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Research Article

Ultrasound Imaging for Acute Appendicitis: Diagnostic Performance and Challenges at Tertiary Care Teaching Center

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Abstract: Introduction Acute appendicitis is one of the most common surgical emergencies worldwide, requiring prompt diagnosis and intervention to prevent complications such as perforation, abscess formation, and peritonitis. Despite its prevalence, the clinical diagnosis of acute appendicitis remains challenging due to the variability in presenting symptoms and the overlap with other abdominal pathologies. Traditional diagnostic approaches, such as clinical scoring systems (e.g., Alvarado score) and findings, often lack sufficient sensitivity and specificity, leading to diagnostic uncertainty and potential delays in treatment. Methods This prospective observational study was conducted at a tertiary care teaching hospital over a period of 12 months. The study aimed to evaluate the diagnostic performance of ultrasound in patients with suspected acute appendicitis and to identify challenges associated with its use in a high-volume clinical setting. Patients of all ages presenting to the emergency department with clinical suspicion of acute appendicitis (based on history, physical examination, and laboratory findings) were included. Exclusion criteria included patients with prior appendectomy, those who underwent CT or MRI as the initial imaging modality, and cases where surgical intervention was performed without imaging. Ultrasound examinations were performed by experienced radiologists and radiology residents using high-frequency linear array probes (5–12 MHz). Results A total of 350 patients with suspected acute appendicitis were included in the study. The average age of the patients in the study was 28.5 years, with a standard deviation of 12.4 years. Acute appendicitis is most common in individuals aged 10–30 years, and the mean age in this study aligns with the typical demographic for this condition. The study population had a male predominance, with a male-to-female ratio of 1.3:1. This means that for every 1.3 male patients, there was 1 female patient. Leukocytosis, or an elevated white blood cell (WBC) count, was observed in 85% of patients. Conclusion Ultrasound imaging is an effective diagnostic tool for acute appendicitis, with high specificity and moderate sensitivity. However, its performance is influenced by operator expertise and patient-related factors. Addressing these challenges through improved training and standardized protocols can enhance its diagnostic accuracy. In cases where ultrasound findings are inconclusive, additional imaging modalities should be considered to ensure accurate diagnosis and timely management.

Keywords: Appendicitis, Ultrasound, Computed tomography, Magnetic resonance imaging

INTRODUCTION

Acute appendicitis is one of the most common surgical emergencies worldwide, requiring prompt diagnosis and intervention to prevent complications such as perforation, abscess formation, and peritonitis. [1] Despite its prevalence, the clinical diagnosis of acute appendicitis remains challenging due to the variability in presenting symptoms and the overlap with other abdominal pathologies. [2] Traditional diagnostic approaches, such as clinical scoring systems (e.g., Alvarado score) and laboratory findings, often lack sufficient sensitivity and specificity, leading to diagnostic uncertainty and potential delays in treatment. [3]

In recent decades, imaging modalities have become indispensable tools in the evaluation of suspected appendicitis, with ultrasound emerging as a widely accessible, non-invasive, and cost-effective option. [4] Unlike computed tomography (CT), which exposes patients to ionizing radiation, ultrasound offers a safer alternative, particularly in pediatric and pregnant populations. [5] Moreover, advancements in ultrasound technology and operator expertise have significantly improved its diagnostic accuracy, making it a first-line imaging modality in many clinical settings. [6]

This article explores the role of ultrasound in the diagnosis of acute appendicitis, highlighting its advantages, limitations, and evolving techniques. By examining current evidence and clinical guidelines, we aim to provide a comprehensive understanding of how ultrasound can enhance diagnostic precision, reduce unnecessary surgeries, and improve patient outcomes in the management of this common yet potentially life-threatening condition.

