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Original Research Article

Clinicopathological Predictors of Complicated Acute Appendicitis and Postoperative Morbidity in Children: A Prospective Multidisciplinary Cohort Study

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Abstract:

Background: Early identification of complicated acute appendicitis in children remains challenging, and delayed diagnosis increases postoperative morbidity. This study evaluated clinicopathological predictors of complicated appendicitis and adverse postoperative outcomes.

Methods: A prospective multidisciplinary cohort study was conducted at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, from May 2025 to May 2026. Children aged 3–18 years undergoing appendicectomy were assessed clinically, biochemically, radiologically, operatively, and histopathologically. Participants were classified as uncomplicated or complicated appendicitis. Postoperative complications were recorded for 30 days, and independent predictors were identified using multivariable logistic regression.

Results: Among 160 children, 104 (65.0%) had uncomplicated and 56 (35.0%) had complicated appendicitis. Complicated disease was associated with younger age, symptom duration exceeding 48 hours, fever, guarding, higher Pediatric Appendicitis Scores, leukocytosis, elevated neutrophil-to-lymphocyte ratio and C-reactive protein, hyperbilirubinemia, hyponatremia, appendicolith, and periappendiceal collection. Postoperative morbidity occurred in 18.8% overall and was significantly higher in complicated cases. Delayed presentation, C-reactive protein above 50 mg/L, gangrene or perforation, and generalized peritonitis independently predicted morbidity.

Conclusion: Combined clinical, laboratory, imaging, operative, and pathological assessment enabled effective risk stratification. This multidisciplinary approach may support timely surgery and individualized perioperative care. Early recognition and targeted postoperative monitoring may reduce complications and hospitalization.

Keywords: Acute Appendicitis; Children; Complicated Appendicitis; Clinicopathological Predictors; Postoperative Morbidity.

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Introduction

Acute appendicitis is the most frequent abdominal surgical emergency in children, yet early recognition of complicated disease remains difficult because symptoms, examination findings and inflammatory responses vary with age. Delayed diagnosis may lead to gangrene, perforation, abscess, peritonitis, prolonged hospitalization and postoperative morbidity [1]. Indian studies have shown that the Pediatric Appendicitis Score (PAS) and ultrasonography assist diagnosis and differentiation of complicated cases, while inflammatory biomarkers such as fibrinogen may improve diagnostic accuracy and reduce negative appendicectomy [1, 2]. Operative approach also influences recovery, wound infection and intra-abdominal complications in children with complicated appendicitis [3]. However, isolated clinical, laboratory, operative or histopathological parameters may not adequately predict severity or outcome. A multidisciplinary clinicopathological assessment may provide a more reliable risk-stratification model. Therefore, this study aims to prospectively identify clinical, laboratory, operative and histopathological predictors of complicated acute appendicitis and determine their association with postoperative morbidity among children undergoing appendicectomy at a tertiary-care hospital.

Methods

A prospective multidisciplinary cohort study was conducted in the departments of Pediatrics, General Surgery, at Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram, from May 2025 to May 2026. Children aged 3–18 years who presented with clinical features suggestive of acute appendicitis and subsequently underwent appendicectomy were enrolled consecutively after obtaining written informed consent from parents or legal guardians and age-appropriate assent from older children. Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study. Children managed conservatively without surgery, those with recurrent or interval appendicitis, previous abdominal surgery affecting assessment, chronic inflammatory or malignant disease, severe immunodeficiency, incomplete clinical records, or appendicectomy performed incidentally during another procedure were excluded. At admission, demographic characteristics, duration and migration of pain, fever, vomiting, diarrhoea, anorexia, urinary complaints, hydration, nutritional status, comorbidities, temperature, pulse rate, abdominal tenderness, guarding, rebound tenderness, rigidity, and palpable mass were recorded. The PAS was calculated using predefined clinical and laboratory criteria. Initial resuscitation, correction of dehydration, antibiotic administration, analgesia, and management of associated medical conditions were undertaken according to institutional protocols.

Laboratory investigations included haemoglobin, total leukocyte count, differential leukocyte count, absolute neutrophil count, platelet count, C-reactive protein, serum bilirubin, serum sodium, serum albumin, and renal function tests. Neutrophil-to-lymphocyte and platelet-to-lymphocyte ratios were calculated from complete blood counts. Abdominal ultrasonography findings, including appendiceal diameter, non-compressibility, wall thickening, appendicolith, periappendiceal fluid, abscess, and probe tenderness, were documented. The operating surgeon recorded the surgical approach, operative duration, intraoperative appearance of the appendix, presence of suppuration, gangrene, perforation, appendicolith, appendicular mass, abscess, localized or generalized peritonitis, peritoneal contamination, drain placement, and conversion from laparoscopic to open surgery. Appendicitis was intraoperatively categorized as uncomplicated or complicated. Complicated appendicitis was defined by the presence of gangrene, perforation, appendicular abscess, or purulent peritonitis. All removed appendices were fixed in 10% neutral-buffered formalin and submitted for histopathological examination. The pathologist, blinded to the proposed predictor classification wherever feasible, assessed mucosal ulceration, neutrophilic infiltration, transmural inflammation, suppuration, necrosis, gangrene, perforation, periappendicitis, lymphoid hyperplasia, eosinophilic infiltration, parasitic infestation, fecolith-related changes, and unexpected lesions. Histopathological diagnosis was considered the reference standard for clinicopathological correlation.

