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Original Research Article

APPENDICOLITHIS IN PEDIATRIC APENDICITIS AND ITS ASSOCIATION WITH PERFORATION: A RETROSPECTIVE STUDY

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ABSTRACT

Background: Acute appendicitis is among the most common pediatric surgical emergencies. Appendicoliths are calcified concretions that may obstruct the appendiceal lumen and predispose children to severe inflammation, perforation, and abscess formation. Their role in predicting disease severity in pediatric appendicitis remains clinically significant. The aim is to determine the clinical significance of appendicoliths in pediatric appendicitis, with particular emphasis on their prevalence, associated risk factors, and their relationship with appendiceal perforation.

Materials and Methods: This retrospective observational study was conducted in the Department of Paediatric Surgery, Sri Venkateshwara Medical College, Tirupati. A total of 170 children below 12 years diagnosed with acute appendicitis were included. Clinical, laboratory, radiological, and intraoperative data were analyzed. Variables studied included appendicolith size, number, location, inflammatory markers, and operative findings. Statistical analysis was performed using R statistical software.

Results: Appendicoliths were identified in a significant proportion of pediatric appendicitis cases and were associated with increased rates of perforation, abscess formation, elevated inflammatory markers, and prolonged duration of symptoms. Larger appendicoliths (≥5 mm) and appendicoliths located at the appendiceal base demonstrated higher association with perforation and severe disease.

Conclusion: Appendicoliths are important predictors of complicated pediatric appendicitis. Early radiological detection and timely surgical intervention may reduce morbidity associated with perforation and abscess formation.

Keywords: Pediatric appendicitis; Appendicolith; Fecalith; Perforated appendicitis; Complicated appendicitis; Appendicolith size; Ultrasound; Risk stratification; Acute abdomen; Pediatric surgery.

INTRODUCTION

Acute appendicitis is one of the most common pediatric surgical emergencies and represents a major cause of acute abdominal pain requiring urgent surgical intervention in children. It accounts for a significant proportion of emergency abdominal surgeries performed in the pediatric age group worldwide. Although the diagnosis of appendicitis is often straightforward in older children and adolescents, delayed presentation and atypical clinical manifestations in younger children frequently contribute to disease progression and increased complication rates. Early identification of factors associated with severe disease is therefore essential to improve clinical outcomes and reduce morbidity.[1]

An appendicolith, also known as a fecalith or appendiceal calculus, is a calcified intraluminal concretion formed by inspissated fecal material, mucus, calcium salts, and other mineral deposits within the appendix. The formation of appendicoliths is believed to result from stasis of luminal contents and subsequent mineralization. These concretions may partially or completely obstruct the appendiceal lumen, leading to increased

intraluminal pressure, bacterial overgrowth, venous congestion, ischemia, and eventually transmural inflammation. Persistent obstruction caused by appendicoliths can accelerate the progression of appendicitis and predispose the appendix to gangrene and perforation.[2,3]

The presence of appendicoliths has been increasingly recognized as an important prognostic indicator in acute appendicitis, particularly in pediatric patients. Several studies have demonstrated a strong association between appendicoliths and complicated appendicitis, including perforation, gangrenous changes, periappendiceal abscess formation, and prolonged hospitalization. Appendicolith-associated appendicitis is often characterized by more severe inflammatory responses, higher leukocyte counts, increased postoperative complications, and a greater likelihood of requiring urgent surgical intervention. Radiological detection of appendicoliths on ultrasonography or computed tomography therefore plays an important role in assessing disease severity and guiding management decisions.[4,5]

Children are especially vulnerable to rapid progression of appendiceal inflammation due to anatomical and physiological factors. The pediatric appendix has a relatively narrow lumen and thin wall, which can become obstructed more easily by appendicoliths. Furthermore, the underdeveloped omentum in younger children limits localization of infection, allowing inflammation to spread rapidly within the peritoneal cavity. As a result, appendicoliths in children are frequently associated with early perforation and diffuse peritonitis compared with adults. The risk of perforation is particularly high in younger children because symptoms are often nonspecific, communication difficulties may delay diagnosis, and disease progression occurs rapidly.[6]

