

Accuracy of Ultrasonography in Diagnosing Acute Appendicitis

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Abstract

Introduction: Appendicitis is inflammation of the appendix, a small, tubular organ in the right lower abdomen that is attached to the large intestine. **Aim:** To evaluate the accuracy of sonography in diagnosing acute appendicitis in patients with Alvarado score 4–7. **Methods:** This is a retrospective cross-sectional study. **Setting:** this study performed in Al-Emam Al-Sadeq Teaching hospital during a one-year period from 1/2023 to 1/2024. **Sample:** Patients with Alvarado score 4-7 and divided them in two groups: those with Ultrasound study prior to surgery (group A) and those without any imaging modalities for diagnosis of AA (group B). The demographic information, histopathology, physical examination, laboratory data, sonography report and histopathological reports of patients were gathered. **Results:** A total of 100 patients had Alvarado scores 4-7 including 58 males and 42 females. 50 patients did not have any imaging and 50 had undergone sonography before operation. Ultrasound had overall sensitivity of 62 %, specificity 80 %, PPV 88 %, NPV 48% and accuracy of 69 %. Negative appendectomy rate was 12 % in group A and 48 % in those group B, with a higher rate in females. **Conclusion:** Ultrasound is more useful when the patient is female, and has 78.9% specificity; however, it is not reliable when the result is negative and maybe other accessory modalities such as CT scan are required for a more accurate diagnosis. **Recommendations:** Modified Alvarado score” plus ultrasound as a method of choice for diagnosing appendicitis. Modified Alvarado score is the Alvarado score missing the shift of left of leukocytes, Health education program about early detection of appendicitis and Ongoing research about Ultrasonography in Diagnosing Acute Appendicitis

Keywords: Acute Appendicitis, Ultrasound, Alvarado Score, Sonography

Introduction

Appendicitis is inflammation of the appendix, a small, tubular organ in the right lower abdomen that is attached to the large intestine.

Common causes of acute appendicitis include infections, tumors, or accumulation of calcified feces (appendicolith) in the appendix. The most common symptom of acute appendicitis is pain in the right lower abdomen. More than half of patients first experience discomfort in the midabdominal area, which later becomes more localized to the right lower abdominal area. Other symptoms include loss of appetite, nausea, vomiting, and low-grade fever (Walter, 2021).

Acute appendicitis (AA) is with no doubt one of the most common causes of surgical emergencies worldwide. Appendectomy is the gold standard treatment for AA. A successful outcome depends on an early diagnosis followed by appendectomy before development of any complication such as gangrene or perforation. with an estimated North American incidence of 100 cases per 100,000 individuals. Early and accurate diagnosis of appendicitis is important. A missed or delayed diagnosis is associated with increased morbidity and mortality secondary to perforation, and removal of a normal appendix has been associated with increased mortality (Mekakas et al., 2022).

The clinical diagnosis of acute appendicitis is based on history and physical, laboratory evaluation, and imaging. Classic symptoms of appendicitis include vague periumbilical pain, anorexia/nausea/intermittent vomiting,

migration of pain to the right lower quadrant, and low-grade fever. The diagnosis of acute appendicitis is made in approximately 90% of patients presenting with these symptoms. Laparoscopic appendectomy remains the most common treatment. However, increasing evidence suggests that broad-spectrum antibiotics, such as piperacillin-tazobactam monotherapy or combination therapy with either cephalosporins or fluoroquinolones with metronidazole, successfully treats uncomplicated acute appendicitis in approximately 70% of patients (Moris et al., 2021).