Postoperative management was provided according to disease severity and institutional protocols. Children were monitored for fever, pain, vomiting, ileus, wound complications, intra-abdominal collection, sepsis, need for intensive care, reoperation, duration of antibiotic therapy, and length of hospital stay. Postoperative morbidity included surgical-site infection, prolonged ileus, intra-abdominal abscess, readmission, reintervention, or any complication occurring within 30 days after surgery. Follow-up assessments were performed during hospitalization and after discharge through scheduled outpatient visits or telephone contact. Data were entered into a structured proforma and analysed using appropriate statistical software. Continuous variables were expressed as mean with standard deviation or median with interquartile range, while categorical variables were presented as frequencies and percentages. Comparisons between uncomplicated and complicated appendicitis were performed using the independent-samples t-test or Mann–Whitney U test for continuous variables and chi-square or Fisher's exact test for categorical variables. Variables significantly associated with complicated appendicitis or postoperative morbidity in univariate analysis were entered into multivariable logistic regression models. Adjusted odds ratios with 95% confidence intervals were calculated, and receiver-operating-characteristic curve analysis was used to assess predictive accuracy. A p value below 0.05 was considered statistically significant.

Results

A total of 160 children undergoing appendicectomy were included, of whom 104 (65.0%) had uncomplicated appendicitis and 56 (35.0%) had complicated appendicitis. As shown in Table 1, children with complicated disease were significantly younger than those with uncomplicated appendicitis (9.1 ± 3.6 versus 11.2 ± 3.4 years; $p<0.001$). Symptom duration exceeding 48 hours, fever, vomiting, guarding or rigidity, and a PAS of at least eight were significantly more frequent among complicated cases. Table 2 demonstrates that total leukocyte count, neutrophil-to-lymphocyte ratio and C-reactive protein concentrations were significantly higher in children with complicated appendicitis. Hyperbilirubinaemia, hyponatraemia, appendicolith, periappendiceal collection and prolonged operative duration were also significantly associated with complicated disease. Operative and histopathological diagnoses

showed high concordance in both groups. Postoperative outcomes are presented in Table 3. Overall morbidity occurred in 30 children (18.8%) and was significantly greater in complicated than uncomplicated appendicitis (39.3% versus 7.7%; p<0.001). Surgical-site infection, intra-abdominal collection, prolonged ileus, readmission and hospital stay were increased in the complicated group. Multivariable analysis identified symptom duration beyond 48 hours, CRP above 50 mg/L, gangrene or perforation, and generalized peritonitis as independent predictors of postoperative morbidity.

Table 1: Demographic and clinical characteristics according to appendicitis severity

Variable	Appendicitis		Test statistic	p value
	Uncomplicated	Complicated		
Age, years, mean ± SD	11.2 ± 3.4	9.1 ± 3.6	t=3.65	<0.001
Age <10 years, n (%)	31 (29.8)	30 (53.6)	χ^2=8.76	0.003
Male sex, n (%)	62 (59.6)	36 (64.3)	χ^2=0.34	0.559
Symptom duration >48 hours, n (%)	18 (17.3)	39 (69.6)	χ^2=43.75	<0.001
Fever, n (%)	48 (46.2)	46 (82.1)	χ^2=19.19	<0.001
Vomiting, n (%)	60 (57.7)	43 (76.8)	χ^2=5.82	0.016
Guarding/rigidity, n (%)	22 (21.2)	42 (75.0)	χ^2=44.48	<0.001
PAS, mean ± SD	6.2 ± 1.4	8.1 ± 1.1	t=8.75	<0.001
PAS ≥8, n (%)	20 (19.2)	40 (71.4)	χ^2=42.86	<0.001
PAS: Pediatric Appendicitis Score; SD: standard deviation.				