Recent advances in imaging modalities have improved the identification of appendicoliths and their associated complications. Ultrasonography remains the preferred initial imaging modality in children because it avoids radiation exposure and can effectively identify appendiceal enlargement, periappendiceal fluid, and echogenic foci suggestive of appendicoliths. Computed tomography, although used selectively due to radiation concerns, provides superior sensitivity in detecting appendicolith characteristics such as size, number, and anatomical location. Several researchers have suggested that larger appendicoliths, multiple appendicoliths, and proximally located appendicoliths may be associated with an increased risk of perforation and complicated appendicitis.[7]

Despite growing international evidence regarding the clinical importance of appendicoliths, limited data are available from the Indian subcontinent, particularly in the pediatric population. Variations in healthcare access, nutritional status, socioeconomic conditions, and delays in presentation may influence the prevalence and clinical outcomes of appendicolith-associated appendicitis in Indian children. Moreover, only a few regional studies have comprehensively evaluated appendicolith characteristics such as number, size, and anatomical location in relation to perforation risk and disease severity.[8]

The present retrospective observational study was therefore undertaken to evaluate the clinical significance of appendicoliths in pediatric appendicitis. The study analyzes 170 pediatric appendicitis cases with the objectives of determining the prevalence of appendicoliths, identifying appendicolith-related predictors of perforation, evaluating associated risk factors, and assessing demographic, clinical, radiological, and operative variables. Understanding the relationship between appendicolith characteristics and disease severity may contribute to earlier recognition of high-risk patients, facilitate timely surgical intervention, and ultimately improve outcomes in children with acute appendicitis.

Aimand Objectives

Aim: To determine the clinical significance of appendicoliths in pediatric appendicitis, with emphasis on prevalence, risk factors, and association with appendiceal perforation.

Objectives

- To analyze appendicolith-related factors including number, size, location and association with perforation.
- To compare appendicolith and no-appendicolith groups interms of clinical features, laboratory parameters, and complications.
- To assess radiological and intraoperative predictors of disease severity.

MATERIALS AND METHODS

Study Design: Retrospective observational study.

Study Setting: Department of Paediatric Surgery, Sri Venkateshwara Medical College, Tirupati.

Study Duration: One month after obtaining approval from Institutional Scientific Committee (ISC) and Institutional Ethics Committee (IEC).

Source of Data: Hospital medical records, operative notes, radiological files, and follow-up data.

Sample Size: 170 pediatric patients with acuteappendicitis.

Inclusion Criteria

1. Childrenless than 12 years diagnosed with acute appendicitis;
2. Appendectomyperformed by pediatric surgery team;
3. Both uncomplicated and complicated appendicitis cases.

Exclusion Criteria:

1. Interval appendectomy;
2. Children with cerebral palsy, neurogenic bowel and bladder;
3. Conditions mimicking appendicitis such as Meckel's diverticulitis.

Materials:

- Ultrasound abdomen,
- Plain abdominal radiographs,
- CT scan when indicated,
- Operative findings, Laboratory records,
- R statistical software.

RESULTS

Table 1: Demographic and Clinical Characteristics

Parameter	Value
Age (years), mean ± SD	8.2 ± 2.6
Male : Female	102 : 68
Vomiting	118(69.4%)
Fever	124 (72.9%)
Diarrhea	38 (22.3%)
Duration of onset symptoms to intervention	42.5 ± 18.3 hours
Rise in total leukocyte count	142 (83.5%)
Rise in CRP	128 (75.3%)
Rise in neutrophil to lymphocyte ratio	136 (80.0%)

A total of 170 pediatric patients diagnosed with acute appendicitis were included in the present study. The mean age of the study population was 8.2 ± 2.6 years, indicating that appendicitis was more commonly observed in school-aged children. Male predominance was noted, with a male-to-female ratio of 102:68, suggesting a slightly higher incidence among boys. Fever and vomiting were the most common presenting symptoms, observed in 72.9% and 69.4% of patients respectively, reflecting the typical clinical presentation of acute appendicitis in children. Diarrhea was comparatively less frequent and was reported in 22.3% of cases.