Several scoring systems have been used globally for early diagnosis of AA. One of the most practical scoring systems is the Alvarado scoring system which is based on history, physical examination, and some laboratory investigations that are convenient to apply. Nevertheless, definite diagnosis can only be made after the operation and by histopathology examination of the collected specimens. The alvarado score consists of 8 parameters (Table 1). Patients with Alvarado scores of 9 or 10 almost certainly have AA, so the accepted management for these patients is to proceed with appendectomy as soon as possible without further work up. Patients with scores 0-4 have very low chance of having appendicitis and imaging studies are not recommended for them as well. Those that have scores of 7 and 8 are still very likely to have appendicitis and scores of 5 or 6 are not exactly diagnostic but may still have AA. These clinically equivocal cases need further investigations helping with the diagnosis (Kinesya et al., 2021).

Preoperative imaging is an important component in diagnosing appendicitis and reducing the negative appendectomy rate (NAR). According to the American College of Radiology Appropriateness Criteria, contrast-enhanced CT is the first-line imaging test for diagnosing appendicitis in adults. CT is highly accurate, with sensitivities ranging from 85.7% to 100%, specificities ranging from 94.8% to 100%, and NARs ranging from 1.7% to 7.7%. The main drawback of CT is that it exposes patients to ionizing radiation, which is of greatest concern in the pediatric and obstetric populations. CT is also more expensive than US and carries a small but quantifiable risk of allergic reaction to contrast medium (Crocker et al., 2020).

Point-of-Care Ultrasound (POCUS) is a quick, useful, noninvasive, and inexpensive diagnostic tool used for the diagnosis of trauma, abdominal pain, dyspnea, and chest pain in the emergency department (ED). However, the diagnostic accuracy of ultrasound in the ED may be different from those reported in previous studies owing to the setting and time constraints in ED (Cho et al., 2021).

Some studies suggest CT scan as a modality of choice in diagnosis of questionable cases of AA. On the other hand some other studies recommend primarily ultrasonography as a modality of choice in diagnosis of equivocal patients and CT scan should be only used for those that have inconclusive US. Ultrasonography have many advantages; it can be done quickly, it is rather cheap, requires no preparation of the patient, does not need ionizing radiation nor any contrast; plus, we do not have access to CT scan for patients suspected of acute appendicitis in our hospital setting due to large number of patients admitted in ER and relatively lower number of CT scan machines and the importance of time in diagnosis of AA. So in patients with equivocal signs of AA, it is the only accessory modality that can help the surgeon (Mittal et al., 2019)

In case of diagnosing acute appendicitis in the first diagnostic stage, low sensitivity or low NPV may lead to discharge from the emergency room (ER) of patients who actually have appendicitis. Missed diagnoses lead to treatment delay. In patients with uncomplicated appendicitis, a delay for up to at least 24 h does not appear to increase the postoperative complication rate. However, in complicated appendicitis, delaying appendectomy leads to more complications. In contrast, low specificity or low PPV may lead to overdiagnosis, causing high negative appendectomy rates (NARs). Therefore, both ruling in and ruling out acute appendicitis are important (Bom et al., 2021)

Table (1). Alvarado Score

Manifestations	Score
Symptoms	
Migratory pain	1
Anorexia	1
Nausea and/or vomiting	1

Signs	Right lower quadrant tenderness	2
	Rebound tenderness	1
	Fever	1
Laboratory data	Leukocytosis	2
	Shift to the left in leukocyte count	1
Total		10

Patient and methods

• **Design of the Study:**

This study is a retrospective cross-sectional study. All of the acute appendicitis patients at our hospital had open appendectomy due to the facility availability of equipment.

• **Setting of the study**

This study included the patients who referred from 01/2023 to 01/2024 to Al-Emam Al-Sadeq Teaching Hospital.

• **The study instruments and sampling**

We evaluated all the patients who had undergone open appendectomy, with Alvarado scores between 4-7 and divided them in two groups: (group A) were those patients that had abdominopelvic ultrasound as an accessory modality for diagnosing AA which was carried out by radiology resident prior to their surgery and (group B) were those who did not have any imaging study before their surgeries. Diagnosis of AA was made through “acute appendicitis” or “gangrenous appendix” written in the histopathology results of the appendectomy.

