



Clinical scores (Alvarado and AIR scores) versus imaging (ultrasound and CT scan) in the diagnosis of equivocal cases of acute appendicitis: a randomized controlled study

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Introduction About 50% of acute appendicitis cases are atypical in their presentation. The objectives of this study was to assess and compare the feasibility of clinical scores [Alvarado and Appendicitis Inflammatory Response (AIR)] and imaging [ultrasound and abdominopelvic computed tomography (CT) scan] in the evaluation of equivocal cases of acute appendicitis in a clinical trial to identify that subset of patients who really need and will benefit from imaging, mainly CT scan.

Methods: A total of 286 consecutive adult patients with suspected acute appendicitis were included. The clinical scores, including Alvarado and AIR scores and ultrasound, were done for all patients. Abdominal and pelvic CT scans were done for 192 patients to resolve the diagnosis of acute appendicitis. The sensitivity, specificity, positive and negative predictive values, and accuracy rate of both clinical scores and imaging (ultrasound and CT scan) were compared. The final histopathology was used as the gold standard for which the diagnostic feasibility of the clinical score and imaging were compared.

Results: Out of 286 total patients who presented with right lower quadrant abdominal pain, a presumptive diagnosis of acute appendicitis was made in 211 patients (123 males and 88 females) after thorough clinical evaluation, clinical scores, and imaging, and they were submitted to appendectomy. The overall prevalence of acute appendicitis proved by histopathology as a gold standard was 89.1% (188 patients) with a negative appendectomy rate of 10.9%. Simple acute appendicitis was reported in 165 (78.2%) patients and perforated appendicitis in 23 (10.9%) patients. For patients with equivocal clinical scores (≥ 4 to ≤ 6), the sensitivity, specificity, predictive values, and accuracy rate of CT scan were significantly higher than those of Alvarado and AIR scores. Patients with low clinical scores (≤ 4) and high clinical scores (≥ 7), the sensitivity, specificity, predictive values, and accuracy rate of clinical scores and imaging were comparable. The diagnostic feasibility of AIR scores was significantly higher than the Alvarado score, and the clinical scores were associated with significantly higher diagnostic accuracy than ultrasound. CT scan is unlikely to be needed and will add little to the diagnosis of acute appendicitis for patients with high clinical scores (≥ 7). The sensitivity of the CT scan for perforated appendicitis was lower than that for nonperforated appendicitis. The use of CT scans for query cases did not change the negative appendectomy rate.

Conclusion: CT scan evaluation is beneficial only for patients with equivocal clinical scores. For patients with high clinical scores, surgery is recommended. AIR score was superior to the Alvarado score in terms of sensitivity, specificity, and predictive values. A CT scan is usually not required for patients with low scores since acute appendicitis is unlikely; in such cases, ultrasound could be of help to exclude other diagnoses.

Keywords: acute appendicitis, AIR score, Alvarado score, CT scan, ultrasound

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HIGHLIGHTS

- For typical cases, clinical scores can diagnose acute appendicitis, and no further imaging is required.
- Clinical scores, mainly AIR scores, can predict acute appendicitis with high sensitivity, specificity, and accuracy rates.
- For equivocal cases, a CT scan may reduce the rate of negative appendectomy and the rate of perforation.
- Graded compression US is the first choice for suspicious cases of acute appendicitis with low scores.

Introduction

Acute appendicitis is still the most common emergency entity encountered in general surgical practice, and appendectomy remains the most frequently performed emergency surgical procedure. Although the diagnosis and treatment of acute

appendicitis in its typical presentations are straightforward and easy, these typical presentations, however, are found in 50% of cases or even less^[1]. Such equivocal cases lead either to a missed or delayed diagnosis, complications such as perforation, or lead to unnecessary surgery. Hence the clinical diagnosis of atypical cases of acute appendicitis is challenging and mandates a collaboration of clinical, laboratory, and imaging findings^[2].

Prompt and accurate diagnosis with timely appropriate treatment is crucial for the successful management of acute appendicitis in spite of advances in diagnostic tools. The decision to proceed to appendectomy or not remains a surgical dilemma, especially in patients with atypical symptoms, which could be met in small children, the elderly, young females, and when the appendix is in an unusual position^[3]. The main goal in the management of atypical cases of acute appendicitis is to decrease the rate of negative appendectomies without increasing the rate of complications such as perforation and sepsis^[4].

