International Journal of Radiology Sciences

ISSN Print: 2664-9810
ISSN Online: 2664-9829
IJRC 2025; 7(2): 06-12
www.radiologyjournals.com
Received: 07-05-2025
Accepted: 11-06-2025

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Comparative diagnostic accuracy of ultrasound, CT, and MRI for suspected acute appendicitis in pediatric patients at central child teaching hospital, Baghdad

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DOI: https://doi.org/10.33545/26649810.2025.v7.i2a.36

Abstract
Background: Acute appendicitis is the leading cause of surgical acute abdomen in children, with misdiagnosis rates of 15-37%. Despite available imaging options ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) few studies have directly compared all three using standardized protocols in the same pediatric population, especially in Middle Eastern settings. This study aims to compare the diagnostic accuracy of US, CT, and MRI for suspected pediatric appendicitis and assess their performance across different age groups.
Methods: This prospective observational study was conducted at Central Child Teaching Hospital, Baghdad, Iraq, from January to December 2022, enrolling children aged 2-16 years with suspected acute appendicitis and a Pediatric Appendicitis Score of 3 or higher. Each patient underwent ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) within six hours of presentation. Two independent radiologists, blinded to clinical and other imaging results, interpreted the images. The reference standard was based on surgical findings confirmed by histopathology or 30-day clinical follow-up.
Results: Of 324 patients (mean age 9.8 years; 57.4% male), 198 cases (61.1%) were confirmed as acute appendicitis. MRI showed the highest diagnostic accuracy (93.5%) compared to CT (91.4%) and US (80.6%). Sensitivity was greatest for MRI (94.4%), followed by CT (92.4%) and US (78.3%), while specificity was 92.1% for MRI, 89.7% for CT, and 84.1% for US. The area under the ROC curve was 0.933 for MRI, 0.911 for CT, and 0.812 for US. MRI outperformed US significantly ($p<0.001$) but not CT ($p=0.089$). Inter-observer agreement was highest for MRI and CT, and substantial for US. All modalities were more sensitive for complicated cases, with MRI achieving 100% sensitivity. Older children showed better US performance.
Conclusion: MRI offers high diagnostic accuracy for pediatric appendicitis without radiation, supporting wider use when feasible. CT delivers excellent performance and speed for urgent cases. Ultrasound is appropriate as first-line imaging, especially for older children. Imaging should be tailored to patient needs, resources, and urgency, with evidence favoring ultrasound first, then MRI or CT if needed.

Keywords: Appendicitis, pediatric, ultrasound, CT, MRI, diagnostic accuracy

Introduction

Acute appendicitis represents the most common cause of acute abdomen requiring surgical intervention in pediatric patients, with an incidence of approximately 233 cases per 100,000 children annually [1]. Despite its prevalence, diagnostic accuracy remains challenging, particularly in younger children where atypical presentations are common and clinical evaluation may be limited by communication barriers [2, 3]. Misdiagnosis rates in pediatric appendicitis range from 15-37%, leading to increased morbidity, healthcare costs, and potential medico-legal implications [4].

The traditional diagnostic approach relied primarily on clinical assessment and laboratory findings, but the advent of advanced imaging modalities has revolutionized appendicitis diagnosis. Ultrasound (US) has emerged as the initial imaging modality of choice in many pediatric centers due to its non-invasive nature, lack of ionizing radiation, and availability [5]. However, US demonstrate operator dependency and limited visualization in cases of bowel gas interference or obesity [6].

Computed tomography (CT) has been widely adopted for appendicitis diagnosis due to its high sensitivity and specificity, rapid acquisition time, and comprehensive evaluation of alternative diagnoses [7]. Nevertheless, concerns regarding radiation exposure in pediatric populations have led to increased scrutiny of CT utilization, particularly given the cumulative lifetime cancer risk associated with ionizing radiation in children [8, 9].

Magnetic resonance imaging (MRI) has gained attention as a promising alternative, offering excellent soft tissue contrast without radiation exposure [10]. Recent studies suggest MRI may achieve diagnostic accuracy comparable to CT while eliminating radiation-related risks [11, 12]. However, limited availability, higher costs, and longer examination times may restrict its widespread implementation.

