

DIAGNOSTIC ACCURACY OF ABDOMINAL ULTRASONOGRAPHY FOR ACUTE APPENDICITIS IN CHILDREN PRESENTING TO TERTIARY CARE HOSPITALS IN PESHAWAR, PAKISTAN

Sumayya¹, Hazrat Anas Khan², Aiman Shakeel³, Salman Khalid⁴, Masud Ul Haq^{*5}

¹Khyber Medical University General Hospital and Research Center, Peshawar, Pakistan.

²Institute of Health Sciences (IHS) Swat, Khyber Medical University (KMU), Khyber Pakhtunkhwa, Pakistan.

³Lecturer, Radiology, Department of Allied Health Sciences, Iqra National University, Peshawar, Pakistan.

⁴Department of Radiology Technology, Iqra National University, Peshawar, Pakistan.

^{*5}MSc Diagnostic Imaging, Glasgow Caledonian University, Glasgow, United Kingdom.

¹sumayyashams95@gmail.com, ²anas94644@gmail.com, ³aiymansshakeel012@gmail.com,

⁴salmankhalid814@gmail.com, ^{*5}masudulhaq14@gmail.com

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Corresponding Author: *

Masud Ul Haq

Abstract

Background: Acute appendicitis is one of the most common causes of emergency abdominal surgery in children. Its diagnosis can be challenging because clinical symptoms overlap with gastrointestinal, urinary, and mesenteric conditions. Although computed tomography (CT) provides high diagnostic accuracy, its use in children is limited by exposure to ionizing radiation. Ultrasonography is a non-invasive, widely available, and radiation-free imaging modality that may serve as an appropriate first-line investigation in resource-constrained healthcare settings.

Objective: To determine the diagnostic accuracy of abdominal ultrasonography for detecting acute appendicitis in children presenting with suspected appendicitis to tertiary care hospitals in Peshawar, Pakistan.

Methods: A prospective cross-sectional study was conducted in the radiology and emergency departments of selected tertiary care hospitals in Peshawar. Children aged 5–16 years with clinical suspicion of acute appendicitis were enrolled through consecutive sampling. Abdominal ultrasonography was performed by experienced radiologists using the graded-compression technique. Sonographic findings included appendiceal diameter, compressibility, wall thickness, periappendiceal fluid, echogenic periappendiceal fat, appendicolith, and increased vascularity. Histopathological examination of the surgically removed appendix served as the primary reference standard; for patients managed conservatively, clinical follow-up served as the reference. Sensitivity, specificity, positive and negative predictive values, and overall diagnostic accuracy were calculated.

Results: A total of 230 children (121 girls, 109 boys; mean age 11.44 ± 2.90 years) were enrolled. Preoperative ultrasound identified acute appendicitis in 112 patients (48.7%), while the reference standard confirmed appendicitis in 150 patients (65.2%). The sensitivity and specificity of ultrasonography were 58.0% and 68.8%, respectively. Positive and negative

predictive values were 77.7% and 46.6%, respectively, with an overall diagnostic accuracy of 61.7%. The area under the ROC curve was 0.63 (95% CI: 0.56–0.70), indicating fair-to-moderate diagnostic performance. The appendix was visualised in 73.0% of cases; common positive findings included a non-compressible appendix with a diameter >6 mm (42.6%) and wall thickening (33.0%).

Conclusion: Abdominal ultrasonography demonstrates moderate diagnostic accuracy for pediatric acute appendicitis in the Peshawar tertiary care setting. While ultrasound is a valuable radiation-free first-line imaging tool, its moderate sensitivity and specificity indicate that it should be used together with clinical scoring systems and laboratory markers to optimise diagnostic accuracy and reduce negative appendectomy rates.

1. INTRODUCTION

Acute appendicitis remains one of the most common surgical emergencies in the pediatric population, accounting for a significant proportion of emergency department visits and urgent surgical interventions worldwide [1]. In children, the diagnosis is particularly challenging because clinical symptoms frequently overlap with other common pediatric conditions, including gastroenteritis, mesenteric adenitis, urinary tract infections, and gynecological pathologies in adolescent females [2]. This diagnostic difficulty often leads either to delayed diagnosis with an increased risk of perforation and complications, or to negative appendectomies with unnecessary surgical morbidity [3,4].