Several scoring systems, such as the Alvarado score (AS) and Appendicitis Inflammatory Response (AIR) score were introduced, which consist of clinical and laboratory findings to aid diagnosis and predict management of patients with suspicion of acute appendicitis, but none of these is widely accepted and general consensus on any of these scores is still lacking^[5].

Since the diagnosis of acute appendicitis is mainly clinical and because of the wide differential diagnosis of right lower abdominal pain that mimics appendicitis in their presentations, negative appendectomy rates of 10–20% or even higher, especially in young female patients, were deemed to be the norm^[4]. However, this is no longer acceptable because even though the complications of negative appendectomy are low, complications and sequelae such as pelvic abscess, intestinal obstruction secondary to adhesions, and enterocutaneous fistulas secondary to stump leakages can result in significant morbidity and long hospitalization, which are cost noneffective^[6,7]. Therefore, the old saying (when in doubt, get it out) is no longer valid or accepted^[6]. Preoperative imaging, such as ultrasound and computed tomography (CT) scan imaging, has been used increasingly in the evaluation of suspicious cases of acute appendicitis to improve the diagnostic feasibility and to decrease negative appendectomy rates to less than 10%, but their role is still another major controversy, and the use of these diagnostic imaging has its own limitations, mainly the adverse effects of radiation, the cost, and the fact that they are not always available^[8,9].

The main objective of this study is to assess and compare the feasibility of clinical scores (AS and AIR scores) and imaging (graded compression ultrasound and CT scan) in the diagnosis of suspected cases of acute appendicitis and to suggest which patients should undergo CT scan to confirm acute appendicitis.

Methods

This is a prospective randomized controlled study for the period between April 2016 and December 2020 conducted in one major hospital in which 286 consecutive young and adult patients (166 males and 120 females) presented with right lower quadrant abdominal pain and a presumptive diagnosis of acute appendicitis were enrolled. Their age range is 18–46 years (average 28.2 years). Patients' characteristics and clinical data were collected and recorded (Table 1). Patients with abdominal mass diffuse peritonitis, sepsis, and pregnant patients were excluded.

Table 1

The Alvarado score (AS) and the Appendicitis Inflammatory Response (AIR) score

Diagnostic features	AS	AIR score
Migrating RIF pain	1	1
Anorexia	1	
Nausea/vomiting	1	1
Tenderness RLQ	2	
Mild		1
Moderate		2
Severe		3
Rebound tenderness	1	
Elevation of temperature	1	1
Leukocytosis	2	
> 10.0 to 14.9 × 10 ⁹ /l		1
> 15.0 × 10 ⁹ /l		2
Shift to the left of neutrophils	1	
70–84%		1
85%		2
C-reactive protein		
10–49 g/l		1
> 0 g/l		2

Alvarado score (AS): 0 ≤ 4, unlikely appendicitis; 4 to ≤ 7, equivocal; ≥ 7, probably and high likely appendicitis. Acute appendicitis response (AIR) score: 0 ≤ 5, unlikely appendicitis; 5 ≤ 8, equivocal; ≥ 9, high likely appendicitis.
RIF, right iliac fossa; RLQ, right lower quadrant.

Upon admission to the hospital, a thorough history and careful clinical exam, blood tests, and urinalysis were made for all patients. Blood tests include complete blood count, C-reactive protein (CRP), blood sugar, and pregnancy tests. Besides, abdominal and pelvic high-resolution grayscale ultrasound using graded ultrasound compressive technique and color Doppler was done for all patients. The exam was considered positive for acute appendicitis when the findings demonstrated noncompressible blind ended peristaltic tubular structure in the right lower quadrant, appendiceal diameters greater than 6 mm, and target lesion appearance in transverse section, luminal distention, free fluid in the right lower quadrant and pelvis, presence of calcified appendicolith, and localized tenderness with graded compression. The results of the ultrasound exam were distributed between consistent with acute appendicitis, not conclusive, a non-visualized appendix, and diagnostic of other pathologies.

ASs and AIR scores were calculated for all of these patients (Table 2). Abdominal and pelvic ultrasound exam was routine and done for all patients.