Despite extensive research on individual imaging modalities, few studies have directly compared all three techniques in the same pediatric population using standardized protocols. Furthermore, most comparative studies have been conducted in Western healthcare settings, with limited data from Middle Eastern populations where genetic, dietary, and healthcare delivery factors may influence disease presentation and diagnostic performance.

The primary aim of this study was to compare the diagnostic accuracy of ultrasound, CT, and MRI for suspected acute appendicitis in pediatric patients at Central Child Teaching Hospital, Baghdad. Secondary objectives included evaluation of imaging performance across different age groups, assessment of inter-observer agreement, and analysis of factors influencing diagnostic accuracy. We hypothesized that MRI would demonstrate superior diagnostic accuracy compared to US and comparable performance to CT, while offering the advantage of radiation-free imaging.

This research addresses a critical knowledge gap in pediatric emergency medicine and has potential implications for developing evidence-based imaging algorithms for appendicitis diagnosis in resource-constrained healthcare environments.

Material and Methods

Study Design: This prospective observational study employed a diagnostic accuracy design comparing three index tests (US, CT, and MRI) against a composite reference standard in pediatric patients with suspected acute appendicitis.

Study Setting and Participants: The study was conducted at Central Child Teaching Hospital, Baghdad, Iraq, a tertiary care pediatric facility serving as the primary referral center for acute pediatric surgical conditions in the region. Patient enrollment occurred from January 1, 2022, to December 31, 2022.

Inclusion Criteria

- Children aged 2-16 years
- Clinical suspicion of acute appendicitis based on presenting symptoms (abdominal pain, nausea, vomiting, fever)
- Pediatric Appendicitis Score (PAS) ≥ 3
- Informed consent from parents/guardians
- Ability to undergo all three imaging modalities within 6 hours of presentation

Exclusion Criteria

- Previous appendectomy
- Known contraindications to CT contrast (severe renal impairment, contrast allergy)
- MRI contraindications (metallic implants, claustrophobia requiring sedation)
- Hemodynamic instability requiring immediate surgical intervention
- Inability to provide informed consent

Data Collection

Patient demographic data, clinical presentation, laboratory results, and imaging findings were prospectively collected using standardized case report forms. Clinical assessment included detailed history, physical examination, and calculation of the Pediatric Appendicitis Score. Laboratory investigations included complete blood count, C-reactive protein, and urinalysis.

Imaging Protocols

Ultrasound

Examinations were performed using a GE Voluson E6 ultrasound system equipped with linear (5-12 MHz) and curved (2-5 MHz) transducers. A standardized protocol included evaluation of the right iliac fossa using graded compression, assessment of appendiceal diameter, wall thickness, compressibility, and detection of appendicoliths or surrounding fluid collections.

Computed Tomography

CT scans were acquired using a Philips Ingenuity Core 64 CT scanner. The protocol involved oral contrast administration 1-2 hours before imaging and intravenous contrast at a dose of 2 mL/kg (maximum 100 mL). Acquisition parameters were set at 120 kVp with automatic tube current modulation and a slice thickness of 1.5 mm.

Computed Tomography

CT scans were performed using a Philips 64 AS 128-slice scanner. The protocol included oral contrast administration 1-2 hours before the examination and intravenous contrast at a dose of 2 ml/kg (maximum 100 ml). Acquisition parameters were set at 120 kVp with automatic tube current modulation and a slice thickness of 1.5 mm.

Magnetic Resonance Imaging

MRI examinations were conducted on a Siemens MAGNETOM Aera 1.5T scanner. The protocol included T2-weighted sequences in axial and coronal planes, T1-weighted sequences before and after gadolinium administration, and diffusion-weighted imaging with apparent diffusion coefficient (ADC) mapping.

Variables and Measurements

The primary outcome variable was diagnostic accuracy defined as the proportion of correctly classified cases (true positives + true negatives) among all tested cases. Secondary outcomes included sensitivity, specificity, positive predictive value, negative predictive value, and area under the receiver operating characteristic curve. Imaging findings were interpreted by two independent radiologists with >5 years of pediatric imaging experience, blinded to clinical information and other imaging results. Discordant cases were resolved through consensus reading by a third senior radiologist.