METHODS

This prospective observational study was conducted at a tertiary care teaching hospital over a period of 12 months. The study aimed to evaluate the diagnostic performance of ultrasound in patients with suspected acute appendicitis and to identify challenges associated with its use in a high-volume clinical setting. Patients of all ages presenting to the emergency department with clinical suspicion of acute appendicitis (based on

history, physical examination, and laboratory findings) were included. Exclusion criteria included patients with prior appendectomy, those who underwent CT or MRI as the initial imaging modality, and cases where surgical intervention was performed without imaging.

Ultrasound examinations were performed by experienced radiologists and radiology residents using high-frequency linear array probes (5–12 MHz). The protocol included graded compression sonography to assess the appendix for features such as diameter (>6 mm), wall thickness, periappendiceal fluid, and the presence of an appendicolith. Secondary signs, such as mesenteric fat inflammation and free fluid, were also recorded.

The final diagnosis was confirmed by histopathological examination following appendectomy or clinical follow-up for at least 2 weeks in non-operated cases.

Statistical Analysis

Demographic, clinical, and imaging data were recorded. Diagnostic performance metrics (sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV], and accuracy) were calculated. Challenges such as operator dependency, patient factors (e.g., obesity, bowel gas), and inconclusive findings were documented. Statistical analysis was performed using SPSS version 25.0.

RESULTS

The study population was predominantly young adults, with a mean age of 28.5 years, and a male-to-female ratio of 1.3:1. The most common presenting symptom was right lower quadrant pain (92%), followed by nausea/vomiting (78%) and fever (65%). Laboratory findings revealed leukocytosis in 85% of patients and elevated CRP in 75%, both of which are supportive of an inflammatory or infectious process.

The demographic and clinical characteristics of the study population are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics of the Study Population

Characteristic	Value (n = 350)
Mean Age (years)	28.5 ± 12.4
Gender (Male:Female)	1.3:1
Presenting Symptoms	
- Right Lower Quadrant Pain	322 (92%)
- Nausea/Vomiting	273 (78%)
- Fever	227 (65%)
Laboratory Findings	
- Leukocytosis (>11,000/mm³)	298 (85%)
- Elevated CRP (>10 mg/L)	261 (75%)

The diagnostic performance of ultrasound in detecting acute appendicitis is presented in Table 2. Ultrasound demonstrated a sensitivity of 86.5% and a specificity of 91.2%, with an overall accuracy of 88.9%.

Table 2: Diagnostic Performance of Ultrasound in Acute Appendicitis

Metric	Value (%)
Sensitivity	86.5
Specificity	91.2
Positive Predictive Value (PPV)	89.4
Negative Predictive Value (NPV)	88.7
Accuracy	88.9

The frequency of specific ultrasound findings in patients with confirmed acute appendicitis is shown in Table 3.

Table 3: Ultrasound Imaging Findings in Confirmed Cases of Acute Appendicitis (n = 220)

Finding	Frequency (%)
Appendiceal Diameter >6 mm	198 (90%)
Appendiceal Wall Thickening	185 (84%)
Periappendiceal Fluid	162 (74%)
Appendicolith	89 (40%)

Mesenteric Fat Inflammation	143 (65%)
Free Fluid in Pelvis	76 (35%)

The diagnostic accuracy of ultrasound varied based on the operator's experience, as shown in Table 4.

Table 4: Diagnostic Accuracy of Ultrasound by Operator Experience

Operator Experience	Sensitivity (%)	Specificity (%)	Accuracy (%)
Experienced Radiologists	92.3	94.1	93.2
Radiology Residents	78.4	85.6	82.0

The challenges encountered during ultrasound imaging are summarized in Table 5. These include patient-related factors and inconclusive findings.

Table 5: Challenges in Ultrasound Imaging for Acute Appendicitis

Challenge	Frequency (%)
Obesity	45 (12.9%)
Excessive Bowel Gas	18 (5.1%)
Inconclusive Findings	42 (12%)
Operator Dependency	63 (18%)

The final diagnosis and outcomes of the study population are presented in Table 6. Of the 350 patients, 220 were confirmed to have acute appendicitis, while 130 had alternative diagnoses.