Sixty-two patients (38 males and 34 females) with low clinical scores (AS ≤ 4 and AIR score ≤ 5) were observed for expectant management. CT scan was done for 14 patients and appendectomy was done for 11 of them. Other patients were discharged home improved without surgical intervention, and these patients were advised to be seen 1 month later after their discharge for follow-up or consult a physician for any new complaint. None of them have recurrent symptoms or had appendectomy elsewhere within this period. These patients were considered to have no appendicitis for statistical analysis purposes.

Out of a total of 88 patients (58 males, 30 females) with ASs at least 7 and AIR score of at least 8, 42 patients were submitted for CT scans. Acute appendicitis was then considered highly probable, and thus all these patients presented for appendectomy.

Table 2
Patients characteristics and their clinical presentation

Variable	N [% (mean)]
Male	166 (58)
Female	120 (42)
Age (years)	16–52 (34.6)
Duration of symptoms (hours)	6–96 (28.6)
Migrating RIF pain	147 (51.4)
Anorexia	208 (72.7)
Nausea and vomiting	177 (61.9)
Localized tenderness	188 (71.6)
Rebound tenderness	167 (58.4)
Elevated temperature	124 (51.4)
Leukocytosis	236 (82.5)
Shift to left (neutrophilia)	221 (77.3)
C-reactive protein (elevated > 10 mg)	189 (66.1)
Urological symptoms	114 (39.9)
Gynecological symptoms	36 (12.6)
Miscellaneous (nonspecific) symptoms	26 (9)
Patients who underwent surgery	211
Clinical scores (AS and AIR)	
Low scores ≤ 4	62 (21.7)
Equivocal scores (≥ 4 to ≤ 7)	136 (47.6)
High scores ≥ 7	88 (30.8)
Patients with appendicitis	188 (89.1)
Simple	165 (78.2)
Complicated	23 (10.9)
Negative appendectomy	23 (10.9)

AIR, Appendicitis Inflammatory Response; AS, Alvarado; RIF, right iliac fossa.

Overall, 136 patients (68 males, 78 females) had atypical presentations and equivocal clinical scores (ASs between 4 and 7 and AIR scores between 5 and 8); a CT scan with IV contrast was done within 24–72 h after admission. According to CT scan findings, acute appendicitis was diagnosed in 112 patients.

CT scan findings that were consistent with acute appendicitis were appendiceal diameter greater than 6.5 mm, appendiceal wall thickening greater than 3 mm with enhancement, or peri-appendiceal inflammatory changes (fat stranding), peri-appendiceal fluid collections, appendicular mass (phlegmon), abscess formation, and appendicolith. The results of CT scans were divided accordingly into positive for acute appendicitis, equivocal or not conclusive, and negative findings for acute appendicitis.

Subsequent management was decided according to the CT scan findings; 112 out of 136 patients were preceded for appendectomy, either open or laparoscopic, which was conducted by a senior house officer under the supervision of consultant surgeons or registrars. The clinical scores, findings, and imaging results were ultimately compared with the final histopathology of the patient who underwent appendectomy. Patients whose histopathology reports showed acute appendicitis, whether simple or complicated, were considered to have undergone a therapeutic appendectomy, while those whose reports revealed a normal appendix or other different pathology were considered to have had a negative appendectomy. The sensitivity, specificity, accuracy rate, and predictive values of clinical scores and imaging were assessed and compared using the final histopathology results as the gold standard. Equivocal and not conclusive results CT scans were considered positive for acute appendicitis and indication for diagnostic laparoscopy and appendectomy even if there were no gross features of acute appendicitis. SSPS test

version 22 (SPSS, IBM Company, Chicago, Illinois, USA) and *t* test for statistical analysis. A *P* value less than 0.05 is considered statistically significant. The study was conducted in accordance with ethical principles that have their origin in the Declaration of Helsinki. It was conducted with patients' verbal and analytical approval before the sample was taken. The whole study protocol, patient information, and informed consent from all patients were reviewed and approved by a local ethics committee. The work has been reported in line with the Consolidated Standards of Reporting Trials (CONSORT) criteria (<https://www.consort-statement.org>) and was registered at researchregistry: <http://www.researchregistry.com> (registration ID).