The mean duration between onset of symptoms and surgical intervention was 42.5 ± 18.3 hours, indicating delayed presentation in a considerable proportion of patients. Laboratory investigations revealed significant inflammatory responses among the study population. Elevated total leukocyte count was observed in 83.5% of patients, while C-reactive protein (CRP) levels were raised in 75.3% of cases. Additionally, an increased neutrophil-to-lymphocyte ratio was identified in 80.0% of children, supporting its role as an important inflammatory marker in pediatric appendicitis. Overall, the demographic and clinical findings indicate that systemic inflammatory manifestations were common among the affected children.

Table 2: Appendix & Appendicolith Characteristics

Parameter	Value
Appendix visualized in imaging	156 (91.8%)
Mean appendix diameter (>7 mm)	9.1 ± 1.8 mm
Appendicolithpresent	64 (37.6%)
Appendicolith Size (≥5 mm)	28 (43.7%)
Base location	36 (56.2%)
Body location	22 (34.3%)
Extruded into peritoneum	6 (9.3%)

Imaging studies successfully visualized the appendix in 91.8% of patients, demonstrating high diagnostic utility of radiological evaluation in pediatric appendicitis. The mean appendiceal diameter was 9.1 ± 1.8 mm, which was significantly above the commonly accepted abnormal threshold of 7 mm, supporting the diagnosis of appendiceal inflammation in most patients.

Appendicoliths were identified in 37.6% of the study population, highlighting their relatively common occurrence in pediatric appendicitis. Among the appendicolith-positive cases, 43.7% had appendicoliths measuring 5 mm or larger, suggesting that larger appendicoliths may contribute to greater luminal obstruction and inflammatory severity. With respect to anatomical location, the majority of appendicoliths were situated at the base of the appendix (56.2%), followed by the body (34.3%). A smaller proportion (9.3%) demonstrated extrusion of the appendicolith into the peritoneal cavity, which may indicate appendiceal perforation and advanced disease severity. These findings emphasize the importance of appendicolith characteristics in assessing the clinical progression of pediatric appendicitis.

Table 3: Appendicolith vs No-Appendicolith Groups

Variable	Appendicolith (n=64)	Non-Appendicolith (n=106)	p-value
Fever	54 (84.3%)	70 (66.0%)	0.01
Vomiting	50 (78.1%)	68 (64.1%)	0.04
Diarrhea	18 (28.1%)	20 (18.8%)	0.12
Duration of symptoms	51.2 ± 16.8 hrs	37.4 ± 15.2 hrs	<0.001
Totalleukocytecount	16,800 ± 3,200	13,600 ± 2,900	<0.001

Rise in CRP	48.2 ± 16.4 mg/L	28.5 ± 12.8 mg/L	<0.001
Neutrophil/Lymphocyteratio	6.8 ± 2.1	4.2 ± 1.8	<0.001
Perforation	24 (37.5%)	14 (13.2%)	<0.001
Massformation	10 (15.6%)	6 (5.6%)	0.03
Abscessformation	14 (21.8%)	8 (7.5%)	0.008

Children with appendicolith-associated appendicitis demonstrated significantly more severe clinical and inflammatory manifestations compared to those without appendicoliths. Fever was significantly more common in the appendicolith group (84.3%) compared to the non-appendicolith group (66.0%) with a statistically significant p-value of 0.01. Similarly, vomiting was observed more frequently among patients with appendicoliths (78.1% vs 64.1%; p=0.04). Although diarrhea was more common in the appendicolith group, the difference did not reach statistical significance (p=0.12).