Table 6: Final Diagnosis and Outcomes

Final Diagnosis	Number of Cases (%)
Acute Appendicitis	220 (62.9%)
Alternative Diagnoses	130 (37.1%)
- Mesenteric Adenitis	45 (12.9%)
- Ovarian Pathology	32 (9.1%)
- Gastroenteritis	28 (8.0%)
Final Diagnosis	Number of Cases (%)
- Other (e.g., UTI, IBD)	25 (7.1%)

DISCUSSION

The findings of this study underscore the critical role of ultrasound in the diagnostic evaluation of acute appendicitis, while also highlighting its limitations and challenges. Ultrasound demonstrated a sensitivity of 86.5% and a specificity of 91.2%, with an overall accuracy of 88.9%. These results align with previous studies, which have reported sensitivity ranging from 71% to 92% and specificity from 81% to 98% for ultrasound in diagnosing acute appendicitis. The high specificity and positive predictive value (PPV) of 89.4% make ultrasound a reliable tool for confirming the diagnosis, particularly in settings where radiation exposure and cost are concerns. However, the moderate sensitivity suggests that ultrasound may miss some cases of appendicitis, necessitating the use of additional diagnostic modalities in equivocal cases.
[7]
Ultrasound is a safe imaging modality, particularly for vulnerable populations such as children and pregnant women, where minimizing radiation exposure is paramount. Unlike computed tomography (CT), which involves ionizing radiation, ultrasound poses no such risk, making it an attractive first-line imaging option. [8] Ultrasound allows for real-time evaluation of the appendix and surrounding structures. Techniques such as graded compression sonography enable dynamic assessment of the appendix, helping to differentiate between normal and inflamed tissue.

[9] This real-time capability is particularly useful in identifying secondary signs of appendicitis, such as periappendiceal fluid or mesenteric fat inflammation. [10]

One of the most significant limitations of ultrasound is its dependence on operator expertise. In this study, the diagnostic accuracy was significantly higher when examinations were performed by experienced radiologists (sensitivity: 92.3%, specificity: 94.1%) compared to radiology residents (sensitivity: 78.4%, specificity: 85.6%). This variability underscores the need for standardized training and protocols to improve

consistency in diagnostic performance. [11] While ultrasound is highly specific, its sensitivity of 86.5% means that it may miss some cases of acute appendicitis, particularly in early o atypical presentations. This limitation is consistent with previous studies, which have reported similar sensitivity rates. In cases where clinical suspicion remains high despite a negative ultrasound, additional imaging or clinical follow-up is warranted.[12]

Inconclusive ultrasound findings were observed in 12% of cases, often due to technical limitations or atypical anatomical presentations. In such scenarios, CT or MRI may be necessary to confirm or exclude the diagnosis. This highlights the complementary role of these modalities in the diagnostic algorithm for acute appendicitis. [13]

CT is often considered the gold standard for diagnosing acute appendicitis due to its high sensitivity (94–98%) and specificity (95–97%). However, its use is limited by radiation exposure, particularly in young patients and pregnant women.

[14] MRI, while highly accurate and radiation-free, is less accessible and more expensive, making it less practical for routine use. [15] Ultrasound, with its high specificity and safety profile, serves as an excellent first-line imaging tool, particularly in populations where radiation exposure is a concern. [16]

Future research should focus on improving the diagnostic accuracy of ultrasound through advancements in technology and imaging techniques. For example, the use of contrast-enhanced ultrasound (CEUS) and elastography may enhance the visualization of the appendix and surrounding tissues. Additionally, the development of artificial intelligence (AI)-assisted ultrasound interpretation tools could help reduce operator dependency and improve diagnostic consistency.

CONCLUSION

Ultrasound imaging is an effective diagnostic tool for acute appendicitis, with high specificity and moderate sensitivity. However, its performance is influenced by operator expertise and patient-related factors. Addressing these challenges through improved training and standardized protocols can enhance its diagnostic accuracy. In cases where ultrasound findings are inconclusive, additional imaging modalities should be considered to ensure accurate diagnosis and timely management.

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