Results

This is a prospective randomized controlled study in which a total of 286 consecutive young and adult patients (166 males, 58% and 120 females, 42%) with a presumptive diagnosis of acute appendicitis were enrolled for the period between April 2016 and December 2020. Male-to-female ratio was 1.2 : 1. Age ranged between 16 and 52 years, with a mean of 34.6 years. Patients' characteristics and their clinical presentations are illustrated in Table 2.

Clinical scores, including AS and AIR scores, were obtained for all patients enrolled in this study, and they were divided accordingly (Table 2).

Sixty-two, 21.7% (38 males, 24 females) patients recorded low clinical scores (AS ≤ 4 , AIR score ≤ 5). Ultrasound exam was done for all these patients, and diagnosis of acute appendicitis was found in 9 (14.5%) cases only. CT scan was done for 14 (22.6%) patients, and a diagnosis of acute appendicitis was made for 11 (17.7%) of them. Acute appendicitis was approved in 9 (81.8%) patients by final histopathology. The rest of the patients (51) were treated conservatively, and acute appendicitis was excluded. None of them have recurrent symptoms or had appendectomy elsewhere within the follow-up period. These patients were considered to have no appendicitis for statistical analysis purposes. The diagnosis of these cases appeared later to be as follows: 14 cases with right preterit stones, 12 cases with renal stones and UTI, 9 cases with mesenteric lymphadenitis, 5 cases with mid-cycle pain, and pelvic inflammatory disease in 4 female patients. The other 7 cases remained with a diagnosis of nonspecific abdominal pain and improved on conservative treatment (Table 3).

Table 3
Final diagnosis in patients with low clinical scores

Diagnosis	N (%)
Acute appendicitis	6 (9.7)
Complicated ovarian cyst	5 (8.0)
Right ureteric stones	14 (22.6)
Right renal stones and UTI	12 (19.4)
Mesenteric lymphadenitis	9 (14.5)
Mid-cycle pain	5 (8.0)
Pelvic inflammatory disease	4 (6.5)
Nonspecific abdominal pain	7 (11.3)
Total	62 (100)

UTI, urinary tract infection.

Patients with a score of at least 7 were 88 patients, 30.8% (54 males, 34 females); 54 (61.4. %) were patients diagnosed with this condition by ultrasound. CT scan was done for 42 patients, and diagnosis of acute appendicitis was found in 33 (37.5. %) patients diagnosed by CT scan. Appendectomy, either open or laparoscopic, was done for all these cases. Acute appendicitis was approved in 84 patients (95.5%) including 30 patients with CT scan exams.

Complementary CT scan was offered for 136 patients, 47.6% (68 males, 78 females) with atypical presentations and equivocal clinical scores (4 to ≤ 8). Acute appendicitis was diagnosed in 67 patients by ultrasound and in 112 patients by CT scan for whom appendectomy was done. Acute appendicitis was approved in 103 patients (75.7%).

Thus, out of 286 total patients presented with right lower quadrant abdominal pain, presumptive diagnosis of acute appendicitis was made in 211 patients (123 males, 88 females) after thorough clinical evaluation, clinical scores, and imaging, and submitted to appendectomy. The overall prevalence of acute appendicitis proved by histopathology as a gold standard was 89.1% (188 patients) with a negative appendectomy rate of 10.9%. Simple acute appendicitis was reported in 165 (78.2%) patients, and perforated appendicitis in 23 (10.9%) patients.

For clinical scores, a cutoff point of at least 7 for AS and at least 8 for AIR was considered diagnostic for acute appendicitis. The overall sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy rate of the AS were 88.3%, 78.5%, 87.4%, 76%, and 82.6% and those for the AIR score were 93.3%, 84.1%, 88.4%, 78.8%, and 88.6%, respectively. The data reported in this study has shown that the sensitivity, specificity, and accuracy rate of the AIR score were significantly higher than the AS; $P=0.05$ (Table 4).

The sensitivity, specificity, PPV, NPV, and accuracy rate of ultrasound in this study were 72%, 65%, 82.6%, 44.8%, and 72.2%, respectively (Table 5).