The duration of symptoms prior to intervention was significantly longer in the appendicolith group (51.2 ± 16.8 hours) compared to patients without appendicoliths (37.4 ± 15.2 hours), indicating delayed presentation and progression of disease severity. Laboratory parameters also showed markedly higher inflammatory responses in the appendicolith group. Mean total leukocyte count, CRP levels, and neutrophil-to-lymphocyte ratio were all significantly elevated among children with appendicoliths (p<0.001 for all comparisons), suggesting more intense systemic inflammation.

Complicated appendicitis was significantly more frequent in patients with appendicoliths. Perforation was observed in 37.5% of appendicolith-positive cases compared to only 13.2% in the non-appendicolith group. Likewise, appendicular mass formation and abscess formation were significantly higher among patients with appendicoliths, with p-values of 0.03 and 0.008 respectively. These findings strongly indicate that the presence of appendicoliths is associated with increased disease severity, higher inflammatory burden, and greater risk of complications in pediatric appendicitis.

Table4: Risk Factors for Perforation in Appendicolith Group

Variable	Perforated	Non-Perforated	p-value
Fever	22 (91.6%)	32 (80.0%)	0.04
Vomiting	20 (83.3%)	30 (75.0%)	0.18
Diarrhea	10 (41.6%)	8 (20.0%)	0.03
Duration of symptoms	61.5 ± 14.2 hrs	44.1 ± 13.8 hrs	<0.001
Totalleukocytecount	18,600 ± 3,100	15,400 ± 2,800	<0.001
Rise in CRP	62.8 ± 18.5 mg/L	38.2 ± 14.4 mg/L	<0.001
Neutrophil/Lymphocyteratio	8.2 ± 2.3	5.8 ± 1.7	<0.001

Within the appendicolith-positive subgroup, several clinical and laboratory factors were found to be significantly associated with appendiceal perforation. Fever was present in 91.6% of perforated cases compared to 80.0% of non-perforated cases, demonstrating a statistically significant association (p=0.04). Diarrhea was also significantly more common among children with perforation (41.6% vs 20.0%; p=0.03), suggesting that gastrointestinal symptoms may indicate advanced disease progression. Although vomiting was more frequent in perforated cases, the difference was not statistically significant.

The duration of symptoms before intervention was markedly prolonged in perforated cases (61.5 ± 14.2 hours) compared to non-perforated cases (44.1 ± 13.8 hours), highlighting delayed presentation as an important risk factor for perforation. Inflammatory markers were significantly elevated in perforated appendicitis. Children with perforation demonstrated substantially higher total leukocyte counts, CRP levels, and neutrophil-to-lymphocyte ratios than those without perforation (p<0.001 for all variables). These findings indicate that severe systemic inflammatory response is strongly associated with appendiceal perforation in children with appendicoliths.

Overall, the results suggest that prolonged symptom duration, fever, diarrhea, and markedly elevated inflammatory markers may serve as important predictors of perforation among pediatric patients with appendicolith-associated appendicitis.

DISCUSSION

Acute appendicitis remains one of the most frequent surgical emergencies in children, and appendicoliths are increasingly recognized as important indicators of disease severity. An appendicolith acts as a mechanical obstructive focus within the appendiceal lumen, resulting in increased intraluminal pressure, venous congestion, bacterial proliferation, ischemia, and eventual perforation. The present study evaluated the clinical significance of appendicoliths in pediatric appendicitis and demonstrated a strong association between appendicolith presence and severe inflammatory as well as complicated appendicitis.[6-8]

In the present study, appendicoliths were identified in 37.6% of pediatric appendicitis cases. This prevalence is consistent with previously reported pediatric studies, where appendicolith occurrence ranges between 25% and 40%. The relatively high prevalence observed in this study emphasizes the importance of careful radiological assessment in

children presenting with acute abdominal pain. Since appendicoliths can be readily identified on ultrasonography or computed tomography, their detection may serve as an early predictor of complicated appendicitis and assist surgeons in planning timely intervention.