Table 2: Laboratory, ultrasonographic, operative and histopathological findings

Variable	Uncomplicated	Complicated	Test statistic	p value
Total leukocyte count, ×10³/μL	12.4 ± 3.1	17.2 ± 4.2	t=8.22	<0.001
Neutrophil-to-lymphocyte ratio	5.1 ± 2.4	9.3 ± 4.1	t=8.11	<0.001
C-reactive protein, mg/L	24.6 ± 18.2	79.5 ± 45.6	t=10.85	<0.001
Bilirubin >1.0 mg/dL, n (%)	17 (16.3)	29 (51.8)	χ^2=22.62	<0.001
Sodium <135 mmol/L, n (%)	12 (11.5)	23 (41.1)	χ^2=19.04	<0.001
Appendicolith on ultrasound, n (%)	15 (14.4)	20 (35.7)	χ^2=9.72	0.002
Periappendiceal collection, n (%)	3 (2.9)	25 (44.6)	χ^2=45.99	<0.001
Operative duration, minutes	49.8 ± 15.3	76.4 ± 22.7	t=8.84	<0.001
Histopathological–operative concordance, n (%)	98 (94.2)	52 (92.9)	χ^2=0.12	0.729

Table 3: Postoperative outcomes among the study members

Outcome	Uncomplicated	Complicated	Test statistic	p value
Any postoperative morbidity, n (%)	8 (7.7)	22 (39.3)	χ^2=23.80	<0.001
Surgical-site infection, n (%)	5 (4.8)	12 (21.4)	Fisher's exact	0.002
Intra-abdominal collection, n (%)	1 (1.0)	8 (14.3)		<0.001
Prolonged ileus, n (%)	3 (2.9)	9 (16.1)		0.004
Readmission within 30 days, n (%)	2 (1.9)	6 (10.7)		0.02
Hospital stay, days, median (IQR)	3 (2–4)	7 (5–9)	U=1008	<0.001

Discussion

The present prospective study demonstrated that more than one-third of children undergoing appendicectomy had complicated appendicitis, while postoperative morbidity affected nearly one-fifth of the cohort. Children with complicated appendicitis were younger and more frequently presented after 48 hours of symptoms, with fever, vomiting, guarding, rigidity and higher PASs. These observations emphasized the continuing difficulty of recognizing appendicitis early in younger children, who may provide an incomplete history and exhibit nonspecific symptoms. A large Western Indian series similarly reported that delayed recognition contributed to perforation, peritonitis and postoperative complications among children undergoing laparoscopic appendicectomy [4]. The strong association between symptom duration beyond 48 hours and complicated disease in the present study supported the concept that progressive appendiceal obstruction, bacterial proliferation, ischemia and necrosis eventually resulted in gangrene or perforation. Indian investigators evaluating the PAS found that structured clinical scoring improved diagnostic consistency, particularly when combined with ultrasonography [1, 5]. However, clinical scores should not replace repeated examination because early appendicitis and atypical disease may produce intermediate scores. The greater frequency of guarding and rigidity among complicated cases reflected advanced parietal peritoneal

irritation. Surgeons' clinical assessment of severity may nevertheless differ from operative findings, highlighting the importance of integrating clinical, laboratory, imaging and intraoperative information rather than relying on a single assessment [6].

The laboratory findings provided additional evidence that systemic inflammatory responses increased with appendiceal severity. Children with complicated appendicitis had significantly higher leukocyte counts, neutrophil-to-lymphocyte ratios and C-reactive protein concentrations than those with uncomplicated disease. A prospective Indian study reported that leukocyte count, absolute neutrophil count, neutrophil-to-lymphocyte ratio, C-reactive protein and plasma fibrinogen were significantly elevated in histologically confirmed pediatric appendicitis, with fibrinogen demonstrating particularly useful diagnostic accuracy [2]. Another Indian study concluded that inflammatory markers, when interpreted alongside ultrasonography, assisted in distinguishing complicated from uncomplicated appendicitis [7]. In the present analysis, C-reactive protein above 50 mg/L independently predicted postoperative morbidity, possibly because C-reactive protein reflected the duration and extent of tissue inflammation more reliably than leukocyte count alone. Mean platelet volume and other readily available hematological indices have also been investigated as inexpensive adjunctive markers, although their performance has varied across populations [8]. The association of hyponatremia with complicated appendicitis was consistent with research from an Indian pediatric surgical centre, where low serum sodium was proposed as a marker of severe inflammation and perforation [9]. Inflammatory cytokine-mediated antidiuretic hormone release, fluid shifts, vomiting and reduced oral intake may contribute to sodium reduction. Hyperbilirubinemia was also significantly more frequent in complicated cases, supporting the possibility that bacterial translocation, endotoxemia and cytokine-mediated impairment of hepatic bilirubin excretion accompanied gangrenous or perforated disease [10]. These results suggested that combinations of biomarkers were more clinically meaningful than isolated abnormal values.