CT scan, which was requested for 192 out of 286 patients, was diagnostic for acute appendicitis in 156 patients giving a sensitivity, specificity, PPV, NPV, and accuracy rate of 93.2%, 88.7%, 72.2%, 90.3%, and 92.3%. Definite diagnosis of acute appendicitis approved by intraoperative findings and histopathology as a gold standard was approved in 144, giving an accuracy rate of 92.3%. The results further showed that the sensitivity and specificity of CT scan for perforated appendicitis were less than in simple nonperforated appendicitis (89.3 and 86.6% for perforated appendicitis versus 94.4 and 88.2% for simple appendicitis; the difference, however, was not significant; $P>0.05$). Our results showed that moderate to severe fat stranding, the presence of extraluminal air, and focal defect in enhancing appendiceal

Table 4
Diagnostic characteristics of the Alvarado and AIR scores

Diagnostic variable (%)	Alvarado score				AIR score			
	≤ 4	4-7	≥ 7	Overall	≤ 5	5-8	≥ 8	Overall
Sensitivity	86.4	76.2	93.6	88.3	91.6	79.2	96.2	93.3
Specificity	78.1	64.3	88.1	78.5	84.7	65.1	89.4	84.1
PPV	92.3	82.2	93.4	87.4	94.2	84.2	93.0	88.4
NPV	74.2	64.2	80.4	76.1	80.7	72.0	85.3	78.8
Accuracy rate	81.2	73.1	91.8	82.6	82.6	77.3	92.9	88.6

NPV, negative predictive value; PPV, positive predictive value.

Table 5
Sensitivity, specificity, predictive values and accuracy rate of clinical scores, ultrasound, and CT scan in the current study

Diagnostic variable	Clinical scores			Ultrasound (%)	CT scan (%)
	AS	AIR			
Sensitivity (%)	88.3	93.3		72	93.2
Specificity (%)	78.5	80.1		65	88.7
PPV (%)	87.4	88.4		82.6	72.2
NPV (%)	76.1	78.8		44.8	90.3
Accuracy rate (%)	82.6	86.6		72.2	92.3

AIR, Appendicitis Inflammatory Response; AS, Alvarado; CT, computed tomography; NPV, negative predictive value; PPV, positive predictive value.

wall were significantly associated with severe and perforated appendicitis. The CT scan findings in the current study are illustrated in Table 6.

Discussion

Acute appendicitis remains the most common cause of lower abdominal pain requiring surgery. Diagnosis of suspicious cases of acute appendicitis still represents a real challenge, mainly in females of childbearing age and extreme ages, where other intra-abdominal and gynecological conditions mimic acute appendicitis in their clinical presentation^[2,10]. Although the diagnosis of typical cases of acute appendicitis can be made easier depending on clinical and laboratory tests, management of query cases with an atypical presentation which constitutes about one-third to one-half of cases, represents a dilemma of balancing negative appendectomy rate and complications such as perforation and sepsis^[11]. Thus several numerical clinical scores such as AS and AIR and others were produced based on clinical data and blood inflammatory biomarkers to confirm or exclude the probability of acute appendicitis^[12]. Evidence have shown that the use of imaging like ultrasound and CT scan, in addition to clinical assessment by clinical scores that consist of symptoms, signs, and blood inflammatory biomarkers, has greatly reduced the negative appendectomy rate to less than 10%^[6,12,13].

Both the AS and AIR score systems consist of symptoms, signs, and laboratory results. Symptoms are more in the AS, while the AIR score includes a CRP value. Our results showed that the AIR

Table 6
CT scan findings of 192 patients with right lower quadrant abdominal pain suspicious for acute appendicitis

CT findings (No. 192)	N (%)
Dilated appendix (diameter ≥ 6.5 mm)	138 (66.7)
Wall thickening (> 2 mm)	129 (56.8)
Mesenteric fatty stranding	123 (48.4)
Periappendicular fluid	105 (44.3)
Appendicolith	48 (16.1)
Mesenteric lymph nodes	58 (19.8)
Extra luminal air	29 (10.9)
Focal defect in enhancing appendiceal wall	24 (7.3)
Other diagnoses	23 (5.7)
Normal appendix	19 (9.4)
Inconclusive findings	14 (3.6)

CT, computed tomography.

