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Assessing the Precision of Ultrasound in Diagnosing Acute Appendicitis

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Abstract

Acute appendicitis is a frequently occurring abdominal ailment that is well-known for its difficult diagnosis. It is critical to get an accurate and timely diagnosis in order to reduce the dangers of postponing surgical surgery. The purpose of this study is to evaluate the diagnostic performance of ultrasonography in Saudi Arabian patients of acute appendicitis in comparison with histological results. It also aims to investigate any possible relationship between the proficiency of the sonographers participating and the accuracy of ultrasound in identifying acute appendicitis.

A retrospective analysis was carried out on patients who had ultrasonography examination and who presented to the emergency department with a clinical suspicion of acute appendicitis. Every patient had multiple diagnostic criteria recorded, including wall thickness, compressibility, appendix visibility, free fluid presence, appendix diameter ≥7 mm, and compressibility.

The findings showed that only 61 of the 132 patients had an appropriate ultrasonography diagnosis. Of these, 17 were true negatives and 44 were true positives for appendicitis. On the other hand, 2 patients with negative histological findings were mistakenly diagnosed as positive on ultrasonography, and 69 patients with positive histopathological results were given false negative ultrasound diagnosis. Remarkably, there was no discernible correlation found between the sonographers' experience level and ultrasound accuracy.

The study's findings highlight the inadequate diagnostic precision of ultrasonography in the identification of instances of acute appendicitis. Moreover, it implies that sonographers' years of expertise had little bearing on how accurately acute appendicitis was diagnosed by ultrasonography.
Keywords: acute appendicitis, diagnostic accuracy, abdominal ultrasonography, sonographer expertise

Introduction

Approximately 7% of people may experience acute appendicitis in their lives, making it a common abdominal ailment. Because it can mimic a number of gastrointestinal, urologic, or gynecologic disorders based on clinical and laboratory data, diagnosing it can be rather difficult. Misdiagnosis and needless laparotomy in pregnant patients can cause serious consequences that negatively impact the health of the fetus. The degree of inflammation frequently leads to variable clinical presentations, and every 12 hours, there is a 5% increase in the chance of perforation. This highlights the significance of prompt management to reduce the risk of harmful outcomes, including wound abscesses and perforation. It has been observed that the fatality rate from acute appendicitis is about 0.25% in all age categories. (Omari et al., 2014)

Positive appendectomies result from traditional diagnostic methods that only include the patient's history and physical examination; these rates can range from 16% to 47%. These rates are lowered to 6% to 10% when medical imaging modalities are included in the diagnostic procedure. Among imaging modalities, computed tomography (CT) is the most sensitive and specific for appendicitis diagnosis. However, exposure to ionizing radiation limits its use, especially in pregnant women and children. (Vriesman and Puylaert, 2006)

A good substitute is ultrasound (US), a non-ionizing imaging method. Its use in pediatric patients has resulted in a significant drop in negative appendectomy rates, which helps to minimize radiation exposure—which is especially important in cases involving young patients. The safety profile, affordability, and real-time imaging capabilities of US have made it a popular diagnostic tool for appendicitis since its inception in the 1980s. But when it comes to identifying probable cases of acute appendicitis, graded compression ultrasonography's performance varies greatly. Its sensitivity and specificity range from 44% to 100% and 47% to 99%, respectively.

This variability may be attributed to the sonographer's expertise and skill level. (Storm-Dickerson and Horattas, 2003)

In a major Saudi Arabian hospital, this study attempts to evaluate the diagnostic accuracy of US in instances of acute appendicitis by contrasting its effectiveness with histology, which is the gold standard, and by looking into possible relationships between sonographer skill and ultrasound accuracy. (Wagner et al., 2008)

Materials and Methods

Patients

Between February 2019 and December 2020, an observational, retrospective, hospital-based cross-sectional investigation was carried out in The Applied Hospital, King Saud City, Al-Shemaysi, Saudi Arabia. Patients who had ultrasonography (US) exams after presenting to the emergency room (ED) with clinical symptoms suggestive of acute appendicitis were included in the study. From each patient's medical file, information was taken out regarding their age, sex, sonography report, and histopathological findings. The time between the US examination and the surgery, however, was not recorded.

