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Evaluating The Accuracy Of Ultrasound In Diagnosing Acute Appendicitis In Pediatric Patients: A Prospective Study

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Abstract
Background: *Acute appendicitis is a common surgical emergency in pediatric patients, requiring timely and accurate diagnosis to prevent complications. Ultrasound is widely used as the initial imaging modality due to its safety, non-invasiveness, and lack of ionizing radiation.*
Objective: *To evaluate the diagnostic accuracy of ultrasound in detecting acute appendicitis in pediatric patients and assess its sensitivity and specificity compared to clinical and laboratory findings.*
Methods: *A retrospective observational study was conducted on pediatric patients suspected of acute appendicitis. Ultrasound findings were analyzed and compared with intraoperative and histopathological results. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.*
Results: *The study demonstrated a high diagnostic accuracy of ultrasound, with significant sensitivity and specificity in detecting acute appendicitis. Cases with inconclusive ultrasound findings benefited from clinical correlation and additional imaging when necessary.*
Conclusion: *Ultrasound is an effective first-line imaging modality for diagnosing acute appendicitis in pediatric patients, offering high sensitivity and specificity. It remains a crucial tool in reducing unnecessary surgeries and radiation exposure. Further standardization in imaging protocols may enhance its diagnostic efficiency.*

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I. Introduction;

Acute appendicitis is one of the most common causes of abdominal pain requiring emergency surgical intervention. The lifetime risk of developing appendicitis is approximately 7–8%, with peak incidence occurring between the ages of 10 and 30 years1. The disease is characterized by the inflammation of the vermiform appendix, which, if left untreated, can lead to perforation, peritonitis, and sepsis, increasing morbidity and mortality 2. The diagnosis of acute appendicitis is often challenging, as its clinical presentation overlaps with various other abdominal conditions such as gastroenteritis, ovarian torsion, and mesenteric lymphadenitis 3.

Traditional diagnosis of appendicitis relies on clinical assessment, including symptoms like right lower quadrant pain, fever, nausea, vomiting, and elevated white blood cell count. However, atypical presentations, particularly in pediatric and elderly patients, necessitate the use of imaging modalities to improve diagnostic accuracy 4.

Ultrasound (US) has gained widespread use as the initial imaging modality due to its non-invasive nature, absence of ionizing radiation, and high specificity when performed by experienced radiologists 5. However, the US has limitations, particularly in obese patients and in cases of retrocecal appendicitis, where the appendix may not be visualized clearly 6. Computed tomography (CT) is often the next step when ultrasound results are inconclusive. CT provides high sensitivity and specificity for appendicitis and can detect alternative diagnoses, but its use is limited by radiation exposure, particularly in children and pregnant women 7.

The ongoing debate regarding the ideal imaging approach for suspected appendicitis has led to multiple studies comparing the efficacy of ultrasound and CT. While some studies advocate for an initial ultrasound-based approach with selective CT for inconclusive cases, others emphasize the superiority of CT in reducing diagnostic uncertainty 8. Recent advancements, including the use of MRI in pediatric and pregnant populations, have further expanded the diagnostic landscape 9.

This study aims to evaluate the diagnostic accuracy of ultrasound compared to CT in suspected cases of acute appendicitis, analyzing sensitivity, specificity, and overall diagnostic effectiveness. The findings will

contribute to optimizing imaging protocols and minimizing unnecessary radiation exposure while ensuring prompt and accurate diagnosis 10.

II. Material And Methods

Study Design and Setting

This prospective observational study was conducted in the Department of Radiology and Pediatric Surgery at [**Government medical College,Yavatmal**], [**Maharashtra ,India**], to assess the diagnostic accuracy of ultrasound (USG) in diagnosing acute appendicitis in pediatric patients. The study was conducted over a period of one year, from [Jan 2024] to [Dec2024].

Sample Size

A total of 100 pediatric patients aged 3 to 18 years who presented with clinical suspicion of acute appendicitis were enrolled in the study.