score is more accurate and with higher sensitivity in excluding acute appendicitis in patients with low risk (low scores ≤ 5) and also more accurate in predicting acute appendicitis in those patients with high score (≥ 7) than the AS. Our findings were consistent with the results of Kollár *et al.*^[6]. Metin *et al.*^[14] reported in their comparative study the AIR's score was more significant for the prediction of complicated appendicitis compared with the AS. They found that CRP is the most important differential item for the AIRs. The use of the AIRs can decrease unnecessary imaging studies and negative appendectomy rates. The authors of this study reported in their previous research^[15] that the combined positive results of leukocytosis, neutrophilia, and CRP results in good predictors of acute appendicitis with high sensitivity, specificity, and accuracy rate. All these three triple tests are included in the AIR scores. de Castro *et al.*^[16] in their study strongly validate the AIR score for patients with acute appendicitis. The AIR score has a high discriminating power and outperforms the AS, which supported our findings. Kollár *et al.*^[6] and de Castro *et al.*^[16] reported that the AIRs have higher accuracy and greater discriminative power than the AS in diagnosing and differentiating simple and perforated acute appendicitis as a result of the addition of the CRP. Several studies reported that acute appendicitis is unlikely when the leukocytes and CRP are normal^[17–19]. Yokoyama *et al.*^[20] have shown in their study that elevated CRP is considered to be a surgical indication marker for acute appendicitis, and its level is consistent with the severity of appendicitis.

Debates are still ongoing as to whether these imaging studies should be requested in all patients with suspected appendicitis or if they should be limited to those with atypical clinical presentations. For patients with confusing clinical presentation and equivocal clinical scores, complementary imaging like abdominal and pelvic ultrasound and CT scan can be added to the investigation as a potentially useful diagnostic tool. Multidetector CT scans and graded compression Doppler ultrasound are important imaging modalities that particularly improve diagnostic accuracy in patients with atypical or equivocal appendicitis^[21–23].

The choice between ultrasound and CT scan depends on several factors, such as availability, experience and expertise of a physician, age and sex of the patient, and duration of the illness. Graded compression ultrasound is usually requested as an initial imaging tool, particularly for young women of childbearing age and elderly patients presenting with right lower quadrant abdominal pain for the differential diagnosis of other causes of acute abdomen with reported sensitivity, specificity, PPV, NPV, and accuracy rate in the literature ranging between 55–95%, 70–98%, 80–95%, 30–88%, and 55–85%, respectively^[9,24,25]. The sensitivity, specificity, PPV, and NPV, and accuracy rate of ultrasound reported in the current study were 72%, 65%, 82.6%, 44.8%, and 77.2%, respectively, which are consistent with that reported in the literature. An ultrasound exam is rapid, cheap, noninvasive, has no ionizing radiation, and requires no patient preparations or contrast material. However, the use of graded compression has several limitations. It is operator dependant; require high level of skill and experience. Further, nonvisualization of the appendix due to patients' factors such as obesity or retrocecal position resulted in inconclusive findings. Several authors recommend ultrasound as the first imaging tool for pregnant and pediatric patients since ionizing radiation should be avoided and undesirable in these patients' subsets^[26].

When ultrasound is compared to the clinical scores for the diagnosis of query cases of acute appendicitis, none of them is significantly advantageous, and there is no advantage of ultrasound over the clinical scores for the diagnosis of acute appendicitis, but ultrasound improved diagnostic accuracy when the AS and/or AIR scores were low or equivocal. However, the false positive rate is reduced to zero when both studies are positive^[27]. When the clinical scores are high (> 7), an ultrasound is unnecessary. However, for an equivocal clinical score, the additional information provided by ultrasound could improve the diagnostic accuracy. The sensitivity, specificity, and predictive values of clinical scores and ultrasound in our study were comparable, and no significant difference was reported (Table 4). The main advantage of ultrasound was to diagnose other conditions such as complicated ovarian cysts, ectopic pregnancy, and some urological cases. We found that nonvisualized appendix and inconclusive findings by ultrasound examination did not exclude appendicitis.

In a study investigating the feasibility of ultrasound and AS in the diagnosis of acute appendicitis by Ceren *et al.*^[5], the diagnostic accuracy of ultrasound and AS was 58.8% and 51.1%, respectively, but when the two tests are combined, the diagnostic accuracy increases to 91.8%. The accuracy rate of combined tests in our study was 88.9%. Ozkan *et al.*^[9] in their comparative study, the diagnostic accuracy of ultrasound and AS were 57.7% and 65.7%, respectively. Netta *et al.*^[28] reported that patients with inconclusive ultrasound findings and low AS (< 4) are extremely unlikely to have acute appendicitis (NPV, 99.6%). Thus, avoiding unnecessary CT of these patients is a safe approach.