Medical Staff

Emergency physicians directed patients displaying clinical signs of probable acute appendicitis to the radiology department for assessment in the US. Radiologists wrote the sonography reports and oversaw the sonographers as they performed the ultrasound tests. Surgeons made the decision to either monitor the patient or perform an emergency surgical intervention based on the patient's clinical symptoms and sonography results.

US Procedure

The US scanners used for all US examinations were the Philips iU22 or xMATRIX models (Philips, Seattle, WA, USA). Depending on the patient's weight, a linear transducer (5-7 MHz) or a curvilinear transducer (3.5 MHz) was used, and an appendicitis assessment was conducted using a graded compression technique. Every patient had multiple diagnostic parameters recorded, such as wall thickness, appendix visibility, compressibility, free fluid presence, appendix diameter ≥7 mm, and normal look.

Histopathological Results

Following surgery, the histopathological results for every patient were obtained from their medical records. The surgically excised appendices were subjected to

macroscopic and microscopic assessments as part of the histopathology investigation, which focused on symptoms of both acute and chronic inflammation as well as luminal blockage.

Data Analysis

To summarize the data, descriptive statistics such as percentage and frequency were employed. Measures of diagnostic accuracy that were calculated included sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and total accuracy. To evaluate relationships between sonographer experience, diagnostic accuracy, and sociodemographic traits (age and sex), the Chi-square test for independent samples was utilized. The Chi-square test was used to compare the diagnostic performances of sonographers who were divided into three expertise groupings. A bar graph was created to show the specificity and sensitivity of US against several acute appendicitis diagnostic characteristics. In addition, the association between patient age and US features was displayed using a boxplot. Statistical Package for the Social Sciences (SPSS) Version 24 (IBM Corporation, Armonk, NY, USA) was used to analyze data at a 95% confidence interval.

Results

There were 132 patients in the research. Most of the patients (59.8%) belonged to the age group of 21 to 40 years old. The sociodemographic details of the patients and the US diagnosis' accuracy are displayed in Table 1. The accuracy of the US diagnosis did not significantly correlate with the subjects' age ($p = 0.42$) or sex ($p = 0.42$).

Table 1. Socio-demographic characteristics of the patients and accuracy of the ultrasound diagnosis.

Socio-demographic Characteristics	**Number of Patients (%)**	**Number of Accurate Diagnosis (%)**
Sex		
Male	48 (36.4%)	20 (32.8%)
Female	84 (63.6%)	41 (67.2%)
Age range		
1–20	37 (28%)	18 (48.6%)
21–40	79 (59.8%)	36 (47.4%)
41–60	7 (5.3%)	4 (50%)
61–80	7 (5.3%)	1 (14.3%)

81–100	1 (0.76%)	0 (0.0%)

Note: There was no significant association between the accuracy of the ultrasound diagnosis and the sex and age of the subjects.

Out of the 132 individuals in the study, only 61 had a correct ultrasound diagnosis. Of them, only 44 had an appendix diagnosis (true positives) and 17 had a true negative (not appendicitis). erroneous negative diagnoses were given to 69 patients with positive histopathologic results, whereas erroneous positive diagnoses were given to 2 patients with negative histopathologic findings. The results of the analysis showed that the US had the following values: 89.5% specificity (95% CI 66.8 to 98.7), positive predictive values (PPV) of 95.7% (95% CI 85.3 to 98.8), negative predictive values (NPV) of 19.8% (95% CI 16.6 to 23.4), and sensitivity of 38.9% (95% CI 29.9 to 48.5). Overall diagnosis accuracy was 46.2% (95% confidence interval 37.5–55). The two cases that were mistakenly labeled as positive (false positive) had free fluid in one patient and diameter ≥7 mm in the other. Additionally, both patients were female.