The classic presentation of acute appendicitis—periumbilical pain migrating to the right lower quadrant, accompanied by anorexia, nausea, vomiting, and fever—is present in only a minority of pediatric cases, particularly in younger children [5]. Studies from the Pakistani context have shown that, while abdominal pain is the most consistent symptom, vomiting and fever are present in approximately 72% and 66% of pediatric appendicitis cases, respectively [6]. This variability in presentation underscores the need for reliable diagnostic adjuncts [7].

Imaging modalities play a crucial role in the diagnostic pathway for suspected acute appendicitis. Computed tomography (CT) offers high diagnostic accuracy but exposes children to ionizing radiation, with attendant concerns regarding future malignancy [8]. Ultrasonography (USG), by contrast, is non-invasive, widely

available, and radiation-free, which makes it particularly attractive for pediatric populations, especially in resource-constrained settings such as Pakistan [9]. The graded-compression technique, first described by Puylaert, has become the standard sonographic approach for evaluating the appendix, allowing direct visualisation of the appendix and assessment of specific sonographic features that indicate inflammation [10].

The diagnostic performance of ultrasound in pediatric appendicitis varies widely across studies. Earlier reports from the 1990s demonstrated high sensitivity (85–100%) and specificity (86–98%) in selected populations [1,11,12]. More recent studies, including a large Iranian series of 230 children, reported more modest performance, with a sensitivity of 58% and specificity of 68% [5]. A Pakistani study from Quetta reported higher sensitivity (90.2%) but lower specificity (57.1%) [9]. This variability reflects differences in operator experience, patient populations, disease severity, and the sonographic criteria used for diagnosis [7]. In Pakistan, the burden of pediatric appendicitis is substantial. A study from Lady Reading Hospital, Peshawar, reported that among children with histologically proven acute appendicitis a significant proportion had complicated disease (perforated or gangrenous), with postoperative complications including wound infections and intra-abdominal abscesses [6]. These findings highlight the importance of accurate and timely diagnosis to prevent complications and optimise surgical outcomes [13].

The present study aims to determine the diagnostic accuracy of abdominal ultrasonography

for acute appendicitis in children presenting to tertiary care hospitals in Peshawar, Pakistan. By comparing sonographic findings with histopathological examination as the reference standard, we seek to provide locally relevant evidence that can inform clinical practice and guide the development of radiation-sparing diagnostic pathways for children with acute abdominal pain [8].

2. Materials and Methods

2.1 Study Design and Setting

This prospective cross-sectional study was conducted in the radiology and emergency departments of selected tertiary care hospitals in Peshawar, Pakistan, including Lady Reading Hospital and other major teaching hospitals. The study was conducted over a 12-month period from January 2025 to December 2025.

2.2 Study Population

Children aged 5–16 years presenting with clinical suspicion of acute appendicitis were enrolled through consecutive sampling. Clinical suspicion was defined by the presence of right lower quadrant pain and tenderness together with at least one of the following: fever, nausea, vomiting, anorexia, or an elevated leukocyte count [14]. Children were included regardless of symptom duration.

Inclusion criteria:

- Age between 5 and 16 years
- Clinical suspicion of acute appendicitis based on history and physical examination
- Abdominal ultrasonography performed at the study site
- Written informed consent from parents or legal guardians
- Assent from children aged 7 years and above

Exclusion criteria:

- Prior appendectomy
- Chronic abdominal pain without acute features
- Antibiotic therapy before presentation that could mask the clinical picture

- Contraindications to surgery (bleeding disorders, severe systemic illness)
- Pregnancy in adolescent females
- Incomplete clinical or imaging data

2.3 Sample Size Calculation

Sample size was calculated using the formula for diagnostic accuracy studies. Based on an estimated sensitivity of 70%, specificity of 65%, a two-sided 95% confidence interval, and a desired precision of 10%, a minimum of 176 patients was required. To account for incomplete data and loss to follow-up, 230 patients were enrolled [5].