CT scans have been used increasingly for suspicious and atypical cases of acute appendicitis to decrease the rate of negative appendectomy, and the risk of perforation and sepsis, with a reported sensitivity and specificity ranges between 70 and 98% and 85 and 98%, respectively^[29,30]. CT scan was found by several authors to play a vital role in the management of acute appendicitis and was advised as a first-line imaging tool in the diagnostic workup for suspected acute appendicitis cases, especially those with atypical presentations and equivocal clinical scores^[30–32].

CT scan was requested for 192 out of 286 patients, including 136 patients with atypical presentations and equivocal clinical scores. It was diagnostic for acute appendicitis in 156 (81.25%) patients. Definite diagnosis of acute appendicitis approved by intraoperative findings and histopathology as a gold standard was approved in 144, giving an overall sensitivity, specificity, PPV, NPV, and accuracy rate of CT scan in this study were 93.2, 88.7, 72.2, 90.2, and 92.3, respectively. The results further showed that the sensitivity and specificity of CT scan for perforated appendicitis were less than in simple nonperforated appendicitis (89.3 and 86.6% for perforated appendicitis versus 94.4 and 88.2% for simple appendicitis; the difference, however, was not significant; $P > 0.05$). Diagnosis of acute nonperforated appendicitis was considered if two or more of the following signs were seen on the CT scan: appendiceal diameter greater than 6.5 mm, thickened enhancing wall greater than 2 mm, stranding of periappendiceal fat, and appendicolith. Signs of CT scan specific for perforated appendicitis include a defect in enhancing wall, nonenhancement focal area with enhancement of the remaining appendiceal wall, extraluminal air, extraluminal appendicolith, abscess formation, and inflammatory changes in

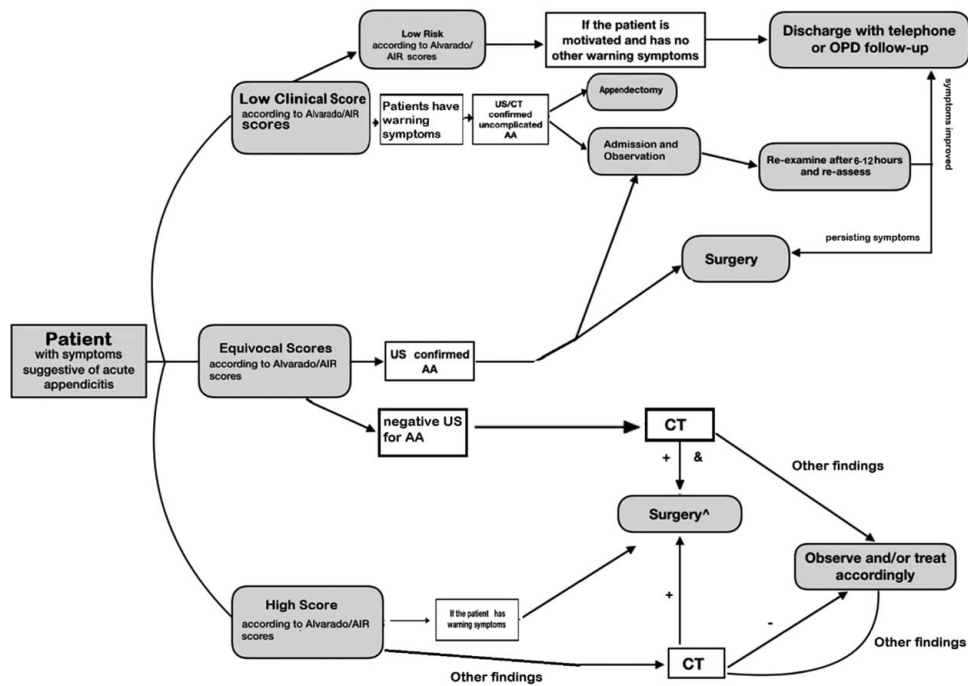


Figure 1. Algorithm for diagnosis of equivocal cases of acute appendicitis.

retroperitoneal space. In patients with equivocal clinical scores (136 patients), a CT scan was diagnostic for acute appendicitis in 112 (82.4%) patients (94 with simple nonperforated and 18 perforated appendicitis). Acute appendicitis was proved by intraoperative findings and final histopathology in 103 patients (97, 86.6%) with simple appendicitis, and 15 (13.4%) had perforated appendicitis giving a diagnostic accuracy rate of 91.7%.