Table 2 displays variations in sonographers' years of experience and how well they diagnose appendicitis. It was discovered that there were no appreciable differences in sensitivity and specificity across any grouping. a comparison made between the ultrasound features that were utilized to make the diagnosis that the sonographers reported and the true and inaccurate US diagnoses. Six categories were created from these US traits, and each category was compared to the histopathological diagnoses (Table 3).

Table 2. The expertise of sonographers and their diagnostic performance in diagnosing appendicitis.

Experience	Sensitivity (%)	Specificity (%)
<10 years	36	83.3
10–19 years	31	89
>20 years	52	100

Note: Chi-square test revealed no significant differences in sensitivity and specificity between the subgroups based on sonographer experience.

Table 3. Ultrasound findings for appendicitis diagnoses.

Imaging Feature	Accurate (N = 61)	Missed (N = 71)
Diameter ≥ 7 mm	17	6
Free fluid	28	25

Lack of compressibility	5	7
No appendix seen	7	24
Normal appearance	2	7
Other	2	2

It was done to evaluate age (years), sensitivity, and specificity against US image attributes. Using a thematic approach, these traits were divided into six main groups, which were then cross-checked with the histopathological diagnosis, as seen in Figures 1-3.

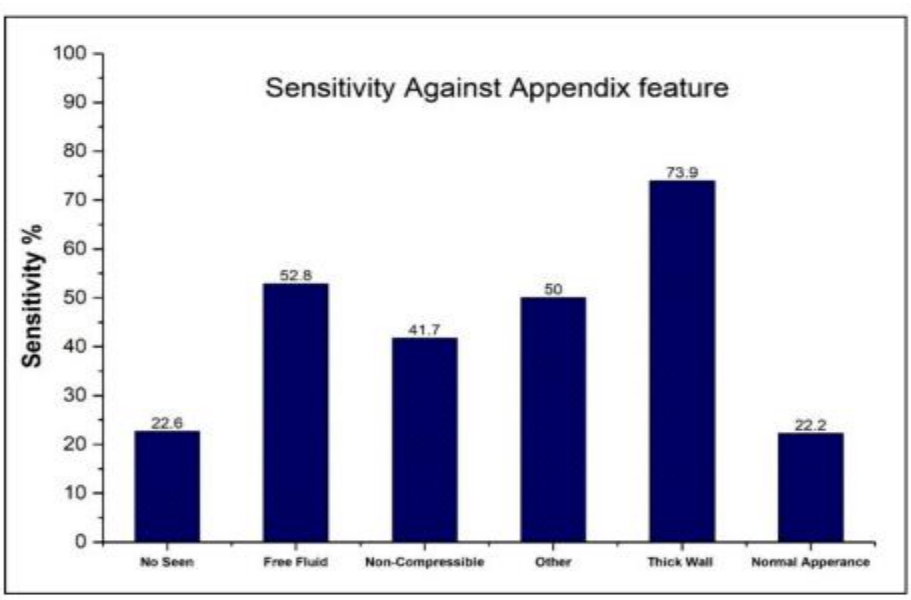

Figure 1. Sensitivity readings against image features.

Figure 2. Specificity readings against image features.