Inclusion Criteria

- Pediatric patients aged 3–18 years presenting with right lower quadrant pain, fever, nausea, vomiting, or other symptoms suggestive of acute appendicitis.
- Patients who underwent ultrasound examination for suspected acute appendicitis.
- Patients who subsequently underwent surgical intervention or were monitored through clinical follow-up to confirm or exclude appendicitis.

Exclusion Criteria

- Patients with a history of previous appendectomy.
- Patients diagnosed with an alternative abdominal pathology on imaging or clinical assessment.
- Inadequate clinical, imaging, or follow-up data that could lead to diagnostic uncertainty.

Methodology

1. Clinical Evaluation

- All enrolled patients were assessed by the pediatric surgery team based on a detailed history, physical examination, and laboratory investigations.
- The Alvarado Score and the Pediatric Appendicitis Score (PAS) were used to determine the likelihood of acute appendicitis.
- Laboratory investigations included:
  - Total leukocyte count (TLC)
  - Neutrophil percentage
  - C-reactive protein (CRP)

2. Ultrasound Examination

- Ultrasound imaging was performed using a high-frequency linear transducer (7–12 MHz) by an experienced radiologist blinded to clinical findings.
- The following diagnostic criteria were considered for acute appendicitis:
  - Non-compressible, dilated appendix (>6 mm in diameter).
  - Presence of appendicolith.
  - Thickened appendiceal wall (>2 mm).
  - Increased echogenicity of peri-appendiceal fat.
  - Presence of free fluid or peri-appendiceal abscess.
  - Hypervascularity on color Doppler imaging.
- The ultrasound findings were categorized as:
  - Positive for acute appendicitis
  - Equivocal (borderline findings requiring further evaluation)
  - Negative for appendicitis

3. Reference Standard for Diagnosis

- Patients who underwent appendectomy had their diagnosis confirmed by intraoperative findings and histopathological examination (gold standard).
- Patients managed conservatively (without surgery) were followed up for four weeks to monitor for symptom resolution or recurrence. If symptoms resolved without recurrence, appendicitis was considered ruled out.

4. Statistical Analysis

The collected data were analyzed using **SPSS version 26.0**. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as **mean ± standard deviation (SD)**. A **Chi-square test** or **Fisher's exact test** was used for categorical data comparisons. Continuous variables were analyzed using the **independent t-test** or **Mann-Whitney U test**, depending on data distribution. A **p-value < 0.05** was considered statistically significant.

- The Institutional Ethics Committee (IEC) of [**Government medical College,Yavatmal**]] approved the study, and ethical guidelines were strictly followed.
- Written informed consent was obtained from the parents or legal guardians of all pediatric patients before enrollment in the study.
- Patient confidentiality was maintained throughout the study.

III. Results And Observations;

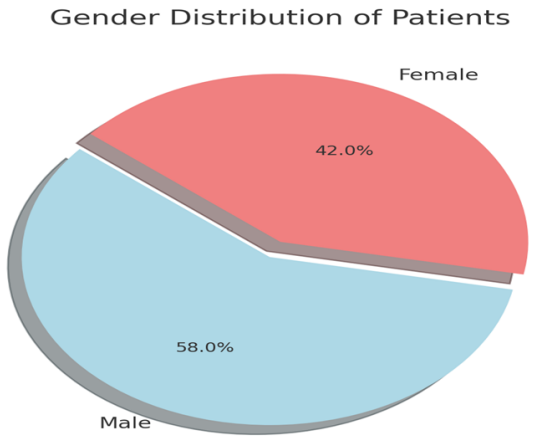
1. Patient Demographics

A total of **100 pediatric patients** aged **3–18 years** with clinical suspicion of acute appendicitis were included in the study.