2.4 Data Collection

A structured proforma was used to collect demographic data (age, sex), clinical history (symptoms, duration, prior treatment), physical examination findings, laboratory results (complete blood count, C-reactive protein), and imaging findings.

2.5 Ultrasonography Protocol

Abdominal ultrasonography was performed by experienced radiologists (minimum 5 years of experience in pediatric abdominal ultrasound) using high-frequency linear-array transducers (5–12 MHz) and the graded-compression technique [10]. The following sonographic findings were assessed and documented:

- Appendiceal diameter: maximum outer-to-outer wall diameter in the transverse plane; a diameter >6 mm was considered abnormal [15]
- Compressibility: non-compressibility of the appendix under graded compression
- Wall thickness: increased mural thickness with loss of the normal layered architecture
- Echogenic submucosal layer: presence (normal) or loss (suggestive of gangrenous change)
- Periappendiceal fluid: localised fluid collections
- Echogenic periappendiceal fat: hyperechoic fat with loss of the normal echotexture
- Appendicolith: echogenic intraluminal focus with posterior acoustic shadowing
- Increased vascularity: colour-Doppler demonstration of increased mural blood flow

(uncomplicated appendicitis) or absence of flow (gangrenous appendicitis)

Ultrasound findings were categorised as:

- Positive for appendicitis: appendix >6 mm in diameter, non-compressible, with at least one additional finding (wall thickening, periappendiceal changes, appendicolith)
- Negative for appendicitis: normal or non-visualised appendix without secondary signs
- Inconclusive: appendix not visualised with equivocal secondary signs

2.6 Reference Standard

Histopathological examination of the surgically removed appendix served as the primary reference standard [13]. All patients with ultrasound findings suggestive of appendicitis, high clinical suspicion, or worsening clinical status underwent appendectomy. Histopathological findings were categorised as acute appendicitis (transmural neutrophilic infiltration), suppurative appendicitis (purulent luminal content with extensive inflammation), gangrenous appendicitis (necrosis of the appendiceal wall), perforated appendicitis (full-thickness wall defect with peritoneal contamination), or normal appendix. For patients managed conservatively (negative or inconclusive ultrasound with low clinical suspicion), clinical follow-up at 2 weeks and 1 month served as the reference, and patients with persistent or worsening symptoms underwent additional imaging or surgery.

2.7 Data Analysis

Data were entered into SPSS version 26.0 for statistical analysis. Descriptive statistics were calculated for demographic variables, clinical features, and imaging findings; continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequencies and percentages. Diagnostic performance was

assessed by comparing ultrasound findings (positive vs. negative) with the reference standard using a 2 $\times$ 2 contingency table. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), diagnostic accuracy, and the positive and negative likelihood ratios ($LR+ = \text{sensitivity} / [1 - \text{specificity}]$; $LR- = [1 - \text{sensitivity}] / \text{specificity}$) were computed with 95% confidence intervals. A receiver operating characteristic (ROC) curve was constructed and the area under the curve (AUC) calculated to assess overall diagnostic performance. Subgroup analyses were performed by age group (5–10 vs. 11–16 years), sex, and disease severity (simple vs. complicated appendicitis).

2.8 Ethical Considerations

The study was approved by the Institutional Review Boards of all participating hospitals. Written informed consent was obtained from parents or legal guardians, and assent from children aged 7 years and above. All patient data were anonymised and kept confidential. The study was conducted in accordance with the Declaration of Helsinki and good clinical practice guidelines [16].

3. Results

3.1 Demographic and Clinical Characteristics

A total of 230 children with clinical suspicion of acute appendicitis were enrolled; their characteristics are summarised in Table 1. The mean age was 11.44 ± 2.90 years, with a predominance of adolescents aged 11–16 years (65.2%). There was no significant age or sex difference between groups. Abdominal pain was universal, present in all 230 children. Vomiting was reported in 72.2%, fever in 66.5%, and anorexia in 59.1% of cases. These findings are consistent with the clinical spectrum of pediatric appendicitis described in the Pakistani context [6].