• **Inclusion criteria**

Patients age below 15 and above 60, patients with no medical disease (past medical history negative).

• **Exclusion criteria**

Lack of histopathological report, Alvarado score below 4 and above 7 and incomplete information needed for calculating the Alvarado score.

Administrative and ethical permission

The study protocol was approved by the medical research committee of Al-Emam Al-Sadeq General Teaching Hospital as this was a retrospective study, no informed written consents were required.

• **Study protocol**

All data including the demographic information, history, physical examination, and laboratory data such as leukocytosis, ultrasound and histopathological reports were gathered from the medical records. We then calculated the Alvarado score with the data in the patients' files. Our criteria for positive ultrasound was the exact phrase “in favor of appendicitis” written in report. We also evaluated those cases with sonography reports of “acute appendicitis” separately to evaluate the value of these reports as well.

Leukocytosis was considered as WBC \geq 11,000 and core body temperature above 37.5 °C was accounted as fever. Unfortunately, we could not evaluate shift to the left of leukocytosis which was one of the limitations of our study.

Statistical analysis

We made our statistical analysis by using The Statistical Package for social Sciences, SPSS version 19.0 and Microsoft excel (2018) in order to evaluate the results of the study.

Result

(Table 2) shows that a total of 100 patients had undergone open appendectomy during one year in Al-Emam Al-Sadeq general teaching hospital. One hundred patients had Alvarado score between 4 and 7. All patients sent for histopathology. Fifty-five of them were male (55%) and 45 patients were female (45%).

Table (3) shows that Fifty patients have ultrasound study prior to their surgery named (group A), 25 male and 25 female. Patients' age ranged from 15 to 60 years old with mean age of

Table (5) shows that Of all the 100 patients, 70 patients had acute appendicitis (confirmed by histopathological reports). Forty-four patients from group A (88%) and 26 patients from group B (%). Thirteen patients had normal appendix (13%), 2 patients from group A and 11 patients from group B. Seventeen patients had other diagnosis(17%). Four patients

Table (6) shows that Overall, Sensitivity and specificity of ultrasound in diagnosis of acute appendicitis was 62% and 80%, respectively. Due to small number of patients in extreme age groups (13 patients above 45 years old) it was impossible for us to calculate these equations separately for them; In 15 to 30 years old patients, sensitivity and specificity of ultrasound in diagnosis of acute appendicitis was 65% and 85.7% respectively, in ages between 30 to 45, sensitivity was 62% and specificity was 79.7% and in ages between 45 to 60, sensitivity was 60% and specificity was 75.2% . The overall Table (7) shows that the sensitivity of ultrasonography is 64% and 60% in males and females, respectively and the specificity was 42.8% and 78.9% for males and females, respectively.

So, the ultrasound study is more sensitive in detecting acute appendicitis in males' group. While it is very specific for diagnosis in female group. Ultrasound study was more

25.05. Eight patients were more than 45 years old (16%), 22 patients were between 15 and 30 years old (44%), 20 patients were between 30 and 45 years old (40%).

(Table 4) shows that Fifty patients do not have ultrasound study prior to their surgery named (group B), 30 male and 20 female. Patients' age ranged from 15 to 60 years old with mean age of 27.21. Five patients were more than 45 years old (10 %), 30 patients were between 15 and 30 years old (60%), 15 patients were between 30 and 45 years old (30%).

from group A and thirteen patients from group B. None of the patients had malignancy. Total negative appendectomy rate was (30%) which is 6 patients in group A(12%) and 24 patients in group B(48%). Negative appendectomies were significantly higher in females (21 were female and 9 were male).

accuracy of ultrasound in our study was 69%. The positive predictive value and the negative predictive values of ultrasound were 88% and 48% respectively. In age group of 15-30, accuracy was 71.7%, positive predictive value was 87.5% and negative predictive value was 47.6%. In age group 30-45 years the accuracy of sonography was 69%, positive predictive value was 88.4% and negative predictive value was 47%. In age group 45-60, the accuracy of sonography was 68.5%, positive predictive value was 88.9% and 49.5%.

accurate in male than females which is about (69.2%). Ultrasound not done for 50 patients. Thirty patients of them were male (30%) and 20 of them were female (20%).