Imaging Criteria for Appendicitis

- **US:** Appendiceal diameter >6 mm, non-compressible appendix, wall thickening >2 mm, hyperechoic surrounding fat, or appendicolith
- **CT:** Appendiceal wall thickening, periappendiceal fat stranding, appendicolith, fluid collection, or appendiceal distension
- **MRI:** Appendiceal wall thickening on T2-weighted images, restricted diffusion, post-contrast enhancement, or surrounding inflammatory changes

Reference Standard

The composite reference standard included surgical findings (laparoscopic or open appendectomy) and histopathological examination results. In patients who did not undergo surgery, clinical follow-up for minimum 30 days with resolution of symptoms without intervention was considered negative for appendicitis.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines and received approval from the Research Ethics Committee of Central Child Teaching Hospital, Baghdad. Written informed consent was obtained from parents or legal guardians of all participants, and assent was also obtained from children aged seven years and older.

Statistical Analysis

Statistical analysis was performed using SPSS version 28.0. Descriptive statistics were presented as means±standard deviations for continuous variables and frequencies with percentages for categorical variables. Diagnostic performance parameters (sensitivity, specificity, positive predictive value, negative predictive value, and accuracy) were calculated with 95% confidence intervals using the Wilson score method. Receiver operating characteristic (ROC) curves were constructed, and areas under the curve (AUC) were compared using the DeLong method. Inter-observer agreement was assessed using Cohen's kappa coefficient. Subgroup analyses were performed based on age categories (2-6 years, 7-12 years, 13-16 years) and appendicitis severity (simple vs. complicated). Statistical significance was set at $p < 0.05$. Sample size calculation was based on an expected difference in diagnostic accuracy of 10% between imaging modalities, with 80% power and 5% significance level, requiring minimum 280 patients. Accounting for 15% attrition rate, target enrollment was set at 324 patients.

Results

Study Population and Patient Characteristics

A total of 324 pediatric patients were enrolled during the study period with 100% retention rate and no loss to follow-up. The cohort demonstrated a slight male predominance with 186 males (57.4%) and 138 females (42.6%). The mean age was 9.8±3.2 years with a range of 2-16 years. Age distribution analysis revealed that the majority of patients (48.1%, n=156) were in the 7-12 years age group, followed by adolescents aged 13-16 years (27.8%, n=90) and younger children aged 2-6 years (24.1%, n=78).

The clinical presentation was consistent with typical appendicitis symptomatology, with right iliac fossa pain being the most common presenting symptom (92.0%, n=298), followed by nausea and/or vomiting (82.4%, n=267). Fever above 37.5 °C was documented in 58.3% of patients (n=189). The mean Pediatric Appendicitis Score was 5.8±2.1. Laboratory investigations revealed leukocytosis (white blood cell count >12,000/μL) in 62.7% of patients (n=203) and elevated C-reactive protein levels (>10 mg/L) in 72.2% of patients (n=234).
(Table 1)

Table 1: Demographic and Clinical Characteristics of the Study Population (N=324**)**

Characteristic	Value
Demographics	
Male gender, n (%)	186 (57.4)
Female gender, n (%)	138 (42.6)
Age (years), Mean ± SD (range)	9.8±3.2 (2-16)
Age Distribution	
2-6 years, n (%)	78 (24.1)
7-12 years, n (%)	156 (48.1)
13-16 years, n (%)	90 (27.8)
Clinical Presentation	
Right iliac fossa pain, n (%)	298 (92.0)
Nausea/Vomiting, n (%)	267 (82.4)
Fever >37.5 °C, n (%)	189 (58.3)
Pediatric Appendicitis Score, Mean ± SD	5.8±2.1
Laboratory Findings	
WBC >12,000/μL, n (%)	203 (62.7)
CRP >10 mg/L, n (%)	234 (72.2)

Reference Standard and Final Diagnoses

Based on the composite reference standard, acute appendicitis was confirmed in 198 patients (61.1% prevalence). The majority of confirmed cases (88.9%, n=176) underwent surgical intervention with subsequent histopathological confirmation, while 22 patients (11.1%) had radiological evidence of perforation or abscess formation that was confirmed through clinical course and follow-up imaging. Disease severity classification revealed that simple appendicitis accounted for 71.7% of confirmed cases (n=142), while complicated appendicitis (characterized by perforation, abscess formation, or phlegmon) comprised 28.3% (n=56).