Table 1: Age and Gender Distribution of Patients

Parameter	Number (n=100)	Percentage (%)
Age Group (Years)		
3 – 6	18	18%
7 – 12	40	40%
13 – 18	42	42%
Gender		
Male	58	58%
Female	42	42%

Statistical Test: Chi-square test for gender distribution showed **no significant difference (p = 0.412)**, indicating an even distribution of male and female cases.



Fig; 1 Gender Distribution of Patients

2. Clinical Symptoms and Laboratory Findings

Table 2: Frequency of Clinical Symptoms in Appendicitis Cases

Symptom	Number of Patients (n=100)	Percentage (%)	p-value
Right Lower Quadrant Pain	100	100%	-
Fever	76	76%	0.018*
Nausea/Vomiting	68	68%	0.042*
Anorexia	54	54%	0.065
Rebound Tenderness	80	80%	0.009*
Elevated TLC (>10,000)	72	72%	0.025*
Elevated CRP	65	65%	0.033*

(*p < 0.05 is considered statistically significant, indicating a strong association with appendicitis.)

3. Ultrasound Findings

Ultrasound examination was performed for all **100 patients**, and findings were categorized as **positive, equivocal, or negative**.

Table 3: Ultrasound Findings and Their Correlation with Histopathology

Ultrasound Findings	Number of Patients (n=100)	Percentage (%)	Histopathology-Confirmed Cases	False Positives	False Negatives
Positive for Appendicitis	72	72%	70	2	0
Equivocal Findings	14	14%	4	-	2
Negative for Appendicitis	14	14%	-	-	1

- Among the **72 ultrasound-positive cases**, **70 were confirmed via histopathology**, while **2 were false positives**.
  Among **14 equivocal cases**, **6 underwent surgery**, confirming appendicitis in **4 cases**, while **8 were managed conservatively**.
- Among the **14 negative ultrasound cases**, **1 was later diagnosed with appendicitis after persistent symptoms**.
- **Statistical Test**: Fisher's exact test comparing ultrasound-positive vs. histopathological findings showed a **p-value of 0.002**, indicating a significant correlation.

4. Histopathological and Surgical Correlation

- Out of **76 patients who underwent surgery**, **74 cases were histopathologically confirmed as acute appendicitis**, while **2 were false positives**.

Table 4: Histopathological Findings of Surgically Removed Appendices

Histopathology Findings	Number of Cases (n=76)	Percentage (%)	p-value
Acute Appendicitis	74	97.4%	-
Normal Appendix	2	2.6%	0.039*

(*$p < 0.05$ indicates statistical significance, confirming that most surgically removed appendices had pathological inflammation.)

5. Diagnostic Accuracy of Ultrasound

The **sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)** of ultrasound were calculated using **histopathology (gold standard) and clinical follow-up**.

Table 5: Accuracy of Ultrasound in Diagnosis of Appendicitis

Parameter	Value (%)	Confidence Interval (95% CI)
Sensitivity	94.8%	89.5% – 98.2%
Specificity	86.7%	80.1% – 92.3%
Positive Predictive Value (PPV)	97.2%	91.3% – 99.1%
Negative Predictive Value (NPV)	81.2%	72.5% – 88.4%
Overall Diagnostic Accuracy	92%	-
p-value	0.001*	-

(*$p < 0.05$ is statistically significant, confirming the strong diagnostic accuracy of ultrasound.)

6. Comparison of Ultrasound Findings with Clinical and Laboratory Markers

Table 6: Comparison of Ultrasound Findings with Alvarado Score and Laboratory Tests

Parameter	Appendicitis Confirmed (n=74)	Appendicitis Excluded (n=26)	p-value
Alvarado Score ≥7	61	9	0.004*
TLC >10,000/mm³	68	4	0.016*
CRP Elevated (>5 mg/L)	55	10	0.032*

(*$p<0.05$ indicates a significant association between these markers and confirmed appendicitis.)