Rate of perforated appendicitis was in 17 patients (17%). In group A was 6 patients (10%) and 11 patients from group B (19%)

Table (2). Gender of the patients

Patients	Males	Females	Total
With ultrasound study (group A)	25	25	50
Without ultrasound study (group B)	30	20	50
Overall	55	45	100

Table (3). Age of the patients who do Ultrasound study prior surgery (Group A)

Age of the patients who do Ultrasound study prior surgery (Group A)				
Patients	15 – 30 years	30 – 45 years	45 – 60 years	
Males	12	10	3	25
Females	10	10	5	25
Overall	22	20	8	50
Mean age was 25.05				

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Table (4). Age of the patients who do not have ultrasound study prior surgery (Group B)

Age of the patients who do not have Ultrasound study prior surgery (Group B)

Patients	15 – 30 years	30 – 45 years	45 – 60 years	
Males	17	10	3	30
Females	13	5	2	20
Overall	30	15	5	50

Mean age was 27.21

Table (5). The results of the histopathology

The results of histopathology

Patients	Confirmed	Normal	Others	
Group A	44 (TP)	2 (FP)	4 (FP)	50
Group B	26 (FN)	11 (TN)	13 (TN)	50
Overall	70	13	17	100

T P : True possative , F P : false possative , FN : False Negative , TN : True Negative

Table (6). Analytic results for patients with ultrasonography as an accessory modality of diagnosis (Group A)

Parameters	Overall	15 – 30 years	30 – 45 years	45 - 60 years
Sensitivity (%)	62%	65%	62%	60%
Specificity (%)	80%	85.7%	79.7%	75.2%
PPV (%)	88%	87.5%	88.4%	88.9%
NPV (%)	48%	47.6%	47%	49.5%
Accuracy (%)	69%	71.7%	69%	68.5%

Table (7). Analytic results for males and females patients with ultrasonography (Group A)

Parameters	Males	Female
Sensitivity (%)	64%	60%
Specificity (%)	42.8%	78.9%
Accuracy (%)	69.2%	65%

Discussion

Acute appendicitis is one of the most common etiologies of acute abdomen that leads to operation. Almost 7% of people undergo appendectomy due to diagnosis of acute appendicitis during their lifetime. Although it is a very common pathology its diagnosis still remains a challenge because it mimics many other conditions clinically. Differential diagnosis of acute appendicitis are, but not limited to, mesenteric lymphadenitis, gastroenteritis, right lower lobe pneumonia and numbers of urologic or gynecologic diseases (**Yilmaz et al., 2018**).

Normal appendix in ultrasound study is a compressible blind ended structure with the diameter of

less than 5mm. On the other hand, inflamed appendix has an anteroposterior diameter of ≥ 6 mm and is non-compressible. The existence of appendicolith in sonography also establishes AA. Pathologic criteria that are in favor of tissue diagnosis of acute appendicitis are infiltration of neutrophils in mucosa of the appendix and focal superficial ulceration of the mucosa. However, they are not definite for diagnosis of AA (**Kumar et al., 2020**).

This study showed that sonography had overall sensitivity of 62% which was not significantly different in any age groups or sex. Its overall specificity of was 80% which was significantly higher in female group (78.9% compared to 42.8%). Positive predictive value of ultrasound was 88% which was almost the same between different age groups and sex. This result was in Accordance to (**Collard**

et al.,2021) who conducted a study entitled “Adult appendicitis: Clinical practice guidelines from the French Society of Digestive Surgery and the Society of Abdominal and Digestive Imaging” who found that ultrasound has a sensitivity ranging from 49 to 90 %, a specificity ranging from 47 to 100 %, a positive predictive value of 84 to 93 %, and an overall accuracy of 72 to 94 % for the diagnosis of AA.