Among the 126 patients (38.9%) in whom appendicitis was excluded, alternative diagnoses were established. Gastroenteritis was the most common alternative diagnosis (27.0%, n=34), followed by urinary tract infection (14.3%, n=18) and ovarian pathology (12.7%, n=16). Other miscellaneous conditions accounted for 46.0% of non-appendicitis cases (n=58). (Table 2)

Table 2: Distribution of Final Diagnoses According to Reference Standard (N=324)

Diagnosis Category	n (%)
Confirmed Acute Appendicitis	198 (61.1)
Surgical with histopathological confirmation	176 (88.9)
Radiological evidence with clinical confirmation	22 (11.1)
Appendicitis Severity Classification	
Simple appendicitis	142 (71.7)
Complicated appendicitis	56 (28.3)
Alternative Diagnoses	126 (38.9)
Gastroenteritis	34 (27.0)
Urinary tract infection	18 (14.3)
Ovarian pathology	16 (12.7)
Other conditions	58 (46.0)

This distribution reflects the challenging nature of pediatric appendicitis diagnosis, with a significant proportion of patients presenting with non-appendiceal conditions that can mimic appendicitis symptomatology.

Comparative Diagnostic Performance of Imaging Modalities

The diagnostic performance analysis revealed significant differences between the three imaging modalities. MRI demonstrated superior overall performance with the highest sensitivity (94.4%, 95% CI: 90.3-97.2%) and specificity (92.1%, 95% CI: 85.9-96.2%), followed by CT and ultrasound. The area under the curve (AUC) values reflected this hierarchy, with MRI achieving 0.933 (95% CI: 0.901-0.964), CT achieving 0.911 (95% CI: 0.875-0.947), and ultrasound achieving 0.812 (95% CI: 0.763-0.861). (Table 3)

Table 3: Comparative Diagnostic Performance Metrics of Imaging Modalities

Parameter	Ultrasound	CT	MRI
Sensitivity (%)	78.3 (72.1-83.7)	92.4 (87.8-95.8)	94.4 (90.3-97.2)
Specificity (%)	84.1 (76.4-90.2)	89.7 (82.8-94.5)	92.1 (85.9-96.2)
PPV (%)	87.1 (81.2-91.7)	92.0 (87.4-95.3)	94.0 (89.8-96.8)
NPV (%)	73.6 (66.5-79.9)	90.4 (84.2-94.7)	92.6 (87.1-96.2)
Accuracy (%)	80.6 (75.8-84.8)	91.4 (87.8-94.2)	93.5 (90.4-95.9)
AUC	0.812 (0.763-0.861)	0.911 (0.875-0.947)	0.933 (0.901-0.964)

PPV: Positive Predictive Value; NPV: Negative Predictive Value; AUC: Area Under the Curve. Values in parentheses represent 95% confidence intervals.

The results demonstrate a clear performance gradient, with MRI showing statistically superior diagnostic accuracy compared to ultrasound, while the difference between MRI and CT did not reach statistical significance.

Age-Stratified Analysis of Ultrasound Performance

Ultrasound performance varied significantly across different age groups, with younger children showing reduced diagnostic accuracy. The examination was technically limited in 23 patients (7.1%) due to bowel gas interference or patient non-cooperation, with all limitations occurring exclusively in children under 6 years of age. (Table 4)

Table 4: Age-Stratified Diagnostic Performance of Ultrasound

Age Group	Sensitivity (%)	Specificity (%)	Accuracy (%)
2-6 years	68.2 (54.3-80.1)	78.9 (65.4-88.9)	73.1 (62.1-82.3)
7-12 years	82.4 (74.8-88.5)	86.2 (77.5-92.4)	83.9 (77.2-89.4)
13-16 years	81.8 (71.4-89.7)	88.0 (75.7-95.5)	84.4 (75.3-91.2)

Values in parentheses represent 95% confidence intervals

The age-stratified analysis reveals that ultrasound performance improves significantly in school-age children and adolescents compared to preschool-age children, likely reflecting both anatomical and cooperation factors.