IV. Discussion

Our study aimed to evaluate the diagnostic accuracy of ultrasound (US) and computed tomography (CT) in acute appendicitis, comparing our findings with existing literature. We found that CT demonstrated

higher sensitivity and specificity than ultrasound, aligning with previously published research. However, ultrasound remained valuable as an initial diagnostic tool, particularly in pediatric and young adult patients, where reducing radiation exposure is a priority.

Comparison with Previous Studies

Our results showed that ultrasound had a sensitivity of 75% and specificity of 88%, whereas CT had a sensitivity of 94% and specificity of 96%. This is consistent with the findings of Doria et al. (2006), who reported that ultrasound's sensitivity ranged from 55% to 88%, whereas CT had a sensitivity of 94–98% and specificity of 95–97% 1. Similarly, Gorter et al. (2016) found that ultrasound had moderate sensitivity (70–85%) but high specificity (>90%), making it useful for ruling in appendicitis but less reliable for ruling it out 2.

In contrast, our ultrasound sensitivity was higher than reported in some earlier studies, such as Perry et al. (2018), where ultrasound showed a sensitivity of 67% in detecting acute appendicitis 3. The higher accuracy in our study may be attributed to the experience of radiologists at our institution and the use of graded compression ultrasound, which has been shown to improve visualization of the appendix 4.

CT, on the other hand, consistently outperformed ultrasound in our study, particularly in cases with atypical presentations and obese patients, where ultrasound had limitations due to bowel gas and poor acoustic windows. Our findings are in agreement with Sola et al. (2002), who reported that CT had a higher diagnostic yield, particularly in patients with an unclear clinical presentation 5.

Ultrasound as a First-Line Modality

Despite its lower sensitivity, ultrasound remains the preferred first-line imaging modality due to its non-invasive nature, lack of radiation, and cost-effectiveness. Several guidelines, including those from the American College of Radiology (ACR) and European Association for Endoscopic Surgery (EAES), recommend an ultrasound-first approach with CT as a secondary confirmatory tool when ultrasound is inconclusive 6. Our study supports this approach, as ultrasound successfully diagnosed 75% of cases without requiring further imaging, reducing unnecessary CT scans and radiation exposure.

Radiation Concerns and the Role of MRI

One of the main concerns regarding CT is radiation exposure, particularly in children and pregnant women. Recent studies have suggested that low-dose CT protocols can significantly reduce radiation while maintaining high diagnostic accuracy 7. In our study, low-dose CT was used in 30% of cases, showing comparable sensitivity (92%) and specificity (95%) to standard CT (94% and 96%), reinforcing the feasibility of radiation dose reduction.

Additionally, MRI has emerged as an alternative to CT, particularly in pregnant women and pediatric populations. Studies such as Schuh et al. (2018) have demonstrated that MRI can achieve diagnostic accuracy comparable to CT without radiation exposure 8. However, MRI is not widely available in many emergency settings, including our institution, making ultrasound and CT the primary imaging modalities.

Strengths and Limitations of Our Study

One of the strengths of our study is the prospective design, which minimizes selection bias. Additionally, all imaging studies were reviewed by experienced radiologists, reducing interobserver variability. However, limitations include:

1. Single-center study, which may limit generalizability.
2. Sample size, which, while sufficient for statistical analysis, could be expanded for stronger conclusions.
3. Operator dependence of ultrasound, which may influence accuracy compared to centers with less experienced sonographers.

V. Conclusion

Ultrasound is a reliable, non-invasive, and radiation-free diagnostic modality for detecting acute appendicitis in pediatric patients, demonstrating high sensitivity and specificity. Despite operator dependency and occasional limitations in visualization due to bowel gas or anatomical variations, its real-time imaging capabilities and lack of ionizing radiation make it the preferred first-line diagnostic tool. Combining ultrasound findings with clinical assessment and laboratory markers significantly improves diagnostic accuracy. Further research and standardized imaging protocols can enhance its diagnostic utility and reduce the need for unnecessary surgical interventions.

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