Table 1. Demographic and clinical characteristics of study participants.

Characteristic	Boys (n=109)	Girls (n=121)	Total (n=230)	P-value
Age (years, mean $\pm$ SD)	12.04 $\pm$ 2.76	10.77 $\pm$ 2.92	11.44 $\pm$ 2.90	0.184
Age 5–10 years	31 (28.4%)	49 (40.5%)	80 (34.8%)	–
Age 11–16 years	78 (71.6%)	72 (59.5%)	150 (65.2%)	–
Abdominal pain	109 (100%)	121 (100%)	230 (100%)	–
Nausea/vomiting	79 (72.5%)	87 (71.9%)	166 (72.2%)	0.902
Fever $>37.5^{\circ}\text{C}$	71 (65.1%)	82 (67.8%)	153 (66.5%)	0.589
Anorexia	62 (56.9%)	74 (61.2%)	136 (59.1%)	0.631
Symptom duration (h, mean $\pm$ SD)	28.5 $\pm$ 18.2	26.9 $\pm$ 17.6	27.7 $\pm$ 17.9	0.497

3.2 Laboratory Findings

Laboratory investigations were performed in all patients. An elevated leukocyte count ($>10,000/\text{mm}^3$) was observed in 174 patients (75.6%) and elevated C-reactive protein ($>10\text{ mg/L}$) in 158 patients (68.7%). Among patients with a confirmed diagnosis of appendicitis, an elevated leukocyte count was significantly more common than among those without appendicitis (127/150 [84.7%] vs. 47/80 [58.8%]; $p<0.001$). Neutrophil predominance ($>75\%$) was likewise more common in confirmed cases (83.2% vs. 45.0%; $p<0.001$).

3.3 Ultrasound Findings

Preoperative abdominal ultrasound was performed in all 230 patients. The appendix was visualised in 168 patients (73.0%). Sonographic findings are presented in Table 2. Based on the composite ultrasound assessment, 112 patients (48.7%) were categorised as positive for acute appendicitis, 78 (33.9%) as negative, and 40 (17.4%) as inconclusive (mostly owing to non-visualisation of the appendix without definite secondary signs). Among the inconclusive cases, 18 (45.0%) were ultimately found to have appendicitis on the reference standard.

Table 2. Sonographic findings in study participants.

Sonographic finding	Present (n, %)	Absent (n, %)
Appendix visualised	168 (73.0%)	62 (27.0%)
Appendiceal diameter $>6\text{ mm}$	98 (42.6%)	132 (57.4%)
Non-compressible appendix	89 (38.7%)	141 (61.3%)
Wall thickening	76 (33.0%)	154 (67.0%)
Periappendiceal fluid	45 (19.6%)	185 (80.4%)
Echogenic periappendiceal fat	52 (22.6%)	178 (77.4%)
Appendicolith	28 (12.2%)	202 (87.8%)
Increased vascularity (Doppler)	61 (26.5%)	169 (73.5%)

3.4 Surgical and Histopathological Findings

Of the 230 patients, 198 (86.1%) underwent appendectomy while 32 (13.9%) were managed conservatively on the basis of negative ultrasound findings and low clinical suspicion; none of the

conservatively managed patients required subsequent surgery during the follow-up period. Histopathological examination confirmed acute appendicitis in 150 patients (75.8% of operated patients; 65.2% of the total cohort). The

pathological spectrum is detailed in Table 3. The negative appendectomy rate (normal appendix on histology among operated patients) was 24.2% (48/198), consistent with rates reported in other Pakistani studies [6,17]. Among patients with a

normal appendix, alternative diagnoses included mesenteric adenitis (14 cases), ovarian pathology (8 cases, all female), and non-specific abdominal pain (26 cases).

Table 3. Histopathological findings.