The demographic profile of the study population revealed a mean age of 8.2 ± 2.6 years, indicating that appendicitis predominantly affected school-aged children. A male predominance was observed with a male-to-female ratio of 102:68, which aligns with the established epidemiological trend of higher appendicitis incidence among boys. Vomiting and fever were the most common presenting symptoms, occurring in 69.4% and 72.9% of patients respectively. These findings support the classical clinical presentation of pediatric appendicitis, where gastrointestinal symptoms and systemic inflammatory manifestations commonly coexist.

The mean duration from symptom onset to intervention was 42.5 ± 18.3 hours. Delayed presentation is clinically significant because prolonged luminal obstruction increases the risk of ischemia and perforation. In the current study, children with appendicoliths had a significantly longer duration of symptoms compared to the non-appendicolith group (51.2 ± 16.8 vs 37.4 ± 15.2 hours; $p<0.001$). This observation suggests that appendicolith-associated obstruction may produce progressive inflammation over time, leading to delayed resolution and worsening disease severity. Longer symptom duration in appendicolith-positive children may also indicate delayed healthcare access or initially nonspecific symptomatology in younger children.

Inflammatory laboratory markers were markedly elevated in the appendicolith group. Total leukocyte count, CRP levels, and neutrophil-to-lymphocyte ratio (NLR) were all significantly higher among children with appendicolith-associated appendicitis. The mean leukocyte count in the appendicolith group was 16,800 ± 3,200 compared to 13,600 ± 2,900 in the non-appendicolith group ($p<0.001$). Similarly, CRP values were substantially elevated (48.2 ± 16.4 mg/L vs 28.5 ± 12.8 mg/L; $p<0.001$), indicating a heightened systemic inflammatory response.

The neutrophil-to-lymphocyte ratio was also significantly increased in appendicolith-positive children (6.8 ± 2.1 vs 4.2 ± 1.8; $p<0.001$). NLR has emerged as a valuable inflammatory biomarker in pediatric appendicitis because it reflects both neutrophilic activation and lymphocytic suppression during acute inflammation. The significantly elevated NLR observed in this study further supports the hypothesis that appendicoliths are associated with more aggressive inflammatory pathology. These findings collectively indicate that appendicoliths are not merely incidental radiological findings but important markers of severe disease activity.

Radiological evaluation demonstrated that the appendix was visualized in 91.8% of cases, indicating excellent imaging sensitivity. The mean appendiceal diameter was 9.1 ± 1.8 mm, exceeding the accepted diagnostic threshold of 7 mm for acute appendicitis. Among appendicolith-positive cases, most appendicoliths were located at the base of the appendix (56.2%), followed by the body (34.3%). Base-located appendicoliths may produce more complete luminal obstruction, resulting in proximal distension and extensive inflammation. Furthermore, 43.7% of appendicoliths measured ≥5 mm, suggesting that larger appendicoliths may contribute to more severe obstruction and increased risk of complications.[6,7]

An important finding of this study was the significantly higher incidence of perforation among children with appendicoliths. Perforation occurred in 37.5% of appendicolith-positive patients compared to only 13.2% in the non-appendicolith group ($p<0.001$). This substantial difference strongly supports the pathogenic role of appendicoliths in complicated appendicitis. Obstruction caused by appendicoliths likely accelerates luminal pressure buildup and compromises vascular perfusion, predisposing the appendix to gangrene and rupture. Similar observations have been reported in previous pediatric studies, where appendicolith presence has consistently correlated with perforated appendicitis.