Our results showed that CT scan has a valuable role mainly in patients with equivocal clinical scores (≥ 4 to ≤ 7), particularly in extreme age patients and adult female patients; the sensitivity, specificity, predictive values, and accuracy rate positive of CT scan were significantly superior to that of clinical scores. Patients with clinical scores of 7 and above are less likely to benefit from CT scan examination because the sensitivity, specificity, predictive values, and accuracy rate of clinical scores, especially AIR scores within these score ranges, were not significantly different from those of CT scan (Table 6). Therefore, patients with clinical scores of 7 and above can proceed with surgery without further imaging evaluation, which adds little, if any, for these patients. Our results further showed that patients with low clinical scores (≤ 4) have a low likelihood of acute appendicitis, and a trial of observation and conservative treatment is worthwhile. The overall sensitivity and specificity of clinical scores of 4 or less as a cutoff value to exclude acute appendicitis in this study was 92.4 and 81.6%, respectively. Our results were consistent with that recorded by Winson *et al.*^[33] and Christian *et al.*^[34].

Flum *et al.*^[35] reported in their large trial that the accuracy of diagnosing acute appendicitis and negative appendectomy has not changed or improved over the last 15 years with the increasing use of CT scans. They further found that sensitivity, specificity, and predictive values of CT scan was less for rupture and perforated appendicitis than for simple acute appendicitis. They recommended CT scan only for those patients with atypical

presentations and equivocal clinical scores, for whom a CT scan is usually the imaging modality of choice. These findings are identical to ours. Mohammad *et al.*^[36] on the other hand, reported that CT scan is markedly sensitive, as well as specific, for the differentiation of perforated from nonperforated appendicitis. This, in turn, helps in patient selection for initial nonoperative management. Other authors recommend routine complementary CT for atypical cases, retrocecal appendix, and fatty patients and to look for other diseases when ultrasound evaluation may be of little help^[37,38,39]. A study by Rao^[40] found that 42% of asymptomatic volunteers undergoing CT scans had an appendiceal diameter of greater than 6 mm and that 78% of appendices did not fill after oral contrast. Therefore, CT scan findings must be correlated with the clinical findings.

The limitations of this study were the relatively small sample size of the patients. Larger groups are needed for the evaluation of acute appendicitis with clinical scores and imaging. The second limitation is the narrow limit of the ages: this cohort does not reflect the teenage and pediatric population which lend to the most clinically challenging group to diagnose acute appendicitis (Fig. 1).

Conclusion

If the diagnosis of acute appendicitis is typical and clear from history, clinical examination, and certain inflammatory markers, mainly leukocytosis, neutrophilia, and elevated CRP (high clinical scores), no further imaging is needed. When the clinical presentation is equivocal or query and the diagnosis is uncertain, imaging such as ultrasound and CT scan may reduce the rate of negative appendectomy and rate of perforation. Clinical scores, especially AIR scores, can predict acute appendicitis with

reasonable sensitivity, specificity, predictive values, and accuracy rate. Graded compression ultrasound remains the first-choice imaging for suspicious cases of acute appendicitis, especially with low clinical scores (≤ 4); nevertheless, nonvisualized appendix or inconclusive findings do not exclude appendicitis. To solve such a clinical dilemma, an enhanced CT scan is highly sensitive, specific, and accurate in diagnosing acute appendicitis or other diagnoses in patients with equivocal scores and atypical presentations. However, the efficacy of a CT scan in diagnosing perforated appendicitis is less than in simple appendicitis.

Ethical approval

The study was approved by the ethical committee of the College of Medicine, University of Basrah.

Patient consent

Not applicable.

Sources of funding

None.

Author contribution

I.F.N. and A.F.N.: study design, data collection, and analysis; A.S.J.: writing.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

Research registration unique identifying number (UIN)

The study was registered at Researchregistry: <http://www.researchregistry.com>.

Guarantor

The study is under the authors' responsibility.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data availability statement

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