Eight predictive factors were found to be useful in making the diagnosis of acute appendicitis. The order of importance of each, according to its diagnostic weight, was as follows: localized tenderness in the right lower quadrant (0.84), leukocytosis (0.83), migration of pain (0.72), shift to the left (0.70), temperature elevation (0.69), nausea-vomiting (0.66), anorexia-acetone (0.63), and direct rebound pain (0.59).

The chi-square statistic was calculated for each of the diagnostic indicants. The highest number (48.08) corresponded to migration of pain followed by leukocytosis (33.79), tenderness (27.91), shift to the left (26.90), anorexia-acetone (18.27), and rebound pain (17.43). All of these numbers were statistically significant ($P < .001$). The chi-square for elevation of temperature was 10.23 ($P < .01$). The lowest figures corresponded to nausea-



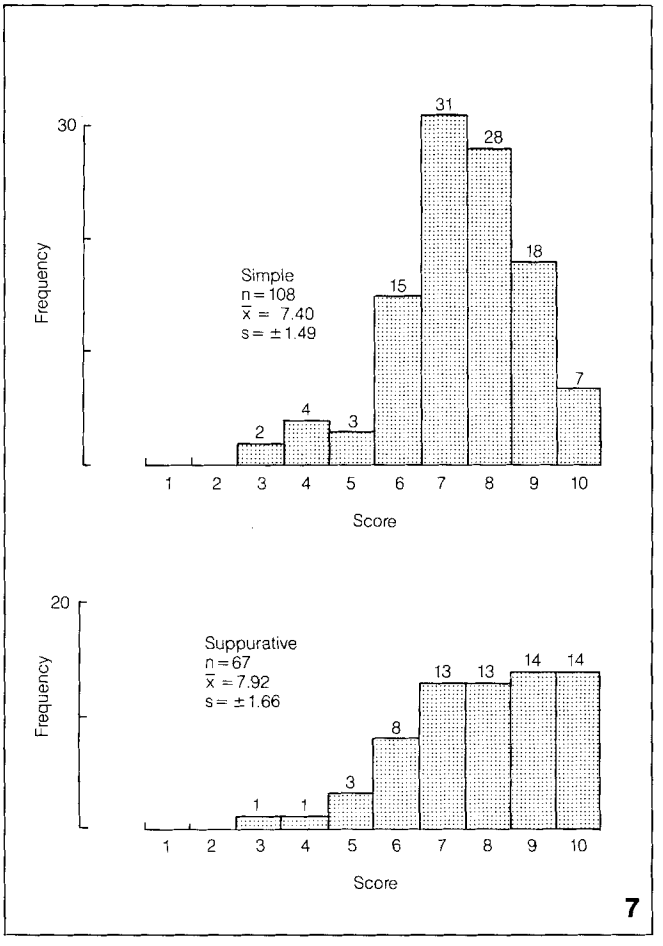




**FIGURE 6.** *Polygon of frequency distribution in appendicitis and nonappendicitis.*

**FIGURE 7.** *Frequency distribution according to the diagnostic score in simple and suppurative appendicitis.*

vomiting (2.03) and rectal tenderness (0.29), with *P* values of less than .2 and .5, respectively.

The diagnostic score for acute appendicitis is different than that for nonappendicitis (Figures 4 and 5). The mean score for acute appendicitis (n = 227) is 7.71 (s ± 1.53) and the mean score for nonappendicitis (n = 50) is 5.24 (s ± 2.02).

Using a polygon of frequency distribution (Figure 6) we can compare the diagnostic score for acute appendicitis with that for nonappendicitis. If we choose a decision cutoff point of 6, (either to operate for appendicitis or observe the patient) we will have 16 potential perforations (5.8%) and 24 unnecessary operations (8.7%). If we choose a cutoff point of 5, the potential perforations drop to 8 (2.9%), but the unnecessary operations rise to 31 (11.2%). The diagnostic score is flexible enough to allow for making the decision on an individual basis.

The mean score increases in relation to the stage of the disease, from 7.40 in simple appendicitis to 8.21 in the subgroup of perforated-abscessed appendicitis (Table 8). For some reason, however, in gangrenous appendicitis, the mean score is slightly lower than the mean score for suppurative appendicitis. This may reflect the famous "treacherous calm" of Dieulafoy, in which the pain and tenderness subside temporarily during the gangrenous stage of the disease.[12]

The frequency distribution according to the score at different stages of acute appendicitis (Figures 7 and 8) shows that in suppurative appendicitis, the histogram is markedly skewed to the right, indicating that at this stage we will have the maximum constellation of signs and symptoms.

## Application of the Diagnostic Score

In the group of patients with acute appendicitis, 17 had a normal WBC; four of these patients had a shift to the left. Tenderness was present in all patients, and migration of the pain was found in 14. The diagnostic score ranged from 4 to 7, with an average of 5.56. There was one case of gangrenous appendicitis and another of perforated appendicitis with normal WBC, but the scores were 7 and 6, respectively. Four patients had acute appendicitis with normal WBC and a score of 4, but they were in the early stages of the disease.