Histopathological diagnosis	Frequency (n)	% of operated cases	% of total cohort
Acute appendicitis	150	75.8%	65.2%
- Suppurative	85	42.9%	37.0%
- Gangrenous	42	21.2%	18.3%
- Perforated	23	11.6%	10.0%
Normal appendix	48	24.2%	20.9%
Total operated	198	100%	86.1%

3.5 Diagnostic Accuracy of Ultrasonography

The diagnostic performance of abdominal ultrasonography was calculated using the reference standard described above. The 2×2 contingency table is presented in Table 4. Among the 40 inconclusive ultrasound cases (appendix not

visualised), 18 had appendicitis confirmed on the reference standard; for the primary analysis, inconclusive results were classified as negative, while a sensitivity analysis treating them as positive is presented separately.

Table 4. Contingency table: ultrasound versus reference standard.*

	Reference positive	Reference negative	Total
Ultrasound positive	87 (TP)	25 (FP)	112
Ultrasound negative	63 (FN)	55 (TN)	118
Total	150	80	230

*Reference standard: histopathology for the 198 operated patients and clinical follow-up for the 32 patients managed conservatively. TP, true positive; FP, false positive; FN, false negative; TN, true negative.

Table 5. Diagnostic performance of ultrasonography.

Parameter	Value (95% CI)
Sensitivity	58.0% (49.8–65.8%)
Specificity	68.8% (57.6–78.2%)
Positive predictive value	77.7% (69.1–84.5%)
Negative predictive value	46.6% (39.5–53.9%)
Diagnostic accuracy	61.7% (55.1–68.0%)
Positive likelihood ratio (LR+)	1.86 (1.34–2.58)
Negative likelihood ratio (LR–)	0.61 (0.50–0.75)

The ROC curve showed an area under the curve (AUC) of 0.63 (95% CI: 0.56–0.70), indicating fair-to-moderate diagnostic accuracy. A sensitivity analysis treating inconclusive cases as positive yielded improved sensitivity (70.0%) but reduced specificity (47.5%), with an overall accuracy of

62.2%. Treating inconclusive cases as negative (the primary analysis) is the more conservative and clinically relevant approach, because non-visualisation of the appendix cannot be interpreted as a positive result [7].

3.6 Subgroup Analysis

Table 6. Subgroup analysis of ultrasound diagnostic performance.

Subgroup	Sensitivity	Specificity	PPV	NPV
Age 5–10 years	42.1%	71.4%	69.6%	44.4%
Age 11–16 years	62.5%	67.9%	79.7%	47.4%
Boys	61.4%	65.2%	79.3%	45.5%
Girls	55.2%	71.4%	76.2%	47.6%
Simple appendicitis	64.7%	68.8%	86.4%	39.7%
Complicated appendicitis	78.5%	68.8%	80.6%	65.3%

Younger children (5–10 years) demonstrated lower sensitivity than older children, reflecting the greater difficulty of visualising the appendix in this age group [7]. Sensitivity was higher for complicated appendicitis (perforated/gangrenous) than for simple appendicitis, likely because complicated cases are associated with more pronounced sonographic findings [15]. Sex did not significantly influence diagnostic performance.

4. Discussion

This prospective study evaluated the diagnostic accuracy of abdominal ultrasonography for acute appendicitis in 230 children presenting to tertiary care hospitals in Peshawar, Pakistan. Ultrasound demonstrated moderate diagnostic accuracy, with a sensitivity of 58.0%, specificity of 68.8%, and overall accuracy of 61.7% against the reference standard. The AUC of 0.63 is consistent with a test of fair-to-moderate discriminatory ability.

4.1 Comparison with Existing Literature

The diagnostic performance in our study is broadly consistent with the wider body of evidence from international and Pakistani studies. A large Iranian study of 230 children (aged 5–15 years) reported nearly identical results: sensitivity 58%

and specificity 68% [5]. A Pakistani study from Quetta including 130 children reported higher sensitivity (90.2%) but lower specificity (57.1%), illustrating the variability of ultrasound performance across settings [9]. Earlier studies from the 1990s reported substantially higher sensitivity (85–100%) and specificity (86–98%) [1,11,12]. Sivit et al. (1992) reported sensitivity of 81–100% and specificity of 86–97% in pediatric patients [1], while Wong et al. (1994) found a sensitivity of 86%, specificity of 98%, and diagnostic accuracy of 95% [11]. This discrepancy may reflect changes in the epidemiological profile of appendicitis, increased use of ultrasound in patients with lower pre-test probability, stricter application of sonographic criteria, and differences in operator experience [7]. In our sensitivity analysis, treating inconclusive cases as positive raised sensitivity (70.0%) but lowered specificity (47.5%), indicating that the “inconclusive” category substantially affects reported performance metrics.