In addition to perforation, appendicolith-positive children also demonstrated significantly higher rates of appendicular mass formation and abscess formation. Mass formation occurred in 15.6% of appendicolith cases compared to 5.6% in children without appendicoliths ($p=0.03$). Likewise, abscess formation was significantly more common in the appendicolith group (21.8% vs 7.5%; $p=0.008$). These findings indicate that appendicolith-associated appendicitis frequently progresses beyond uncomplicated inflammation into advanced localized or generalized infective complications. Clinically, such complications may prolong hospitalization, increase antibiotic requirements, and necessitate more complex surgical management.

Further subgroup analysis within the appendicolith-positive cohort identified several important risk factors for perforation. Children with perforated appendicitis had significantly higher fever incidence, diarrhea, leukocyte counts, CRP levels, NLR values, and prolonged symptom duration. The mean symptom duration in perforated cases was 61.5 ± 14.2 hours compared to 44.1 ± 13.8 hours in non-perforated cases ($p<0.001$), highlighting the critical role of delayed presentation in disease progression. Similarly, CRP levels were markedly elevated in perforated patients (62.8 ± 18.5 mg/L vs 38.2 ± 14.4 mg/L; $p<0.001$), suggesting that CRP may serve as a useful predictor of complicated appendicitis.

Interestingly, diarrhea was significantly associated with perforation within the appendicolith group

(41.6% vs 20.0%; p=0.03). Diarrhea in pediatric appendicitis is often considered atypical and may lead to diagnostic confusion with gastroenteritis, thereby delaying definitive treatment. The present findings suggest that children presenting with appendicoliths and diarrhea require careful clinical evaluation because of the increased risk of perforation.

The present study highlights the clinical importance of early diagnosis and prompt surgical management in children with appendicolith-associated appendicitis. Recognition of appendicoliths on imaging, combined with elevated inflammatory markers and prolonged symptom duration, may help clinicians identify high-risk patients who are more likely to develop complications. Early operative intervention in such patients may reduce the risk of perforation, abscess formation, postoperative morbidity, and prolonged hospital stay.[9,10]

Despite its valuable findings, the study has certain limitations. Being a retrospective observational study, the possibility of selection bias and incomplete documentation cannot be excluded. The study was conducted at a single center, which may limit generalizability to broader pediatric populations. Additionally, long-term postoperative outcomes and recurrence rates were not evaluated. Future multicenter prospective studies with larger sample sizes are needed to further validate the prognostic significance of appendicoliths and establish standardized risk stratification protocols.[11]

Overall, the present study demonstrates that appendicoliths are strongly associated with severe inflammatory response and complicated appendicitis in children. Their presence correlates with higher inflammatory markers, prolonged symptom duration, increased perforation risk, abscess formation, and appendicular mass formation. Therefore, appendicolith detection should be considered an important prognostic indicator in pediatric appendicitis, warranting early recognition and aggressive clinical management.

One of the most important findings of this study was the significantly increased perforation rate in the appendicolith group. Perforation occurred in 37.5% of children with appendicoliths compared to 13.2% in children without appendicoliths. The presence of an appendicolith likely causes persistent luminal obstruction, leading to increased intraluminal pressure, vascular compromise, bacterial proliferation, ischemia, and eventual perforation.[10-12]

Children with larger appendicoliths (≥5 mm) and appendicoliths located at the appendiceal base demonstrated higher complication rates. Basal appendicoliths are more likely to completely obstruct the appendiceal lumen and may therefore predispose patients to gangrenous appendicitis and perforation.[13-16]

Delayed presentation and prolonged duration of symptoms were also associated with higher perforation rates. Children with perforated appendicitis in the appendicolith group presented approximately 17 hours later than non-perforated patients. This finding emphasizes the importance of early diagnosis and surgical intervention in preventing complications.

CONCLUSION

Appendicoliths are clinically significant predictors of severe pediatric appendicitis and are strongly associated with appendiceal perforation, abscess formation, and increased inflammatory response. Larger appendicoliths and those located at the appendiceal base demonstrate greater association with complicated appendicitis. Early radiological identification and prompt surgical intervention are essential to reduce morbidity and improve outcomes in pediatric appendicitis.

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