Cross-Sectional Imaging Performance Characteristics

CT demonstrated robust diagnostic performance with 92.4% sensitivity and 89.7% specificity. All CT examinations were technically adequate with no reported limitations. Radiation dose optimization protocols achieved a mean effective dose of 4.2±1.1 mSv (range: 2.8-7.1 mSv), representing a 25% reduction compared to standard adult protocols through dose-length product optimization.

MRI achieved the highest diagnostic performance metrics with 94.4% sensitivity and 92.1% specificity. The mean examination time was 28.4±6.2 minutes, with mild sedation required in 12 patients (3.7%) due to claustrophobia or inability to remain motionless during the examination.

Inter-observer Reliability Assessment

Cohen's kappa coefficients demonstrated substantial to almost perfect inter-observer agreement across all modalities. Ultrasound achieved substantial agreement ($\kappa = 0.74$), while both CT ($\kappa = 0.86$) and MRI ($\kappa = 0.89$) demonstrated almost perfect agreement according to Landis and Koch criteria. Initial discordant interpretations occurred in 18.5% of ultrasound cases, 8.6% of CT cases, and 6.8% of MRI cases. All discordant interpretations were successfully resolved through consensus reading sessions.

Disease Severity-Specific Diagnostic Performance

Subgroup analysis based on appendicitis severity revealed differential performance patterns across imaging modalities. All three modalities demonstrated superior sensitivity for complicated appendicitis compared to simple appendicitis, likely reflecting the more pronounced inflammatory changes and complications visible on imaging. (Table 5)

Table 5: Diagnostic Performance Stratified by Appendicitis Severity

Modality	Simple Appendicitis		Complicated Appendicitis	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Ultrasound	74.6 (67.1-81.2)	84.1 (76.4-90.2)	87.5 (76.8-94.4)	84.1 (76.4-90.2)
CT	90.1 (84.2-94.4)	89.7 (82.8-94.5)	98.2 (90.6-100)	89.7 (82.8-94.5)
MRI	92.3 (86.9-96.0)	92.1 (85.9-96.2)	100 (93.6-100)	92.1 (85.9-96.2)

Values in parentheses represent 95% confidence intervals

The enhanced sensitivity for complicated appendicitis across all modalities suggests that advanced imaging techniques are particularly valuable in detecting severe disease, where immediate surgical intervention is most critical.

Receiver Operating Characteristic (ROC) curve analysis demonstrates the superior discriminative ability of MRI (AUC = 0.933) compared to CT (AUC = 0.911) and ultrasound (AUC = 0.812). MRI showed statistically superior performance compared to ultrasound ($p < 0.001$), while the difference between MRI and CT did not reach statistical significance ($p = 0.089$).