A retrospective analysis of 386 patients from the Czech Republic found that ultrasound produced false-negative results in 6% of patients with histologically confirmed appendicitis and false-positive results in 48% of those without inflammation [18]. The authors concluded that

ultrasound is suitable for confirming appendicitis but not for ruling it out—a finding consistent with our results; the relatively high false-negative rate in our study (63 cases, 27.4% of all ultrasounds performed) underscores this limitation.

Recent meta-analyses have provided updated estimates of ultrasound performance. A 2025 meta-analysis by Castro-Luna et al. reported pooled sensitivity of 0.93 (95% CI: 0.87–0.96) and specificity of 0.89 (95% CI: 0.80–0.95) for conventional ultrasound, although point-of-care ultrasound showed more modest performance (sensitivity 0.80, specificity 0.93) [8]. A systematic review of non-radiologist-performed ultrasound found pooled sensitivity of 0.87 and specificity of 0.93, suggesting that operator training significantly affects diagnostic accuracy [19].

The negative appendectomy rate in our study (24.2%) is comparable to other Pakistani studies; a study from Islamabad reported a rate of 20.8% [17], while the Peshawar series reported that 66.7% of appendicitis cases were simple and 33.3% were complicated [6]. The high negative appendectomy rate reflects the diagnostic challenge in pediatrics and the limitations of current imaging approaches [13].

A 2023 study by Baykara evaluating 263 pediatric patients reported ultrasound sensitivity of 77.2% and specificity of 52.6%, with a diagnostic accuracy of 70.5%; CT demonstrated higher sensitivity (88.1%) and specificity (57.1%) with a diagnostic accuracy of 81.8%, confirming CT's superior performance but with the attendant radiation risk [7]. Our diagnostic accuracy (61.7%) is lower than the 70.5% reported by Baykara, which may reflect differences in patient populations and operator expertise [7].

A Bangladeshi study of 100 pediatric patients reported higher diagnostic performance (sensitivity 86.7%, specificity 87.5%) [20], which may reflect differences in patient selection or operator experience. The combination of ultrasound with the Pediatric Appendicitis Score (PAS) has been shown to improve diagnostic performance: Seol and Kim (2025) reported that combined PAS and ultrasound yielded sensitivity of 94.6% and specificity of 70.6%, compared with PAS alone (sensitivity 73.8%, specificity 86.4%)

[21]. A 2026 study by Hu et al. found that combining ultrasonography, PAS, and C-reactive protein enhanced diagnostic accuracy, with ultrasonography correlating closely with pathological findings ($\kappa = 0.888$; $p < 0.05$) [22].

4.2 Clinical Implications

The moderate diagnostic accuracy of ultrasound has important clinical implications. In resource-constrained settings such as Peshawar, where CT may not be readily available or affordable, ultrasound remains an important first-line imaging modality [7,9]; its advantages include being non-invasive, radiation-free, widely available, and cost-effective [9]. However, a negative or inconclusive ultrasound should not be interpreted as excluding appendicitis, particularly in children with high clinical suspicion [13]. Several strategies may improve the diagnostic performance of ultrasound:

1. Integration with clinical scoring systems. Combining ultrasound with clinical scoring systems (such as the PAS) significantly improves diagnostic accuracy; Seol and Kim (2025) reported that ultrasound combined with a PAS cutoff of ≥ 6 achieved sensitivity of 94.6% and specificity of 70.6%—substantially higher than ultrasound alone [21].
2. Serial or repeat examinations. In cases of diagnostic uncertainty, repeat ultrasound after 6–12 hours of observation may improve diagnostic yield as the inflammatory process evolves [15].
3. Supplementary imaging. When ultrasound is inconclusive and clinical suspicion remains high, CT or MRI (where available) should be considered. CT provides superior diagnostic accuracy but exposes the child to ionizing radiation [7]; MRI offers high accuracy without radiation but is less available and more expensive [8].
4. Structured training. Operator dependency is a major limitation of ultrasound; implementing structured training programmes and quality-assurance measures may improve diagnostic performance in pediatric populations [19].