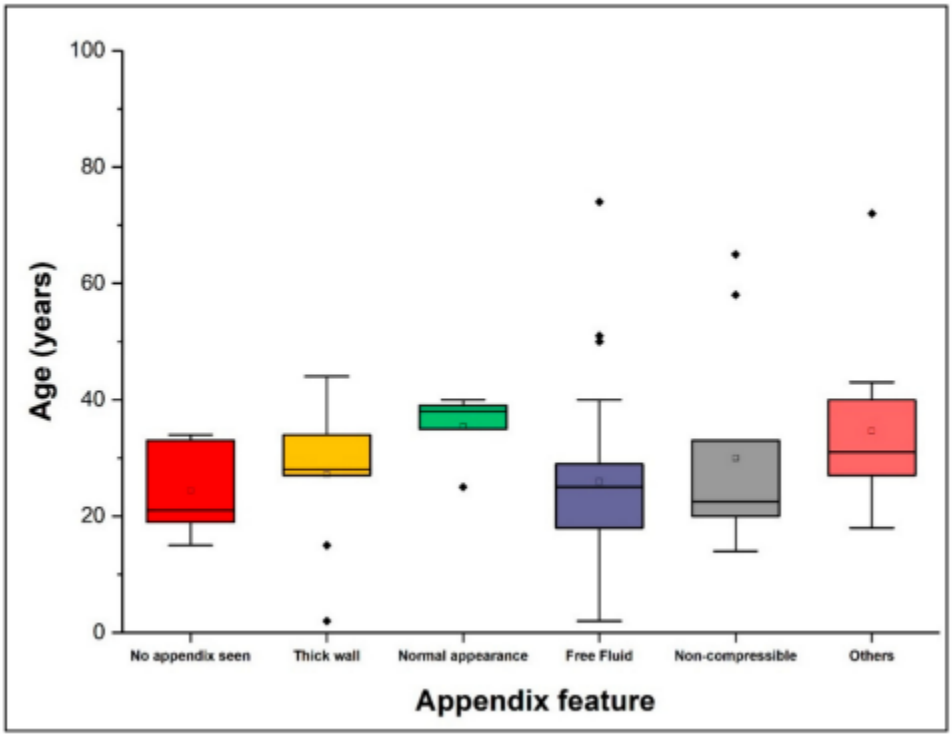

Figure 3. Boxplot illustrating the relationship between patients' age and image features. The black dots represent data outliers.

Discussion

In addition to a physical examination, US has been promoted as a test that could aid in the diagnosis of acute appendicitis. Furthermore, there is now considerable interest in determining the diagnostic accuracy of US for acute appendicitis because to its non-ionizing characteristics. The uncertainty around the diagnostic accuracy of US, as this study has investigated, is the lone disadvantage of using it as a diagnostic method. (Hanafi and Shiri, 2018)

Its specificity ranges from 47% to 99%, and its range is between 44% and 100%. On the other hand, reports have also indicated that if a person with a high degree of competence in the topic makes the diagnosis, the sensitivity of US can reach 90%. (Lee et al., 2001)

In the current investigation, the US had an 89.5% specificity and 38.9% sensitivity for detecting acute appendicitis. The study also showed that there was no meaningful correlation between the sonographers' years of experience and the accuracy of US diagnosis. In this study, only 46.2% of the patients had the proper diagnosis. (Pinto et al., 2013)

D'Souza et al. claim that because US is not sensitive enough to diagnose appendicitis, the appendix is not frequently visible by US. In the current investigation, there were 24 false-negative cases out of a total of 31 patients, and in 21.8% of cases, the appendix could not be visualized. (D'Souza et al., 2015)

When the appendix is deep within the pelvis or positioned retrocecally, the US cannot detect it. Additionally, the detection of appendicitis may be hampered by abundant overlaying intestinal gas. The skill of the sonographer performing the operation also affects the diagnosis. On the other hand, our results provide little proof that years of expertise enhance a sonographer's ability to diagnose appendicitis. (Lorusso et al., 2012)

According to Lee et al., 16% of appendectomies are negative. (Lee et al., 2001) In this study, the percentage of negative appendectomies was far lower—just 1.4% of cases were false positives. Al-Ajerami reported a figure of 4.4%, whereas Summa et al. claimed that 2.2% of appendicitis diagnoses were false positives. (Al-Ajerami, 2012)