This study showed that negative predictive value was low (48%) and was significantly less in our male group This should lead us to the conclusion that when ultrasound report is normal we should more rely on our clinical judgment than the report or perhaps use another modality such as CT scan if possible. This result was in accordance with in agreement with (Nasiri et al., 2018) who conducted a study entitled “Diagnostic values of ultrasound and the modified alvarado scoring system in acute appendicitis” who found that there were a significant difference between positive and negative predictive value of sonography confirming our results (88% for PPV in comparison to 48% for NPV)

Accuracy of ultrasound in our study was 69% which is less than some other studies. From the researcher point of view this due to Ultrasound has also some limitations as well, for example appendix can be covered by overlying gas or overriding boney pelvis. The site of the appendix can also influence on the possibility of evaluation of appendix by ultrasound (e.g. a retrocecal appendix). Obesity is another factor influencing the optimality of sonography. Another problem is that we do not have enough data for the terms like “clinically equivocal” or “suspicious case” in literature to exactly guide us when to perform US .It is however recommended that CT scan is useful for those with Alvarado score between5-8

This study showed that total negative appendectomy rate was 30% (n=30). It was significantly less in male group that was 15% (n=9) compared to female group that was 50% (n=21). There was no same study as ours to evaluate negative appendectomy rates only between Alvarado scores of 4-7. 17 of our negative appendectomies were diagnosed as other pathologies, 13 were normal. No malignancy case was reported. We compared patients that had ultrasound prior to their surgeries (group A) and those who did not have (group B). In group A negative appendectomy rate was 12% and in group B it was 40%.

There were 17 cases of perforated appendicitis. Six patients in group A but there were only 11 cases in those patients without any imaging modalities. From these 17 patients, ultrasound successfully diagnosed 4 cases, was suspicious in 8 cases and was falsely normal in 5 cases. The time from the onset of the disease to accurate diagnosis and treatment is critical in management of patients with acute appendicitis. Delay in diagnosis may cause increased risk of perforation and other complications. In addition, ironically, ultrasound becomes less efficient when there is perforation because the appendix becomes compressible (Li, 2021).

Ultrasound is a rapid modality that can be performed bedside; however, in our hospital it is not performed by a general surgery resident or radiologist in the ER. The

procedure is performed by radiology residents in ultrasound room, so it takes some time to consult with radiology senior and send the patient to sonography room. For this reason, patients who undergo sonography will lose a considerable time. However, it is only a hypothesis because it was not possible for us in this study to exactly measure the time spent from the moment a patient appear to the ER till the time that ultrasound is done for him/her. Important to mention here is that most of our patient who were proceeded with surgery without any further imaging studies were male patients. We do not know whether the gender of the patients have any effect on the perforation rate of acute appendicitis per se.

The biggest limitation of this study was the retrospective nature of it which made us dependent to what was being recorded in patient’s files. Data regarding shift to the left of neutrophils was not available as well; so, we had to omit this criterion from Alvarado score calculation; for the same reason we evaluated patients with Alvarado score between 4-7 instead of 5-8.

Conclusion

Based on the study finding and research hypothesis It can be concluded that

Ultrasound is more useful when the patient is female, and has 78.9% specificity; however, it is not reliable when the result is negative and maybe other accessory modalities such as CT scan are required for a more accurate diagnosis.

Recommendations

On the basis of the result of the study, the following recommendations are suggested

- 1- “modified Alvarado score” plus ultrasound as a method of choice for diagnosing appendicitis. Modified Alvarado score is the Alvarado score missing the shift of left of leukocytes.
- 2- Health education program about early detection of appendicitis.
- 3- Ongoing research about Ultrasonography in Diagnosing Acute Appendicitis

Conflict of Interest

The authors declare no conflict of interest

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