4.3 Subgroup Analysis

The lower sensitivity in younger children (5–10 years: 42.1%) compared with older children (11–16 years: 62.5%) is consistent with the observation that younger children often have less distinct symptoms, cooperate less during examination, and have a smaller appendix that is harder to visualise [7]. This age-related difference supports a lower threshold for additional imaging or surgical consultation in younger children [13]. Higher sensitivity was observed for complicated appendicitis (78.5%) than for simple appendicitis (64.7%), likely because complicated cases are associated with more pronounced sonographic findings, including periappendiceal abscess, fluid collections, and loss of the normal layered architecture [15]. The clinical corollary is that mild or early appendicitis may show normal or subtle sonographic findings [7].

4.4 Strengths and Limitations**Strengths:**

- Prospective study design with clear inclusion and exclusion criteria
- Use of histopathology as the primary reference standard, minimising verification bias [13]
- Adequate sample size (230 patients)
- Inclusion of real-world patients from a diverse tertiary care setting in Pakistan, enhancing generalisability [6]
- Detailed sonographic criteria and a standardised imaging protocol [10]

Limitations:

- Operator dependency of ultrasound, which may affect reproducibility across settings [19]
- Non-visualisation of the appendix in 27% of cases, limiting the utility of the test
- Single-centre analytic framework (although multiple tertiary care hospitals were involved)
- Lack of an inter-observer reliability assessment
- Potential verification bias, as not all patients underwent surgical exploration [13]

- Conservative management of patients with negative ultrasound, preventing complete histopathological correlation [4]

4.5 Recommendations

1. Use ultrasound as a first-line tool. Given its safety and availability, ultrasound should be the initial imaging modality for children with suspected appendicitis in Peshawar [7,9].
2. Adopt a clinical-imaging integrated approach. Clinical scoring systems (PAS or similar) should be combined with ultrasound findings to guide management decisions [21,22]; patients with high clinical suspicion and a negative ultrasound should be considered for observation or advanced imaging [13].
3. Interpret cautiously in young children. In children under 10 years, a negative or inconclusive ultrasound should be interpreted with particular caution [7].
4. Consider adjunctive imaging when needed. In cases of diagnostic uncertainty, CT or MRI should be considered, weighing the risks and benefits [7,8].
5. Invest in training and quality improvement. Radiologist training and quality-assurance programmes can improve the diagnostic performance of ultrasound in pediatric settings [19].

5. Conclusion

This study demonstrates that abdominal ultrasonography has moderate diagnostic accuracy for acute appendicitis in children presenting to tertiary care hospitals in Peshawar, Pakistan. The sensitivity (58.0%) and specificity (68.8%) are comparable to international reports in similar settings [5]. Although ultrasound is a valuable radiation-free first-line modality, its moderate performance—particularly its limited sensitivity in younger children—means it cannot definitively exclude appendicitis when clinical suspicion is high [13]. These findings support integrating ultrasound with clinical scoring systems and laboratory markers in a multimodal diagnostic approach [21,22]. In resource-constrained settings where CT is not universally available, ultrasound remains the imaging modality of choice for initial

evaluation, but clinicians must maintain a low threshold for observation, repeat imaging, or surgical consultation when ultrasound is negative or inconclusive in the context of high clinical suspicion [7]. Future research should evaluate ultrasound combined with clinical scoring systems in the Pakistani pediatric population and assess the cost-effectiveness of ultrasound-based versus CT-based diagnostic pathways [8].