The outer diameter of the vermiform appendix is the most important feature that can affect the US diagnosis of acute appendicitis. When the outside diameter of the vermiform appendix was 7 mm or larger, a prior study reported a sensitivity of 97%

and a PPV of 97%; however, it also revealed a significant percentage of false positives. Inadequate compressibility may also impact diagnosis; hence, reports of 85% sensitivity and 93% PPV have been made. (Brown, 2008)

In this investigation, US was used to accurately diagnose cases when the vermiform appendix's diameter was 7 mm or greater, yielding a sensitivity of 74% and a PPV of 93.3% (refer to Figure 4a, b). A sensitivity of 53% and a PPV of 95% were also made possible by the presence of free fluid (See Figure 4c). Free fluid is a commonly recognized secondary characteristic that is not unique to appendicitis but may frequently be symptomatic of an abdominal ailment. About half of the cases in this study that had free fluid also didn't have a clearly visible appendix. Hence, radiologists contend that in order to verify the inflammation, the appendix needs to be examined. However, the appendix's visibility is frequently challenging. It has been discovered that a follow-up ultrasound examination is required a few hours later to check for secondary characteristics. It greatly enhanced both patient management and ultrasound sensitivity. (Van Randen et al., 2011)

Figure 4. Cont.

Figure 4. Longitudinal (a) and transverse (b) real-time ultrasound scan of acute appendicitis with diameter > 7 mm (white measure) and wall thickness 2.6 mm (green measure) for 33-year-old male patient with pain in the right lower quadrant; transverse (c) real-time ultrasound scan for 34-year-old female patient with suspected appendicitis shows free fluid in the right lower quadrant

The results of the investigation indicated that there was no meaningful correlation between the patients' age and sex and the diagnosis's accuracy. But compared to male patients, female patients received fewer accurate diagnoses. These results are consistent with those of Al-Ajerami and Paulson et al. Gynecological disorders, such as ruptured or bleeding ovarian cysts, may be the cause of the increased frequency of false positives in female patients. These illnesses can mirror the signs and symptoms of acute appendicitis. (Al-Ajerami, 2012)

Because the study population was drawn retrospectively from patients who had appendicemas, it is possible that the study design contributed to the insignificance

of the relationship between the years of expertise of the sonographer and the accuracy of the diagnosis. Additionally, because of the nature of this study, it was not possible to record any cases in which US decided that the appendix was normal and avoided unnecessary surgery. (Hussain et al., 2014)

The results of this investigation showed that US had low NPV, high PPV, high specificity, and low sensitivity, which is also in line with most previous studies. This study also shown the poor diagnosis accuracy in the US. This is consistent with the results of a systematic review and meta-analysis that found there is no difference in the diagnostic accuracy between US and physical examination. But given US's high positive predictive value, it may be the first test to be employed in the diagnosis of acute appendicitis. When making a clinical decision, however, caution should be exercised because this study revealed that in over two-thirds of the instances, US was unable to identify a positive acute appendicitis. Therefore, in highly suspected cases, it could be preferable to perform a CT scan in order to reduce the possibility of serious consequences. According to a prior review, CT's excellent sensitivity (87–100%) and specificity (89–99%) along with its technical repeatability make it a viable option for use as a confirmatory test. (Paulson et al., 2003)

There are several restrictions on this study. Examples of circumstances that might have impacted the accuracy of the diagnosis include the patient's weight, the placement of their appendix retrocectally, and whether or not they were fasting.

Recognizing that at this particular central hospital, ultrasound (US) is not the primary technique utilized to assess appendicitis situations, our study aims to investigate the potential advantages of employing US as a first-line modality to reduce the need for ionizing radiation (CT). To understand the variation in US accuracy, more research could thoroughly audit the sonographers' performance. (Russell et al., 2013)

Conclusion

The study found that although US was not very accurate in diagnosing cases of acute appendicitis, its high specificity and positive predictive value (PPV) justified the use of US as a first-line test for the diagnosis of acute appendicitis.

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