One case of subacute appendicitis was associated with mesenteric adenitis. The patient had tenderness in the right lower quadrant, but his diagnostic score was 4. Retrospectively, perhaps an unnecessary laparotomy could have been prevented. There was another case of appendiceal fibrosis that justified laparotomy because the diagnostic score was 9. One patient with acute pancreatitis and periappen-

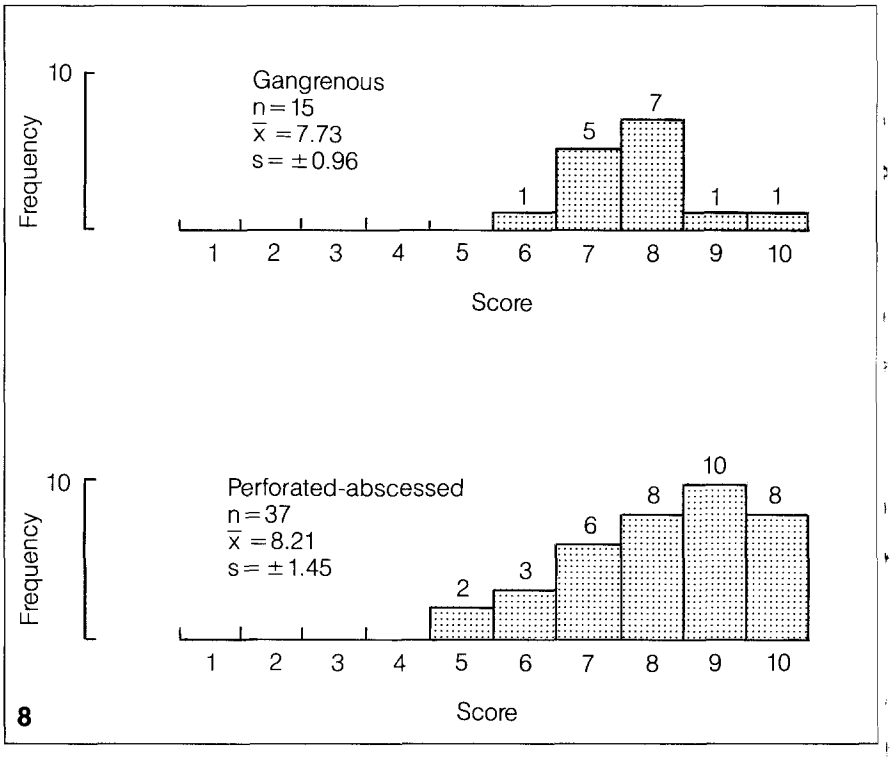



**FIGURE 8.** *Frequency distribution according to the diagnostic score in gangrenous and perforated-abscessed appendicitis.*

dicitis had tenderness and rebound pain in the right lower quadrant and a diagnostic score of 9; therefore, a laparotomy was indicated.

One case of acute appendicitis associated with *Salmonella typhimurium* presented with tenderness and rebound pain in the right lower quadrant and profuse diarrhea. The diagnostic score was 7. Another patient with periappendicitis associated with regional enteritis had a diagnostic score of 4; however, it was difficult to argue against laparotomy in this case.

Six cases of acute appendicitis were accompanied by lymphoid hyperplasia. All had tenderness in the right lower quadrant and a mean diagnostic score of 6.8. Two patients with acute appendicitis associated with mesenteric adenitis had a diagnostic score of 9. In both, the WBC count was elevated.

One patient, a 35-year-old man, complained of severe abdominal pain but had no abdominal tenderness. His temperature was 38.8 C and his WBC was 24,000. A subsequent chest roentgenogram revealed a right lower lobe pneumonia. However, his diagnostic score was 4, and in this case, with a more thorough clinical evaluation, an appendectomy could have been avoided.

One patient with *situs inversus* presented with tenderness and rebound pain in the left lower quadrant. His diagnostic score was 8. At laparotomy a gangrenous appendix was found.

Failure to make an early diagnosis is one reason for the persistently high rate of complications and mortality in acute appendicitis.[1-3] The problem is to secure an early diagnosis using customary clinical and laboratory methods. Several score systems have been devised, but they are cumbersome and difficult to memorize.[8,13] Some[4,8,11,13] require the use of computers, which may not be feasible in all clinical settings. In one study, Computer-aided diagnosis to avoid the negative laparotomy in suspected appendicitis offered no advantage over unaided clinical diagnosis.[11]

## CONCLUSION

We demonstrated that it is possible to approach patients in a rational manner using a simple diagnostic score that might indicate which patients should be observed and which should have surgery. This score is based on symptoms, signs, and laboratory findings commonly present in acute appendicitis. We applied Bayesian analysis,[11,13,14] in which we used prior information obtained from clinical experience to make a reasonable decision. The proposed scoring system is applicable in all clinical situations and does not require the use of a computer.

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