Ultrasonography demonstrated an important role in severity assessment because appendicolith and periappendiceal collection were significantly associated with complicated appendicitis. Indian research comparing the PAS with ultrasonography found that both modalities were useful, while their combined interpretation improved decision-making in children presenting with lower abdominal pain [1]. Appendicolith causes persistent luminal obstruction and may accelerate intraluminal pressure, vascular compromise and perforation. A recent Indian pediatric study found that appendicolith was associated with prolonged abdominal pain and a greater risk of appendicular perforation [11]. Periappendiceal collection was one of the strongest indicators of complicated disease in the present study because it represented localized perforation, abscess formation or advanced surrounding inflammation. Nevertheless, ultrasonography remains operator-dependent, and nonvisualization of the appendix does not exclude appendicitis. Secondary signs, clinical progression and laboratory abnormalities should therefore influence further observation or intervention. Rare anatomical presentations may also complicate diagnostic interpretation; Indian experience with Amyand's hernia showed that an inflamed appendix could occur within an inguinal hernial sac and require an individualized operative decision [12]. Appendicitis in infants remains especially challenging because classical migration of pain and localized tenderness are frequently absent, and delayed presentation commonly results in abscess or perforation [13]. These observations support early pediatric and surgical reassessment when symptoms persist despite an initially inconclusive ultrasound examination.

Operative duration was significantly longer among children with complicated appendicitis, which was expected because gangrene, perforation, abscess, adhesions and peritoneal contamination increased technical difficulty and the need for irrigation, adhesiolysis or drainage. The high concordance between operative and histopathological diagnoses in both groups demonstrated that gross severity assessment was generally reliable. However, histopathological examination remained necessary to confirm transmural inflammation, necrosis, gangrene and microscopic perforation and to detect unexpected conditions. Routine pathological assessment may reveal lymphoid hyperplasia, eosinophilic inflammation, parasitic infestation, granulomatous disease or rare neoplasms that cannot always be identified intraoperatively. The multidisciplinary design of the present study therefore strengthened severity classification by correlating pediatric evaluation, operative findings and pathological confirmation. Regarding operative approach, an Indian-led systematic review and meta-analysis showed that laparoscopic appendicectomy had a favourable overall complication profile compared with open surgery in children with complicated appendicitis [3]. Indian institutional experience has also demonstrated acceptable outcomes using a right subumbilical transverse incision when open surgery was selected for complicated pediatric appendicitis [14]. Consequently, the surgical approach should be determined by disease severity, available expertise, hemodynamic status, equipment and the presence of diffuse contamination rather than by a uniform policy. Standardized intraoperative grading would further improve communication between surgeons, pathologists and pediatricians and permit meaningful comparisons across institutions.

Postoperative morbidity was substantially greater among children with complicated appendicitis, with increased surgical-site infection, intra-abdominal collection, prolonged ileus, readmission and hospital stay. Gangrene or perforation and generalized peritonitis independently predicted morbidity, reflecting the effects of bacterial contamination, devitalized tissue and diffuse inflammation. A recent Indian investigation of pediatric surgical-site infections identified emergency surgery, contaminated wounds, prolonged procedures and other perioperative factors as important determinants of infection [15]. Indian reports of perforated appendicitis complicated by pylephlebitis also illustrated that delayed or severe disease may produce uncommon but potentially serious systemic consequences requiring multidisciplinary care [16]. The present findings supported risk-stratified postoperative monitoring, with closer observation and appropriately selected antibiotic therapy for children presenting after 48 hours, those with markedly elevated C-reactive protein, and those demonstrating gangrene, perforation or generalized peritonitis. Routine postoperative investigations should nevertheless be guided by clinical progress rather than ordered indiscriminately, because Indian pediatric surgical research has questioned the value of repeated tests in clinically stable children [17]. The study was limited by its single-centre design, the dependence of ultrasonography on operator experience and the possible influence of surgeon preference on operative approach and drainage. Despite these limitations, prospective data collection and histopathological confirmation strengthened the findings. Larger multicentre studies should validate practical prediction models combining symptom duration, PAS, C-reactive protein, sodium, bilirubin, appendicolith and periappendiceal collection. Such models may support earlier intervention, rational allocation of resources and individualized counselling regarding postoperative morbidity.

Conclusion

Complicated acute appendicitis in children was strongly associated with younger age, delayed presentation, higher Pediatric Appendicitis Scores, elevated inflammatory markers, hyperbilirubinemia, hyponatremia, appendicolith, and periappendiceal collection. Postoperative morbidity was significantly greater in complicated cases, particularly among children with gangrene, perforation, generalized peritonitis, prolonged symptoms, and markedly elevated C-reactive protein. Close collaboration among pediatricians, surgeons, radiologists, and pathologists improved diagnostic accuracy, operative classification, and outcome assessment. Early recognition of high-risk features, timely surgical intervention, and risk-based postoperative monitoring may reduce complications, hospital stay, and readmissions. Larger multicentre studies are required to validate these predictors and develop a pediatric appendicitis risk model.

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