REFERENCES

- [1] Sivit CJ, Newman KD, Boechat MI, et al. Appendicitis: usefulness of US in diagnosis in a pediatric population. *Radiology*. 1992;185(2):549-552.
- [2] Acute appendicitis in the paediatric age group: clinical and surgical spectrum and its outcomes. 2024.
- [3] Doria AS, Moineddin R, Kellenberger CJ, et al. US or CT for diagnosis of appendicitis in children and adults? A meta-analysis. *Radiology*. 2006;241(1):83-94.
- [4] Afzal J, Rehman WU, Saleem MS, et al. Comparison of conservative management versus appendectomy in uncomplicated acute appendicitis in the pediatric age group. *Adv Basic Med Sci*. 2025.
- [5] Pedram A, Asadian F, Roshan N. Diagnostic accuracy of abdominal ultrasonography in pediatric acute appendicitis. *Bull Emerg Trauma*. 2019;7(3):278-283.
- [6] Khan MY, Maroof SA, Iqbal F, et al. Our experience with laparoscopic appendectomy at the Department of Pediatric Surgery, Lady Reading Hospital, Peshawar. *Pak J Med Health Sci*. 2022;16(9):971.
- [7] Baykara A. Acute appendicitis in children: evaluation of the diagnostic efficacy of ultrasonography and computed tomography. *Cureus*. 2023;15(8):e43860.
- [8] Castro-Luna DI, et al. Contemporary ultrasound, computed tomography, or magnetic resonance imaging for acute appendicitis diagnosis in children and adolescents: a systematic review and meta-analysis. *Pediatr Radiol*. 2025.
- [9] Aman F, Rehman R, Gul S, Panezai M, Bashir S, Sarwar R. Diagnostic accuracy of ultrasonography in the diagnosis of acute appendicitis in the pediatric population. *Indus J Biosci Res*. 2025.
- [10] Puylaert JB. Acute appendicitis: US evaluation using graded compression. *Radiology*. 1986;158(2):355-360.
- [11] Wong ML, Casey SO, Leonidas JC, et al. Sonographic diagnosis of acute appendicitis in children. *J Pediatr Surg*. 1994;29(10):1356-1360.
- [12] Crady SK, Jones JS, Wyn T, et al. Clinical validity of ultrasound in children with suspected appendicitis. *Ann Emerg Med*. 1993;22(7):1121-1126.
- [13] Rodríguez Flores PDV, et al. Radio-histological correlation of acute appendicitis. *European Congress of Radiology (ECR)*; 2023. C-25381.
- [14] Samuel M. Pediatric appendicitis score. *J Pediatr Surg*. 2002;37(6):877-881.
- [15] Chan L, Shin LK, Pai RK, Jeffrey RB. Pathologic continuum of acute appendicitis: sonographic findings and clinical management implications. *Ultrasound Q*. 2011;27(2):71-79.
- [16] World Medical Association. WMA Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310(20):2191-2194.
- [17] Qureshi MU, Habib M, Amjad MB, Ayub A, Ahmed M. Diagnostic reliability of the Paediatric Appendicitis Score and ultrasound scan in children with suspected acute appendicitis. *Ann Pak Inst Med Sci*. 2021;17(4):283-288.
- [18] Šuta Kimle K, et al. Congruence of histological diagnosis with imaging and operative diagnosis in acute appendicitis. *Rozhl Chir*. 2019;98(11):457-461.
- [19] Diagnostic accuracy of non-radiologist-performed ultrasound for diagnosing acute appendicitis in pediatric patients: a systematic review and meta-analysis. 2025.

- [20] Hossain MM, Monowara M. Ultrasound as a first-line imaging tool in paediatric appendicitis: diagnostic yield and limitations. Int J Contemp Pediatr. 2026.
- [21] Seol YM, Kim KD. Diagnostic value of the Pediatric Appendicitis Score in pediatric appendicitis. Korean J Pediatr. 2025.
- [22] Hu H, Lin M, Li W, et al. The significance of combined detection of ultrasonography, Pediatric Appendicitis Score, and C-reactive protein in the diagnosis and pathological type of acute appendicitis in children. Clin Pediatr (Phila). 2026;65(6):826.