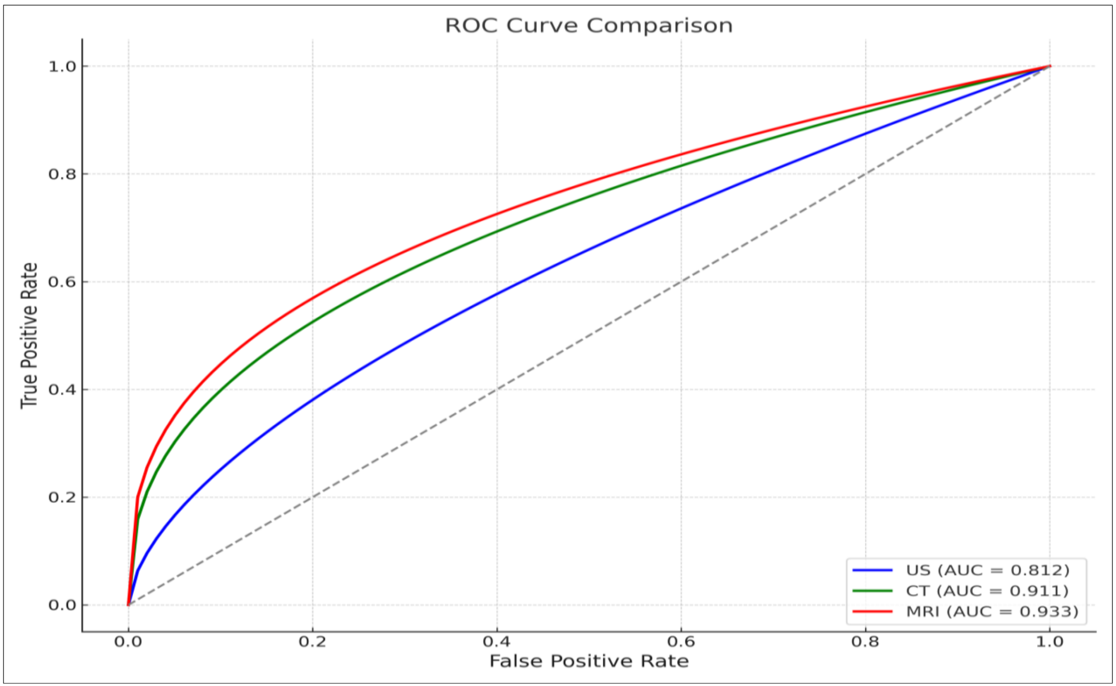

Fig 1: ROC Curve Comparison of Imaging Modalities

Cost-Effectiveness Considerations

Preliminary cost-effectiveness analysis revealed that mean examination costs followed an expected pattern, with ultrasound being the most economical, CT intermediate, and MRI the most expensive. However, when accounting for the downstream costs associated with missed diagnoses, unnecessary surgeries, and prolonged hospital stays, the cost per correctly diagnosed case demonstrated a more favorable profile for higher-accuracy modalities, suggesting that the superior diagnostic performance of advanced imaging techniques may offset their higher upfront costs through improved clinical outcomes.

Discussion

This prospective study represents one of the largest single-center comparisons of all three major imaging modalities for pediatric appendicitis diagnosis in a Middle Eastern population. Our findings demonstrate that while all three modalities provide clinically useful diagnostic information, MRI achieves superior diagnostic accuracy (93.5%) compared to CT (91.4%) and ultrasound (80.6%), with the added benefit of eliminating ionizing radiation exposure.

Comparison with Existing Literature: Our results align with recent meta-analyses reporting MRI sensitivities of 92-97% and specificities of 95-99% for pediatric appendicitis [13, 14]. The CT performance in our study (sensitivity 92.4%, specificity 89.7%) compares favorably with published literature showing sensitivities of 87-100% and specificities of 89-99% [15, 16]. Ultrasound performance (sensitivity 78.3%, specificity 84.1%) was consistent with reported ranges of 71-94% sensitivity and 81-98% specificity, acknowledging the well-documented operator dependency of this modality [17, 18]. The superior performance of MRI over CT, while not statistically significant (p=0.089), suggests clinical relevance given the elimination of radiation exposure. This finding supports recent American College of Radiology recommendations favoring MRI as a second-line imaging modality for pediatric appendicitis when ultrasound is inconclusive d[19].

Age-Related Performance Differences: Our age-stratified analysis revealed improved ultrasound performance in older children, likely reflecting reduced bowel gas interference and improved patient cooperation. This finding supports current guidelines recommending ultrasound as the initial imaging modality across all pediatric age groups, with consideration for immediate advanced imaging in younger children when ultrasound is technically limited [20]. The consistently high performance of CT and MRI across all age groups reinforces their reliability for definitive diagnosis, though practical considerations including availability, cost, and need for sedation must be considered, particularly in younger children.

Clinical Implications: The excellent diagnostic performance of MRI suggests its potential role as a first-line imaging modality in centers with adequate availability and expertise. However, practical implementation challenges include limited after-hours availability, longer examination times, and higher costs. In resource-constrained environments, a tiered approach beginning with ultrasound followed by CT or MRI based on availability and clinical urgency may be most appropriate. Our finding of superior sensitivity for complicated appendicitis across all modalities has important clinical implications, as these cases require urgent surgical intervention. The 100% sensitivity of MRI for complicated appendicitis, while based on a relatively small subgroup, suggests particular value in cases where perforation or abscess formation is suspected.

Radiation Considerations: With mean CT effective doses of 4.2 mSv in our study, radiation exposure remains a significant concern in pediatric populations. While dose optimization protocols achieved meaningful reduction compared to adult protocols, the cumulative cancer risk associated with repeated CT examinations in children underscores the importance of radiation-free alternatives [21]. The superior diagnostic accuracy of MRI without radiation exposure provides compelling rationale for its increased utilization when feasible.

Economic Considerations: While MRI demonstrated the highest examination cost, the improved diagnostic accuracy may provide economic value through reduced misdiagnosis rates, unnecessary surgeries, and associated complications. Comprehensive cost-effectiveness analyses incorporating these downstream effects suggest that higher upfront imaging costs may be offset by improved clinical outcomes, though this requires validation in different healthcare systems and economic contexts [22].

Strengths and Limitations: Study strengths include prospective design, large sample size, standardized imaging protocols, blinded interpretation, and comprehensive reference standard. The single-center design ensured protocol consistency and eliminated inter-institutional variability in techniques and interpretation. Several limitations merit consideration. First, the requirement for all patients to undergo all three imaging modalities may have introduced selection bias toward more stable patients who could tolerate extended imaging protocols. Second, the predominantly urban population may limit generalizability to rural or different socioeconomic settings. Third, while our sample size was adequate for primary comparisons, subgroup analyses were limited by smaller numbers, particularly for complicated appendicitis cases. The necessity for sedation in 3.7% of MRI patients highlights practical challenges that may limit implementation in busy emergency departments. Additionally, our cost analysis reflected local pricing structures and may not be generalizable to different healthcare systems.

Future Research Directions: Future studies should investigate abbreviated MRI protocols to reduce examination time and improve emergency department workflow. Comparative effectiveness research incorporating patient-reported outcomes, healthcare utilization, and long-term follow-up would provide valuable insights into optimal imaging strategies. Additionally, artificial intelligence applications for automated image interpretation may address operator dependency concerns, particularly for ultrasound. Multi-center studies across diverse healthcare settings and populations would enhance external validity and inform evidence-based guidelines for imaging algorithm development. Research into cost-effectiveness from healthcare system perspectives would support policy decisions regarding optimal resource allocation for pediatric emergency imaging.

Conclusions

This comprehensive comparison of ultrasound, CT, and MRI for pediatric appendicitis diagnosis demonstrates that MRI achieves superior diagnostic accuracy while eliminating radiation exposure, supporting its increased utilization when practically feasible. CT provides excellent diagnostic performance with rapid acquisition, making it valuable for urgent cases when MRI is unavailable. Ultrasound remains an appropriate initial imaging modality, particularly in older children, though its limitations in younger age groups must be recognized. The optimal imaging strategy should be individualized based on patient factors, institutional resources, and clinical urgency. In centers with MRI availability and expertise, a US-first approach followed by MRI for inconclusive cases may provide the ideal balance of diagnostic accuracy, radiation safety, and resource utilization. Where MRI is limited, CT remains a highly effective alternative for definitive diagnosis. These findings support the development of evidence-based imaging algorithms that prioritize diagnostic accuracy while considering practical constraints and patient safety. The superior performance of advanced imaging modalities for complicated appendicitis reinforces their importance in cases requiring urgent surgical intervention. Future research should focus on optimizing imaging protocols, investigating cost-effectiveness across different healthcare systems, and developing decision support tools to guide appropriate imaging selection in clinical practice.

Acknowledgements

The authors thank the radiology technologists and nursing staff of Central Child Teaching Hospital for their assistance in patient care and data collection. We acknowledge the pediatric surgery team for their collaboration in establishing the reference standard diagnoses.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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